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WORLD CUP 2006

Electronics off-side

FIFA gives RFID a miss

Viruses threaten RFID tags

RFID passport security at risk?

Projects

- Network Cable Tester
- FM Stereo Test Transmitter
- PCB Short-circuit Locator

10 scopemeters compared

money buys the best?

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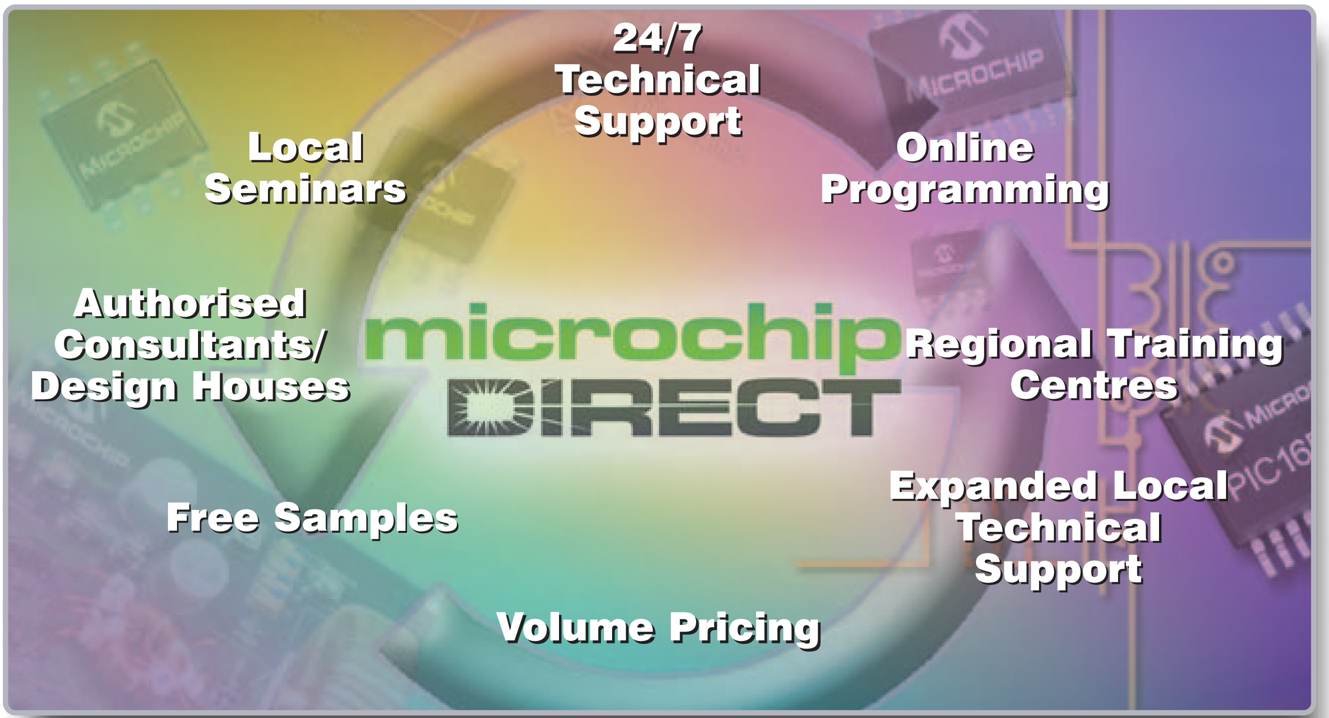

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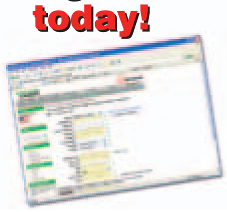

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20 kilovolts missing

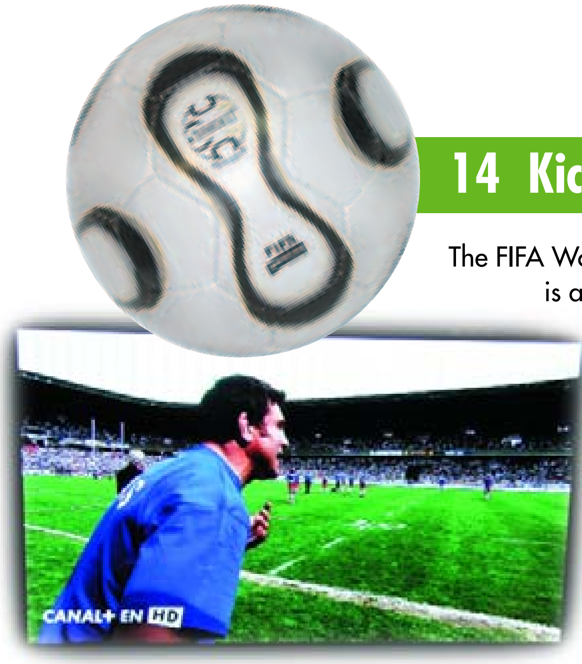
I must confess to being old school when it comes to controls on equipment. When I tried to get some of the scopemeters featured in this issue to 'do' a timebase of 20 ms for me I was soon lost in menus and countless pressing of plastic and rubber buttons even smaller than the ones on my mobile phone. My colleagues, tongue in cheek, tell me it's because "I haven't read the manual" (it's on CD Jan!) or "nobody wants to use a 20-ms timebase". It's only then you realise that test and measurement equipment requires quite a bit of getting used to and that not much has changed in that respect despite the miniaturisation of the instruments proper, and in particular their controls. Gone are the days when muscle was required to pull the trolley carrying my noisy Tektronix 535B tube oscilloscope closer to the workbench. Next, strong manual action was needed on at least five front panel controls to switch the instrument to the desired settings.
As it happened, the instrument, after two decades of intensive use in my electronics workshop, was let down by the very devices that suggest its robustness — the front panel controls! Some rotary switches developed bad contacts, and in some cases the shafts and mini bearings suffered from wear and tear. In one extreme case, a valve circuit in a two-channel 100-MHz plug-in unit failed owing to a complex contact arrangement that was supposed to be 'break before make' but in fact was more like a 'make at all times'. A nice faultfinding job ensued which was remarkable in two ways. Firstly, it was carried out using the 'scope itself fitted with a borrowed plug-in and secondly, I did the soldering with silver solder of which a small quantity was found on a plastic reel fitted on top of the PSU inside the instrument. Courtesy of Tektronix Inc.!
These Tek beasts with their massive hoods at either side are now on Ebay's vintage electronics pages. Rightly so; their functionality has been taken over by portable instruments with 20 times less weight. Hard to beat the crisp image from a 20-kV accelerated CRT, though.

Jan Buiting, Editor

p.s. don't forget to participate in our R8C Design Competition!

32 All in One Hand

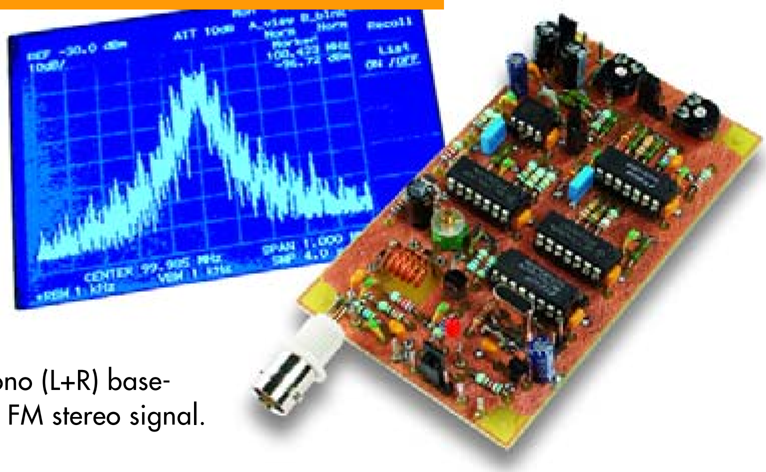
Scopemeters are primarily designed for portable use. Like USB oscilloscopes, many of them are multifunction instruments. Although some models can only be used as oscilloscopes, most of them can also be used as multimeters or (in some cases) FFT analysers. Here we subject a number of these instruments to a close examination.



14 Kick-off for HDTV?

The FIFA World Cup football tournament is an ideal showcase for High Definition television which promises to convey the live action in stunning detail. Each ticket sold for every game carries an RFID tag but the match ball (for the time being anyway) still contains only air… A look at the role of electronics in this upcoming media event.

54 FM Stereo Test Transmitter



This small signal generator uses an ingenious technique to generate a sine wave with very low distortion, a mono (L+R) baseband signal and an FM stereo signal.

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ePassports have an embedded RFID tag containing your personal information which Immigration officials can read remotely; hopefully nobody else will be eavesdropping on this electronic conversation…

elektor electronics — leading the way

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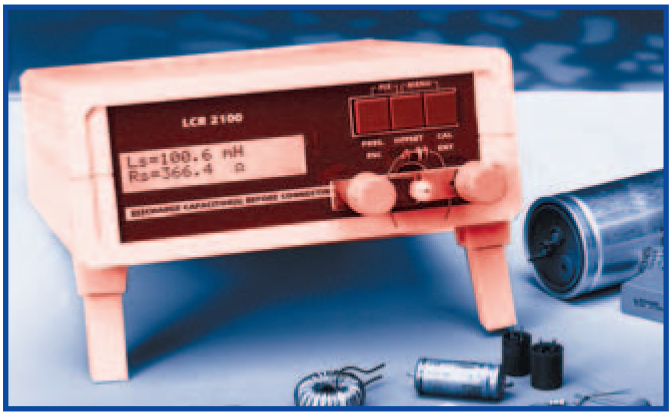


LCD in LCR 2100

Sir — with regard to the Advanced LCR Meter project (April & May 1997, *Ed.*), is it essential to use the Seiko L1642B1J000 LCD as the device is now obsolete and there is not a replacement? Thanks again.

Tom Didcott (UK)

Karel Walraven of Elektor Labs replies — you can use any 2x16 LC display as long as it has a type 44780 or compatible interface. Nearly all LCDs comply with this standard. It is possible however that the physical connections located differently, or swapped, or divided in two rows. Just stick to the pin numbers and it will work.

Problems Down Under

Dear Editor — 14 March 2006, I just received Elektor January 2006 in Brisbane Australia.

1) To the Elektor editor I like to mention, that it would be good if the gap of the publication between Europe and Australia diminish by a few weeks instead of three months.

2) I searched the forum for any posting on Visual Basic from Petros Kronis but strangely could not find any posting relating to VBnet. I found Petros article very interesting. I usually work with www.powerbasic.com and VB6. in 2004, I looked at VB.net 2003 but found it again complicated. People who know how to program VB6 or VBnet are incapable of teaching any beginner.
No offence but I have downloaded probably twenty and more + VB6 / VBnet books, e-books and video learning lessons (since 1995). Every one of these item pretend to be for the VB's newbie, but they're not.
VB programmers who are good at programming VB are INCAPABLE of teaching newbie because they haven't got the necessary teaching skills.

This is why VB is not on the rise but on the decline.
In comparison it is like expecting a University lecturer to teach a 6 years old how to read and write.
University lecturers haven't got the skills necessary to teach a 6 years old how to read and write. What we have here is a generation of people who have learned how to program VB6 and VBnet by rot, without any formal training and without the "art of teaching newcomers to VB".
These "gurus" are very successful to advanced users but not to newbie.

Petros says "Secondly, manual and text books on the subject (Visual Basic programming) lose their readers in the early chapters by delving too deeply into the working of the language". I agree totally with Petros. After being surprised of not finding any posting on VBnet, I would like to exchange some knowledge with other Newbie of VBnet?
Is there any articles, program, example, examples of VB net? I am talking here about simple, beginners examples.

PS: I train people how to learn to sail — I teach them how to crawl on their stomach, then legs and hands , then walk then run. My rate of success is high because I encourage small steps, very very small steps.

Guy (Australia)
(copied from EE Forum)

Dear Peter, we regret the delays in the post, particularly surface mail but as you will appreciate we have no control over what the post is doing (or not) on the seas and in the harbours between the UK and your country. In general, guaranteed delivery dates are not supplied by freight forwarders shipping bulk surface mail, as too many unknown factors are involved.

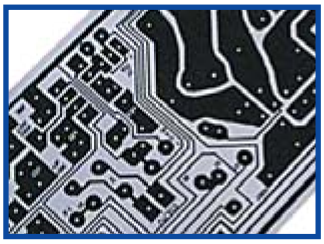
The same goes for the cover price and the exact day of appearance of the magazine, which are only fixed (by contract) for newsstands and bookshops in the UK (hence no foreign currencies are stated on the cover). If you have reason to complain about the situation in your country you should talk to your local distributors, mentioning the date of appearance in the UK (see Sneak Preview).
The situation with subscription copies sent by airmail is much better but I appreciate the option may be too expensive. For example, I just received an email from a subscriber in India that he received his copy of the April 2006 issue (this date: 14 March 2006; magazines bulk supplied to airmail on: 10 March 2006).

Regarding the free VB booklet by Petros Kronis, it is difficult if not impossible to define just what a 'beginner' is — for instance, should we assume that readers need to be told what a 'variable' or a 'program' is? All in all, I think Petros has done a good job introducing VB to us, yes that's including myself. Other readers, please comment on the level of the booklet and if necessary start a topic in the online Forum.

Thanks Peter for your valuable comment; you and other readers down under buying newsstand copies may look forward to receiving, in a few weeks time, the March 2006 issue that comes with a free C Booklet and a poster-size schematic of our Versatile FPGA Unit.

Finally, Elektor issues are usually available for downloading at a delay of –1 (minus one) week relative to the UK newsstands, at –17 (minus 17) percent of the UK cover price. The pdf downloaded on your computer is an exact copy of the printed magazine, including all advertising and in full colour, too. The only proviso is that you have a reasonably fast internet link available.

[Peter has since replied that magazine downloading is not an option owing to slow Internet access in Brisbane]



PCBs on inkjet photo printer

Dear Editor — following last month's contribution on using inkjet printers to produce PCBs I started to further investigate the possibility. In the course my web search I came across a technique that, until now, I had never heard of. It involved printing your PCB design onto inkjet photo paper using a laser printer and transferring the toner to the copper by ironing the inkjet paper onto the PCB. As the photo paper coating is water soluble, the paper can be removed by simply soaking in water. The board is then etched in the conventional way. Credit for this discovery must goes to Thomas Gootee, and the complete technique is explained at www.fullnet.com/u/tomg/gooteepc.htm.
He also has lots of other interesting pages on other aspects of hobby electronics. The inkjet paper that he describes is not available in the UK but I have good experience with 'PCline Glossy Photo Paper' available from PC World. I would also suggest using grease proof paper (baking paper) between the back of the inkjet paper and the iron if you don't want other iron users to brand you with it.
Owain Davies (UK)

Thanks for yet another tip for readers producing their own printed circuit boards. We can confirm that Mr. Gootee's website contains an impressive amount of useful information. The story continues.

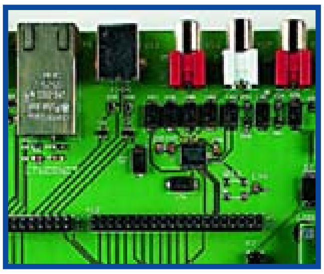
Silence, please!

Dear Jan — allow me to say that I listen to AM radio. Years ago, it sounded great. Now, both the AM and longwave are filled with switch mode power supplies.
The frequency of the switch mode should be crystal controlled and frequency synchronised to a radio transmitter. There should be a series of set frequencies that a switch mode may operate at, and totally locked to a standard frequency.
The RF ripple out of a switch mode is typically 5 to 20 mV. But I want to detect 1 mV from a radio transmitter.
The spread frequency switch modes can cause problems across the whole band.
Any chance you would change the whole world for me, maybe by an article, to apply pressure to chip manufacturers, and change the world laws on radio emissions?

I am not kidding. The radio bands are valuable asset. As a radio listener and radio amateur, I would like radio silence except for intended radio transmitters.

I know that it is pretty impossible as an electronics engineer. So I propose that circuits only radiate at frequency locked set frequencies. That would take no bandwidth, but everyone could have frequency locked notch filters at their radio receivers. Some microprocessors just use an RC as their frequency standard. They transmit in the shortwave range, up and down the bands. The RC networks stop communications.
I ask for silence, across the bands unless radiated energy is intended to transmit, or on a set frequency.
Richard Cooke, G7PMB (UK)

Comment on Peter's wishes and proposals invited from other readers, please mail the Editor.



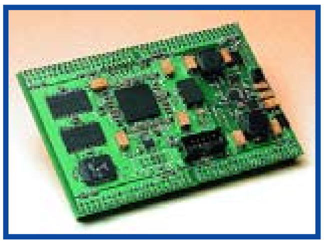
USB on the Elektor FPGA Prototyping Board

Dear Jan — I've had a look at the Elektor FPGA Prototyping Board described in the March 2006 issue. The USB connection is great, but only if it is properly implemented. For full-speed USB a 1.5-kW pull-up to 3.3 V is used (correct in your design). Low-speed also requires a 1.5 kW resistor, but to the D– line, not to ground as in your design. Also, no sensing is implemented on the USB power status. The USB specifications state that 1.5-kW may only be inserted if the voltage line is supplied by the hub connected ahead of it. When the voltage disappears, the pull-up has to be de-activated at the same time.
If this specification is not followed, equipment identification problems may occur with several chipsets and hubs. I can speak from personal experience, having worked as a USB product designer for a number of years.
M. Otto (Germany)

Your observations are correct. The pull-down resistor has to become a pull-up! This requires FET T7 to be replaced by an FDV302P and the resistor to be connected to +3.3 V instead of to ground. If necessary the power sensing may be implemented in software. The first batch of the prototyping board went into production before the error was discovered. The relevant boards will be reworked by hand before shipping to our customers.

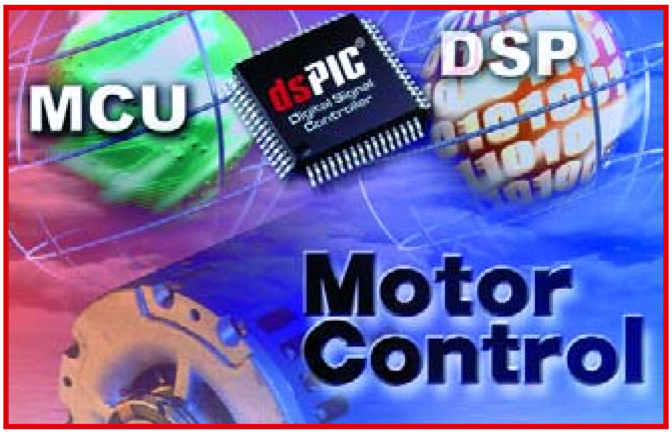
The Odd Bit (and Byte)

Dear Editor — the article on the Versatile FPGA Module (March 2006) states that 8 MB of user RAM are available. However, in the circuit diagram I spotted two CY7C1041CV33 devices, which according to their datasheets are 256k x 16 SRAMs. Consequently the total memory is 1 Mbyte (or 8 Mbit).
The same goes for the flash memory. Here, too, a 128k x 8 memory is used, which means that the memory is only 128 kbytes. The configuration memory, then, is advertised as 4 MB, while 128 x 36 in actual fact. What's happened?
A. Hellinger (Germany)



Of course you right as far as the indications of the memory sizes are concerned. The AT29BV010A is a 1-Mbit memory and each of the RAM chips is good for 4 Mbit (this is correctly stated in the article text). The error is typographic, we should have printed 'Mb' instead of 'MB' in the Technical Features box on page 17 of the article.

Two new 16-bit dsPIC30F with PWM



Microchip announces the continued rollout of its 16-bit dsPIC® Digital Signal Controllers (DSCs) with two new devices. The dsPIC30F5015 and dsPIC30F5016 devices feature an advanced PWM designed for motor-control, power-conversion and lighting applications; a 1 MSPS 10-bit A/D converter; 66 Kbytes of Flash program memory; and full-speed operation (30MIPS) using an internal oscillator. These new devices are ideal for applications that drive power FETs and require advanced algorithmic processing.

The dsPIC digital signal controllers are devices that combine the robust peripherals and interrupt-handling capability of a high-performance 16-bit microcontroller with the computation speed of a fully implemented DSP to produce an optimum single-chip solution. All of Microchip's 16-bit MCU and DSC families share the same core instructions and development tools, and have compatible pin outs and peripherals on similar devices, which means designers can select a low-cost PIC24F, a high-performance PIC24H, or add DSP capability with a dsPIC DSC – all without requiring a significant redesign.

The dsPIC30F5015 and dsPIC30F5016 will operate from 2.5 to 5.5 volts, which is valuable for analog noise immunity or minimizing voltage-translation logic. The devices are available to operate over an extended temperature range of -40 to +125 Degrees C.

Additional key features include:

- 66 Kbytes of Flash program memory, capable of self-programming, of 100,000 erase/write cycles (typical) and with 40-plus years of data retention.
- 2 Kbytes of SRAM; 1Kbyte of on-chip EEPROM
- 8-output advanced PWM, complementary or independent modes, 4 duty-cycle generators and programmable dead time
- Four standard PWMs …./…
- 10-bit analog-to-digital converter with up to 16 signal channels, 1M samples per second, 4 channel simultaneous sampling, and PWM trigger option
- Quadrature Encoder Interface for motor-control applications
- Five 16-bit timers
- and UART peripherals™CAN, SPI, I2C

All of Microchip's controllers use Integrated Development Environment (IDE), which also contains a®the same MPLAB motor-control GUI. The dsPIC DSCs are also supported by specific development systems, including: MPLAB C30 C Compiler, MPLAB ICD 2 In-Circuit Debugger, MPLAB ICE 4000 In-Circuit Emulator and MPLAB Visual Device Initializer.

The dsPIC30F5015 and dsPIC30F5016 are available today in RoHS-compliant, 64- and 80-pin TQFP packages. Samples are available from sample.microchip.com, and the devices can be purchased at www.microchipdirect.com. For additional information visit Microchip's Web site at

www.microchip.com/dspic.

(067111-6)

Multimedia centre has built-in DVB-T

A multimedia centre with a large high resolution monitor and an almost obligatory DVD player is a great thing – especially when it can even be run using the car battery. The days of watching analogue television are numbered, and nobody wants to do without the digital picture quality. Now, thanks to DVB-T, digital television with terrestrial reception is even possible using a simple rod antenna – like the good old analogue tellie, too.

With the All-In-One-Set SV070317, Sevic offers such a device. Thanks to DVB-T, it can receive a digital television picture in a mobile home, in a weekend house, or in a holiday flat and can, therefore, provide information, entertainment, and relaxation everywhere.

The basis is a high-resolution 17-inch TFT-LCD monitor (optionally available with a 15" monitor), which is equipped with a high-quality DVD player with the DVD opening at the top of the device. Aside from DVD's, this player also plays CD's so that the music lover gets use of the integrated speakers. A multi-system TV tuner, which, to the delight of all globetrotters, not only plays PAL, but also NTSC and SECAM signals, rounds off the compact system.

Even the simple expandability was considered at Sevic: an integrated Dolby digital decoder makes it possible to run a fully-fledged surround system after a multi-channel amplifier and the corresponding number of speakers have been installed.

With the compact dimensions making it ideal for use in mobile homes, the Set SV070317 also allows for the power supply to be the car battery using an optionally available 12V wire, so that nothing stands in the way of entertainment. Audio/video VGA as well as Scart inputs round off the universal usability of this set, although the most important functions can, of course, be selected using a remote control.

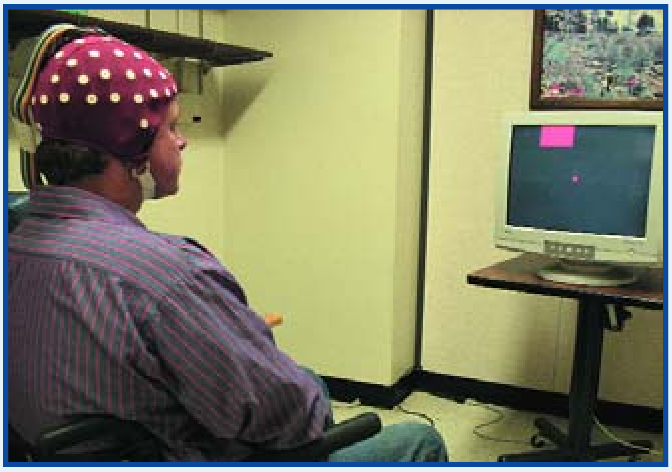
The power consumption is surprisingly low at <5 W in standby and <60 W during normal use, this being a prerequisite for use in mobile operations.

(067081-8)

www.sevic.com

New low-cost device opens communication for the severely paralysed

Cambridge Consultants is providing key technology behind a novel brain-computer interface (BCI) device that translates brain waves into computer control commands — without the need for electrodes implanted in the brain. This represents a breakthrough in the way computers can assist



Wadsworth Center's innovative brain-computer interface device in use, moving a cursor to a target point on the screen.

patients in their daily activities.

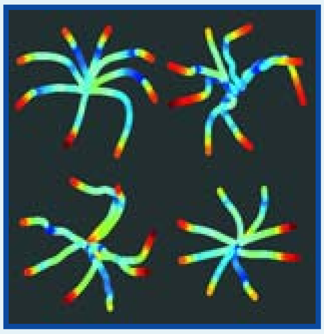
The BCI system is being developed by the Wadsworth Center, a public health laboratory for the New York State Department of Health, to help even individuals who are completely paralysed to communicate with the outside world. The Wadsworth Center's BCI system has been proven to match the capabilities of costly invasive systems that require surgery to implant electrodes in the brain - and should be able to help individuals who have lost all muscular control, something other augmentative or assistive communications approaches such as eyeball-tracking systems cannot.

Cambridge Consultants helped the Wadsworth Center transform a brilliantly engineered and technically complex research equipment into an easy-to use, more portable system suitable for patients and their caregivers - one that can be produced at a fraction of the cost. Field testing of the enhanced BCI system began last month, with up to 10 persons scheduled to receive the system for use at home or in hospitals by June 2006.

For years, brain-computer interface technology has excited researchers as a direct way to harness the human brain for controlling the body and the devices we manipulate. In the near term, this technology can give individuals suffering from conditions such as ALS (amyotrophic lateral sclerosis, also known as Lou Gehrig's disease), or brainstem strokes, the ability to communicate. These individuals face huge challenges in communicating and may even be entirely 'locked in' to their bodies, possessing no muscle control of any type.

Future iterations of the BCI technology hold the potential for controlling medical devices such as wheelchairs and prosthetic limbs. There is also great interest in applications where streamlined communications are essential such as military pilots activating jet defensive mechanisms. The challenge has remained to deliver BCI systems that are accurate, yet affordable and easy to use.

The Wadsworth Center BCI system consists of three primary hardware components and specialised software. A mesh cap holds small sensor electrodes firmly against the user's head. An amplifier is connected to the electrodes and is used to boost the minute analogue signals (measured in microvolts) received from the surface of the scalp into a more robust signal, which is then converted into a digital signal and analysed by specially designed signal processing software running on a PC. Two monitors are connected to the PC, one for the caregiver interface and one for the user interface. Cambridge Consultants helped Dr. Wolpaw's group transform its research-based system, with its inherently technically demanding interface, into a system capable of daily use by non-scientists. One of the hurdles included developing a sensor cap that was comfortable enough for extended wear, yet allowed an untrained caregiver to position the sensors accurately on the head. Positioning deviations from session to session of more than a few millimeters can dramatically affect the accuracy of the system.



Traces recorded from the scalps of four individuals using the BCI system to move a cursor from the centre of a computer screen to targets around the edge. The cursor paths are shown, with colour representing speed at each point, from slowest (blue) to fastest (red).

Cambridge Consultants is pursuing several alternative sensor cap designs to make them more ergonomically comfortable for extended wear and to provide a less obtrusive appearance, without sacrificing repeatability and precision of sensor placement and signal reception. The firm provided electronics hardware and software device drivers to link the BCI software with the hardware from several different manufacturers.

Cambridge Consultants also helped create a graphical software interface with icons and sound so that patients can more readily communicate with their caregivers. For example, patients now can access icons for 'water' and 'food', and traverse a menu with a variety of choices by using their brain waves to transcend the language barrier.

Patients make selections in either of two ways. In one, they pay attention to a particular icon displayed among many in a grid on the computer screen. As the various icons flash in succession, a distinct electrical response is evoked in the brain by the attended icon. The system tracks the timing of the flashes and the evoked response, identifies the attended icon and outputs the appropriate sound, text, and/or environmental control signal. The system can also generate speech from those words created on computer, enabling users to communicate audibly with a caregiver if they choose.

In the second method, the user can imagine particular movements. Even if the user is totally paralysed, this imagined action generates a localised electrical stimulus in the brain that can be detected by the BCI system. The system then maps that action to moving the computer cursor in a particular direction. In this manner, the user can navigate menu structures to select actions and/or perform word processing activities, similar to the way in which people normally use a computer mouse.

Future iterations will provide the ability to interface with environmental control systems to turn lights on and off or change the channel on a television as well as to communicate remotely with caregivers.

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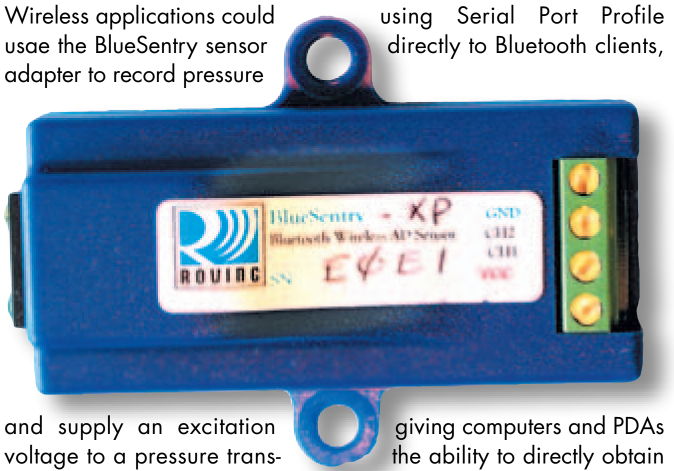
Tel: +44 (0)1223 420024;
Fax: +44 (0)1223 423373.
Web:
www.cambridgeconsultants.com**

Bluetooth compatible sensor interface module

BlueSentry AD is a complete, wireless enabled data acquisition and output control unit, measuring only 3 x 1 inches in size. Powered by AA batteries, car batteries, or any 5-25VDC source, BlueSentry can acquire up to 8, 0-5V inputs at high (16-bit) resolution and send this information to Bluetooth- enabled clients, LANs or anywhere on the Internet. The device can also be wirelessly linked to a paired output module, BlueSentry-DA, to replicate 4 analogue channels at a distance of more than 100 m. Typical applications for the device include process control monitoring, motion detection, temperature/humidity sensing, stress and strain gauges, fluid and gas metering, and scores of other applications where physical cabling is not possible or desirable.

Wireless applications could usae the BlueSentry sensor adapter to record pressure and supply an excitation voltage to a pressure transducer. The 'Sleep' feature of the device allows users to monitor for a longer period of time without replacing batteries.



BlueSentry devices can be operated in two modes. Firstly, BlueSentry AD can be connected using Serial Port Profile directly to Bluetooth clients, giving computers and PDAs the ability to directly obtain data from the sensors.

In access point mode, A BlueLine (*additional product)* access point can acquire, store, and display data over a LAN or the Internet from multiple BlueSentry-AD's, and can remote control multiple BlueSentry-DA's as well.

Key features of the new product include:

- Class I Bluetooth™ radio for long-range operation, up to 100 m
- Sleep mode (4 mA) while still discovererable/connectable
- External trigger activation
- Up to 1 kHz data rates(binary mode, 1 channel)
- Selectable 1 to 8 channels of sampling
- Selectable data capture rates, from 1 Hz to 1 kHz.

Further information is available from Lightwave Scientific Ltd, www.lightwave-scientific.com)

(067111-11)

Extra robust DC-DC converter for military and aerospace applications

International Rectifier (IRF) introduced the high-reliability (HiRel) AHP line of high power, high density hybrid DC-DC converters for digital and analogue circuits that require a well-regulated power source. The AHP converter family features an added over-voltage protection circuit on the input of the device while maintaining backward compatibility to the IR HiRel AFL converter series and other industry-standard converters. Building on the merits of IR's AFL series converters, the AHP series offers as high as 87 percent efficiency and a power density of as much as 84 W per cubic inch.

The new series of converters utilizes 25% less internal components, increasing reliability compared to the AFL series. The AHP series converters are designed to function continuously in rugged environments typically encountered in military and aerospace applications.

The AHP input over-voltage protection will shut down the converter at 110% of the maximum-rated input voltage and will restart when the input voltage drops below this threshold. The AHP converters also feature high power density with no de-rating over the temperature range of -55ºC to +125ºC. This series is offered as part of a complete family of converters providing single and dual output voltages and operating from nominal 270 V DC input and outputs of 3.3, 5, 6, 8, 9, 12, 15, 28, ±5, ±12, and ±15 volts and power ratings from 80 to 120 watts.

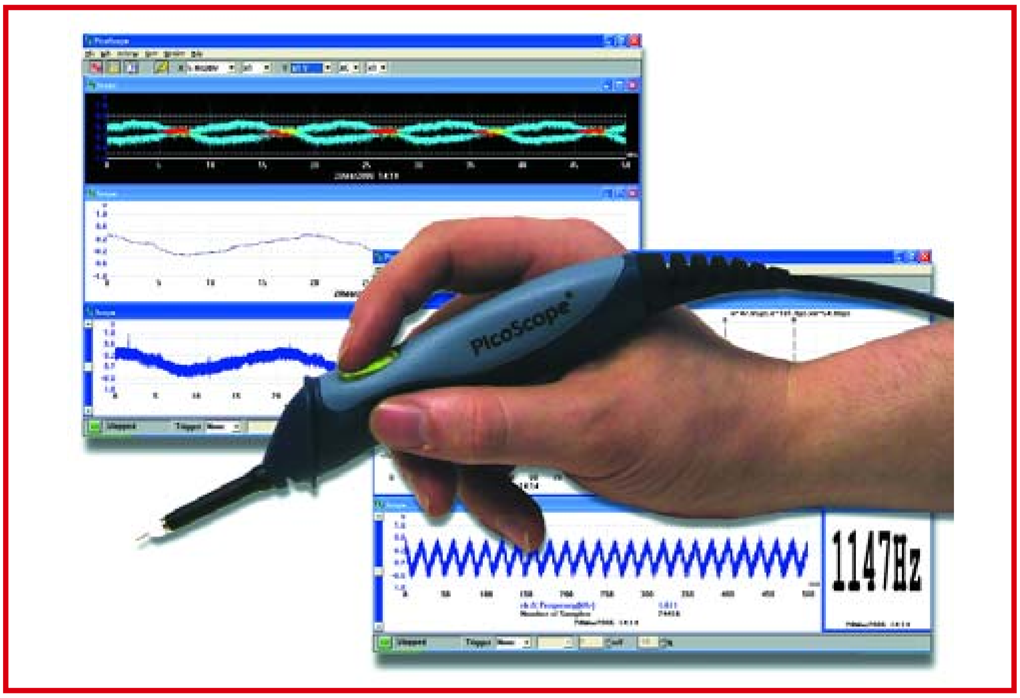
For applications requiring higher output power, individual converters can be operated in parallel. The internal current sharing circuits assure equal current distribution among the paralleled converters. This series incorporates IR's proprietary magnetic pulse feedback technology that provides optimum dynamic line and load regulation response. This feedback system samples the output voltage at the pulse-width modulator fixed clock frequency, nominally 550 kHz. Multiple converters can be synchronized to a system clock in the 500 kHz to 700 kHz range or to the synchronization output of one converter. Under-voltage lockout, primary and secondary referenced inhibit, soft start and load fault protection are provided on all modules. These converters are hermetically packaged in two enclosure variations, utilizing copper core pins to minimize resistive DC losses. Three lead configurations are available. IR's rugged ceramic lead-to-package seal and low profile (0.380") welded seam package assures hermeticity for long-term reliability in harsh environments.

The AHP converters are available in four screening grades to satisfy a wide range of requirements including CH grade, which is fully-compliant to the requirements of MIL-H-38534 for class H. Variations in electrical, mechanical and screening can be accommodated.

www.irf.com

(067111-13)

Designed to fit in your hand



With the new PicoScope 2105 USB PC Oscilloscope, Pico Technology has packed many of the features of a high-performance bench-top oscilloscope into a small, lightweight instrument that can be held like an oscilloscope probe.
When used with the PicoScope software supplied, the PicoScope 2105 converts any laptop or desktop PC with USB support into a powerful oscilloscope, without the need for additional probes or power supplies. An entry-level version, the PicoScope 2104, is also available to suit less demanding applications.
The PicoScope 2105 is suitable for a wide range of troubleshooting tasks on analogue and digital circuits. It has high performance, with a 100 megasample per second real-time sampling rate, a repetitive-signal sampling rate of 2 gigasamples per second provided by digital equivalent-time sampling, and a 25 MHz analogue bandwidth.
The instrument has eight input voltage ranges from ±100 mV to ±20 V. The USB interface and plug-and-play software make installation easy, and the user can set up, start and stop the unit by pressing a single pushbutton. A beam of light from the probe tip illuminates the area under test.
The PicoScope 2104 and 2105 PC Oscilloscopes are supplied with the PicoScope oscilloscope software and PicoLog data logging software, a 32-bit driver with fully documented programming interface, and example programs in C, Visual Basic, Delphi, LabVIEW and VEE. The software is compatible with Windows 98SE, ME, 2000 and XP.
The PicoScope 2104 and 2105 PC Oscilloscopes are available immediately direct from Pico Technology or one of its authorised distributors, at £125 and £199 + VAT respectively. Read further information on the Pico Technology website at www.picotech.com, or request details by calling

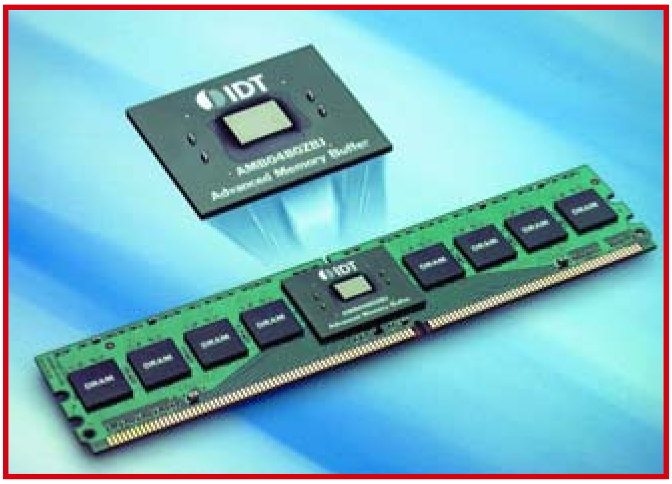
+44 (0) 1480 396 395.

(067111-14)

Advanced Memory Buffer Devices for Fully Buffered DIMMs

Integrated Device Technology, Inc. (IDT); announced that its advanced memory buffer (AMB) devices have passed the Intel Corporation validation process and are available to ship in volume. IDT claims to be the first AMB vendor in the industry to achieve this milestone.

Enabling fully buffered dual in-line memory module (FB-DIMM) solutions, AMB devices help increase the speed and memory capacity of servers and workstations, resulting in improved data-processing capabilities. Integrated onto an FB-DIMM, the IDT AMB devices handle the buffering, collection and distribution of data for each DIMM in a system, thus serving as an essential building block for next-generation, high-speed servers and workstations.
The industry is bringing fully buffered DIMM technology to market to deliver superior reliability and increased memory flexibility in servers and workstations. To support the transition to FB-DIMMs, IDT say it's essential to have a robust and diverse set of companies providing the underlying building blocks.



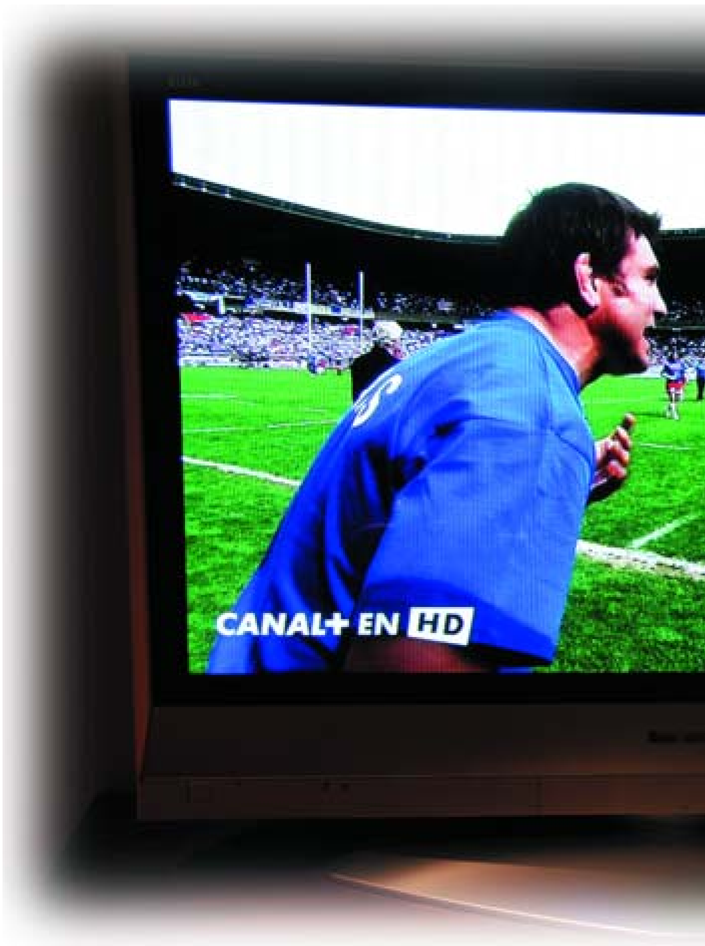
As a result of the combined resources achieved through its recent merger with Integrated Circuit Systems, Inc. (ICS), IDT is prepared to fully service the needs of this growing market, as well as other timing applications. More information about IDT memory interface products can be found on the IDT Web site at **www.IDT.com/?catID=58741.**

(067111-12)

Kick-off for HDTV?

Rainer Bücken

Dedicated footy fans will not need reminding that the FIFA World Cup football tournament hosted by Germany is due to kick off shortly. The event is also an ideal showcase for High Definition TV which promises to convey the live action in stunning detail. Each ticket sold for every game carries an RFID tag but the match ball (for the time being anyway) still contains only air…



The opening match of the 2006 world cup is due to kick off on the 9th June but it's not only the squads of players that will be straining every sinew to give of their best. Behind the scenes will be teams of engineers and technicians ensuring uninterrupted broadcast to the estimated 4 billion viewers worldwide. The month long tournament consists of 64 matches held in 12 football stadiums with an estimated 3.2 million spectators.

The HDTV world cup

'Digital and high definition' is how the international football association FIFA described the picture format for the 2006 games. Digital TV is already widely available but only in standard definition (SD) using 576 lines and in 16:9 aspect ratio widescreen. The same picture rendered on a 4:3 television leaves black horizontal bars above and below the image.

Many years ago the only method of receiving the terrestrial analogue TV signal was via a rooftop aerial but nowadays more options are available. The signals are either analogue or digital and can arrive via a cable, satellite dish or an aerial. A more recent alternative route is via a broadband telephone connection. Broadband bit rates of up to 100 Mbit/s have been achieved using DSL techniques and this makes the connection suitable for services such as IPTV which can stream TV from the internet to a set top box.

In addition to the home TV it is sometimes useful to be able to view on some sort of mobile device; currently there are three competing techniques to show TV pictures on mobile phones. The 'mobile TV' service is available from most phone companies and streams TV pictures to a 3G (UMTS) capable phone over the network. Some of the other competing systems will be touched on later.

25 cameras

Relaying the live action to more than 210 cities around the globe is an enormous responsibility and will be taken care of by the company Host Broadcast Services (HBS) which was founded just after the football world

World Cup electronics technology

Foto: R. Bücken

Figure 1.
The HD camera operators keep in mind the 4:3 picture format. (photo: R. Bücken).

Figure 2.
Match commentators at work. (photo: HBS).

cup event in 1998. The company specialises in providing TV coverage for major sporting events. It is estimated that it could receive a total of around 2 billion Euros in licence fees in deals struck between In Front Sports (a marketing sister company of HBS) and broadcast stations worldwide. A spokesman for the company pointed out that high definition pictures inevitably use more expensive equipment and require a higher bandwidth distribution infrastructure. The Japan/Korea world cup in 2002 used eight HD cameras to record 48 of the matches in HDTV, in comparison this year's tournament will see 25 HD cameras (**Figure 1**) deployed around the field of play for every match. Wireless links have proved to be somewhat unreliable in the past so will not be used during the 2006 games. The team in charge of the coverage at HBS includes experienced directors, producers, camera operators and technical staff from France, Germany and the UK. One of the tasks of the production team is to ensure that viewers using 4:3 aspect ratio television screens do not miss any of the action occurring at the edges of a widescreen 16:9 picture. The 16:9-picture format therefore contains a 'protected' 4:3 central region within which the cameraman will endeavour to contain the action. One channel carries the widescreen picture information while a second carries the 4:3 information. The TV sound channel has many options from stereo to Dolby Digital 5.1. A minimum of 24 microphones positioned around the pitch will ensure that the good natured exchanges between players and cheery encouragement from the bench will be clearly audible (if there is anything left after the expletives have been deleted). Audio feeds from the commentary boxes are also provided (**Figure 2**).

Pictures to the four corners

The production team are responsible for compiling feeds from camera signals, computer graphics and commentaries. The 'Basic International Feed' begins coverage 12 minutes before the match and ends 5 minutes after. The more extensive 'super feeds' provide coverage of 'team specific' action so that cameras following key players and the bench of team A will be sent to the corresponding broadcast station while the antics of the opposing

Will tags keep the touts away?

The 2006 World Cup tickets contain an embedded RFID (Radio Frequency Identification) tag which will make the ticket forger's job much more difficult and also speed up spectator entry to the stadium. The tag is one of the MIFARE family from Philips [1]. Similar smart cards are already in use in Moscow and in London the underground network uses a smart card ticketing system called **Oyster**, allowing commuters to pass quickly through barriers by simply waving the card over a short-range RF scanner at the beginning and end of each journey. No more waiting in line to feed a ticket into a slot. A similar system will soon be operating on the Dutch public transport network and four other countries have announced their intention to use RFID ticketing. A more secure RFID tag is also embedded in the new e-passports currently being issued by countries throughout the EU (see article elsewhere in this magazine).

The 2006 World Cup is the first international event using RFID technology to control spectator entry to the stadium. At the turnstile the ticket must be presented within 10 cm of the scanner for it to be read successfully. The interface conforms to the international ISO14443 standard. The scanner and RFID tag in the ticket exchange information at 106 kbit/s over a 13.56 MHz RF interface to establish if the ticket holder is allowed entry to the current event. The Philips MIFARE Chip used in the ticket has a 512-bit EEPROM which amongst other things contains a 7-Byte long serial number. The manufacturer does not freely give any further information concerning the technical specification in an effort to confound ticket forgers. A spokesman for Philips stressed that none of the ticket holder's personal details are stored on the chip but it has a unique serial number which 'personalises' the ticket and can be cross-referenced on a secure FIFA data base to the name, address, date of birth, nationality and identity card number of the ticket purchaser. UK nationals travelling to any of the games will not carry identity cards because their introduction in the UK is still by no means certain. The only way to tell if the ticket holder and ticket purchaser is the same person is to physically check the stored details of the ticket buyer with another form of identification carried by the ticket holder. It is anticipated that the volume of visitors will be such that only random checks will be possible.

The use of personalised tickets has raised doubts by some who see the era of Big Brother looming closer but the organisers insist the measures are intended to prevent troublemakers from spoiling the enjoyment of the majority and help put an end to the activities of ticket touts who sell-on tickets outside the ground at inflated prices. Troublemakers already known to the police authorities will not personally be allowed to buy tickets in the first place and any tickets that get lost or stolen can be made void on the database. Each ticket number is registered at the turnstile so that it will also not be possible to smuggle the same ticket outside to allow entry of anyone else.

In principle it is perfectly possible to build a scanner capable of reading the serial number of the MIFARE chip of a valid ticket (the September 2006 edition of Elektor Electronics will carry an article describing a scanner capable of doing just that!) even at a distance of about 1 m. With this information it would be feasible for the criminally minded to make an illegal 'ticket emulator' device which could then send out a signal containing the copied number at the turnstile and allow entry, hopefully the chances of this happening are small but if you are lucky enough to have a ticket maybe it's a good idea to keep it in an RF shielded pouch until you get to the turnstile, just to be sure.

[1] www.mifare.net/products/mifare_ultralight.asp

team will be sent to their home broadcast station. The format of these super feeds is a mixture of HD, 16:9 and SD 4:3. The format conversion will either take place locally or at the International Broadcast Centre (IBC) in Munich. The feeds include slow-mo, graphics, additional information and an English language commentary which can be used by any nation that has not sent their own commentators to the games. A team in Munich will be working round the clock to provide the service. It is estimated that the BBC are planning to spend £3 million of licence payers money to send a 300-strong team of football commentators and journalists together with support staff to the event while its main rival ITV will be sending a much smaller squad about a third of the size.

The German channel Premiere promises a full 24/7 football immersion experience during the games for those fans not wishing to miss any of the action. In the UK the rights to show the matches are shared between the BBC and ITV. The Japanese Broadcasting Corporation (NHK) is a big HDTV customer and has already announced the shutdown date of its standard NTSC television broadcasts for 2011. In the USA all 64 games will be transmitted in HD by both Disney channels ABC and ESPN. According to a recent survey conducted by Screen Digest and Goldmedia the US has around 19 million households equipped with HD televisions.
In the UK the BBC are planning to provide free HD coverage of the world cup but you will need to be in possession of all of the following: an HD set-top box, an 'HD ready' TV and a signal from either a cable provider or a satellite receiver. The BBC together with ITV, channel 4 and 5 will also be trialling an HD terrestrial service beamed to the aerials of a few hundred selected viewers in the London area but at present there is insufficient free bandwidth available to provide greater coverage. Preparations are also underway in France to ensure that the games will be available in HDTV format from Canal+, TF1 and M6 which send the signals terrestrially. Most other European countries will be offering similar services.

HDTV is the standard

All of the coverage will initially be captured in HDTV format with other picture formats derived from this source. A normal Standard Definition (SD) picture is made up of 50 half pictures per second (interlaced) each having 720 x 576 pixels giving a total of 414.720 pixels. The HD format also uses 50 half-pictures per second but with 1920 x 1080 pixels giving a total of 2.073.600 pixels. Picture interlacing produces an overall frame rate of 25 frames per second. This production standard is not directly compatible with other world systems especially in countries that have pioneered HDTV namely Japan and the US where 60 Hz is used instead of 50 Hz. A frame rate conversion is therefore necessary and takes place either in the IBC or when the signal arrives in Japan/America.

In the central Outside Broadcast Unit (OBU) at the stadium the main HD picture feed is sent as a High Definition Serial Data Interface signal (HD-SDI 1080i/25) at 1,485 Mbit/s together with the standard definition picture (SD-SDI 625i/25) at 270 Mbit/s. HDTV signals require specialised equipment, **Figure 3** shows an outside broadcast unit belonging to Studio Berlin which can handle feeds from 23 cameras. This unit was built by Thomson at a cost of approximately 10 million Euros and will be used for the six matches held in Berlin and five in

Figure 3.
One of the outside broadcast units of Studio Berlin. (photo: R. Bücken).

Leipzig. It is anticipated that additional 'HD capable' OBUs will be hired to provide backup for the duration of the games.

High speed cables

Two high-speed protected 20 Gbit/s fibre optic cables carry the HD programme signals from each of the 12 stadia to the IBC centre in Munich; one cable alone can handle the entire bandwidth while the second provides backup. Should both these links go down there is also a satellite link which can be brought into play.
The high speed link between the IBC in Munich and the main German broadcast studios in Cologne, Mainz and Berlin is provided by the network supplier T-Systems and consists of a ring-structured underground cable allowing a bit rate of 2.5 Gbit/s using WDM (Wavelength Division Multiplexing). Feeds to the rest of the world are also routed from the IBC through the T-Systems network and then on to either fibre optic or satellite links. Fibre-optic is preferable for the viewer because it introduces less delay in the interviews conducted between studio and stadium.

Have you got what it takes?

So we can be sure that the HD pictures will be available but do you have the equipment at home to display them? To start with most of the major TV manufacturers have been offering 'HD ready' sets for quite a while and at the end of 2005 there were already 700,000 sets in homes around the UK. HDTV set top boxes capable of decoding

Figure 4.
HDTV set top boxes are a little thin on the ground, this one is from Humax (photo: R. Bücken).

Figure 5. TV programmes can also appear on your 3G mobile. (photo: R. Bücken).

compressed H.264/AVC satellite DVB-S2 signals or the QAM 256 modulated cable signals are a little thin on the ground. Boxes from Pace and Humax (**Figure 4)** are currently available and a Philips box has been scheduled for the end of April. PC users are also starting to see plug-in TV cards for their machines capable of decoding the HD signals but these are even rarer than the set top boxes. Failing that it may also be possible to get the World Cup high definition experience by visiting your local cinema.

The Odeon chain is planning to screen all the England matches plus the quarter and semi-final games at selected cinemas in the UK.

And on your mobile?

It would seem a pointless exercise sending HD pictures directly to a mobile phone because of the relatively poor resolution of its screen but HBS offer a 'near-live action' clip service which has been adopted by some UK mobile phone companies. Each clip takes around five minutes to prepare by staff at HBS who crop and zoom the live HD footage to show just the most important/exciting parts of the action. Each clip lasting up to four minutes is then sent to the subscriber's phone. This service may however run into some legal difficulties because many European broadcasters are arguing that this infringes the terms of their licence which gives them the rights to moving images of the games.

In the Netherlands Vodafone have struck a deal to show live world cup footage of all the games and in Germany T-Mobile will offer a similar service while their competitors Vodafone are offering mobile TV via UMTS (**Figure 5**) and DVB-H (Digital Video Broadcast - Handheld) is available in some parts of the country for mobile phones with built-in DVB receivers. DVB-H differs from the conventional DVB-T television broadcast signal in that it car-

Smart balls are on their way

Rainer Bücken

July 30th 1966 was indisputably the high point in English football when the team earned the right to wear a star on the England football strip. The score was level at 2 goals all when Jeff Hurst's shot hit the crossbar and bounced down into the German keeper's goal. He reacted quickly to palm it off the line but did the ball actually cross the line and score? According to the Swiss referee and Russian linesman it had. If they thought it was all over it certainly was a few minutes later when Hurst raced down the pitch in a monumental solo effort to slot home his hat trick and put the final game beyond Germanys grasp. The decision to allow the disputed goal was based on the eye witness evidence of the linesman. According to the rules of football the whole of the ball needs to cross the goal line before a goal is scored and this can be difficult to judge by eye from the sidelines. In an effort to remove any degree of doubt, researchers and engineers have been working hard on the problem of accurately tracking the flight path and positioning of the ball so that in future a computer can adjudicate.

Work on the 'smart ball' was begun by Cairos Technologies in 2000 and collaboration with the Fraunhofer Institut Integrierte Schaltungen (IIS) was forged in 2001, by 2004 the sports company Adidas were also brought in to the venture.

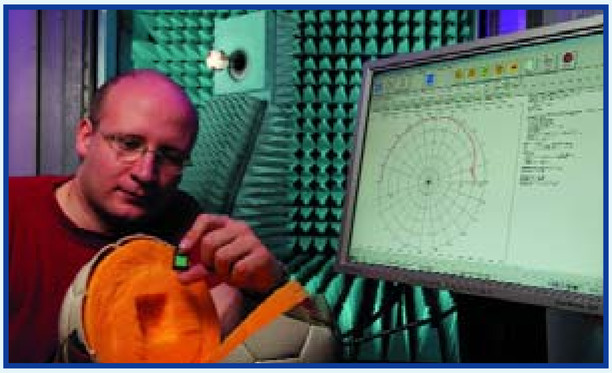
The Cairos system uses an ASIC (Application Specific Integrated Circuit) chip suspended in the centre of the football. The chip contains a transmitter and an inductively charged battery which continually transmits a signal 2000 times per second on the 2.4 GHz band. Receivers placed around the pitch pick up the signal

ries lower resolution picture information more suited to the small screen and the transmitted signal occurs in short bursts, allowing the phone to store and display the received pictures while shutting down the receiver electronics between bursts to prolong battery life.
An interesting alternative device to send TV pictures to your mobile has been developed by the ROK Company and is due for release one week before the World Cup kick off. It provides a kind of 'reverse IPTV' service by linking the video signal output from an existing home TV tuner (Sky digibox included) to your mobile via the home broadband connection. The ROK Black Box streams live TV at an impressive 25 frames per second. It requires a 2.5G or 3G (UMTS) capable phone. A list of compatible phones is shown on their website. Changing the TV channel is performed directly from the mobiles keypad. The advantage of this device is that it is not linked to any specific network or programme, if you've had your fill of football it's a simple job to change over to The Simpsons.
In four years time FIFA will be marketing the 2010 World Cup in South Africa, technology will have moved on and no doubt so will the cost of the broadcasting rights licence. Some have speculated that this bill could rise to 1 billion Euros for the broadcasters in Europe alone. By that time many more of us will be receiving high definition pictures by whatever means, let's just hope there will be something worth watching…

(060053)

Links

www.hbs.tv
www.infrontsports.com
www.bbc.co.uk
www.itv.com
www.rok.tv
www.premiere.de



A prototype ball showing the radio chip packed in foam. (Picture: Fraunhofer IIS).

Aerials around the pitch perimeter detect time differences in the signal received from the smart ball which allows its position to be calculated (picture: Fraunhofer IIS).

and send it to a central controller via fibre optic cables. The time difference between the received signals allows the ball position to be calculated to a resolution of 1.5 cm. A display on the referees watch indicates immediately if the ball crossed the line. The cost of the system is estimated to be in the region of 200,000 Euros for each stadium. A patented suspension system ensures that all the electronics in the smartball are suspended in the centre of mass so that the ball maintains its balance.

The ball was introduced at the FIFA under-17 world cup in Peru in 2005 but the verdict was inconclusive, guardians of the football regulations namely the International F.A. Board (IFAB) and FIFA, took the decision on the 4th of March to put off the introduction of smartball technology for the world cup 2006 saying that more work and testing is necessary before the technology can be adopted. The IFAB and FIFA are also studying other solutions to the problem such as digital cameras used by the Italian football union and UEFA are testing a new communication system for use by the referee and the assistants. A request from a French representative to use a video back-up system was rejected on the grounds that it would introduce an unacceptable delay in the game.

www.fifa.com/de/regulations/regulation
www.cairos.com
www.iis.fraunhofer.de
www.adidas.de

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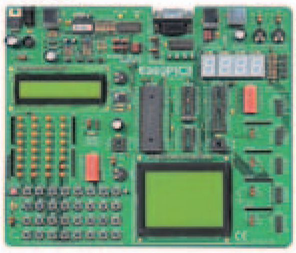

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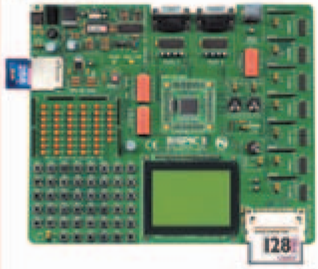

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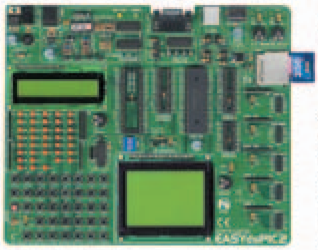

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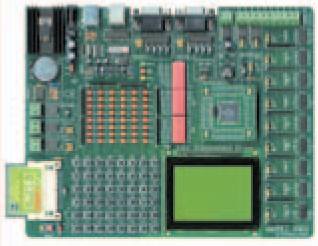

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✓ DS18S20 temperature sensor
✓ USB programming/power lead
✓ Programming software and examples

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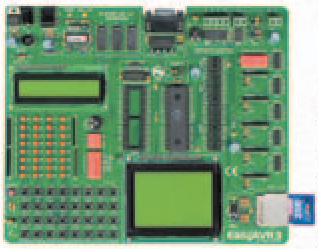

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✓ DS18S20 temperature sensor
✓ USB programming/power lead
✓ Programming software and examples

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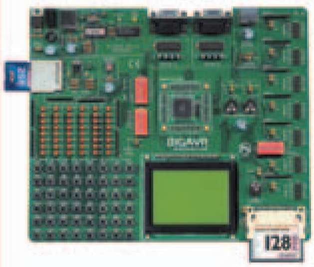

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- Windows 98/ME/2000/XP compatible
- Supports 64-pin AVR microcontrollers
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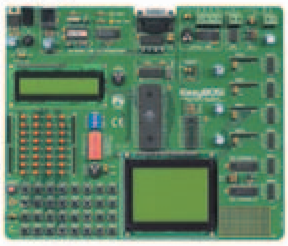

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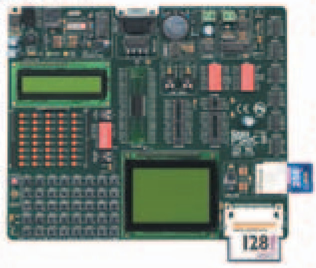

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ePassports

Gerhard Schalk, Philips Austria

If your passport runs out in the next few months the chances are you could be issued with one of the new electronic passports that are being introduced throughout the EU this year. ePassports have an imbedded RFID tag containing your personal information which Immigration officials can read remotely; hopefully nobody else will be eavesdropping on this electronic conversation…

The 5th March 2006 saw the issuing by the UK passport service of the first electronic passport or ePassport. It is planned that the introduction of these new passports will be gradually phased-in over the next few months up till August when the old style passports will be dropped. The themes of biometric data, data protection and identity cards are currently hot topics in the media, just how much personal information will be included in these new passports and how secure will it be?

The ePassports currently being issued contain the same personal information as the old style passport: name, place/date of birth and a 15 kByte JPEG image of the holder. With the exception of the digital photo all of this data is already in the Machine Readable Zone (MRZ) of the passport and can be optically scanned at customs checkpoints, from 2007 it is anticipated that the left and right index fingerprints will also be stored in the passport.

The information is stored as digits in a tiny RFID type tag imbedded in the passport. Several manufacturers produce suitable security tags but the P5CD072 from Philips (a derivative of the 'Smart MX Secure Smart Card Controller' family) [1] is currently market leader in this field with approximately three quarters of the countries introducing ePassports choosing the Philips chip. Another contender is the German company Infineon with the SLE66CLX641 which is used in some German passports. It is not unusual for the authorities to issue contracts to more than one manufacturer to ensure a second source of components. The potential market for these chips is enormous, Infineon have estimated that approximately 2.4 million passports will be issued in Germany this year alone. Worldwide this figure will be close to 125 million.

Smart Card Controllers with contact-less or proximity interfaces are similar to the standard RFID tags but have a much higher level of security built in to them, similar to smart bank cards with an interface connection using eight contact pads. The Production of software for the chips is rigorously controlled in every country issuing ePassports likewise the specification for the chips them-

Will they really be secure?

selves is closely guarded and only a summary of its features are generally available from the manufacturers. The fundamental technical specification of the ePassport was produced by the International Civil Aviation Organization (ICAO) which is part of the family of the United Nations organisations. The document specifies a machine readable travel passport which will soon be introduced worldwide. All the ICAO technical documentation can be freely downloaded from the ICAO home page [3]. The standard defines the worldwide interoperability of machine readable electronic travel documents.

The Smartcard Chip

A smartcard controller is in principle just a specialised type of microcontroller which can securely store sensitive information and has a built-in coprocessor facilitating the computations necessary to handle encrypted data. The Card Operating System (COS) is stored in ROM, security of this data is paramount to ensure correct execution of application software and integrity of stored data.The P5CD072 Smartcard chip is a high security dual interface controller with 160 KByte ROM, 4.6 KByte RAM und 72 KByte EEPROM. The Dual interfaces indicates that the chip has two methods of interfacing to the outside world; either through a number of contact pads (like the ones on your credit card) or contact-less (proximity) using an antenna to receive power and transfer data. The CPU has a 24-bit DPTR which can address a memory space of 16 MBytes. The controller instruction set is totally compatible with 8051 processor code but with some additional instructions to give faster memory addressing for the cryptographic coprocessor together with specific instructions which support the smartcard operating system.

Program development for the 'SmartMX' family of controllers is performed using the special assembler/compiler produced by the specialist software house Kiel. On the grounds of code optimisation (reduced memory usage and higher execution speed) part or all of the operating system is implemented in assembler. Before the finished program is committed to the chip ROM mask it undergoes intensive software testing using emulators produced by Keil or Ashling.

In common with all other smart card devices from diverse manufacturers, data sheets, application notes, example coding and development tools are not available to the general public. A short form specification is all that can be downloaded from the manufacturer's web site [1].

Contact-less Interfacing

The smartcard embedded in your credit/bank card makes use of eight surface contact pads providing connections to VDD, GND, IO1 to IO3, CLK and RST to communicate with the computer behind the 'hole in the wall' cash dispenser. The passport chip however uses a contact-less or proximity interface conforming to ISO/IEC14443.

In place of the eight gold-plated connections used by the majority of smartcards on the market Philips have developed a tiny contact-less chip **Figure 1** occupying an area of just 320 µm. This device is small and robust enough to be embedded in the passport. The chip has two connection pads LA and LB for attachment of the aerial. Before the chip is fitted to the passport (**Figure 2**) it is connected to the antenna and the assembly is mounted in a special carrier material or 'inlay'.

The ICAO has specified contact-less technology because it is inherently more reliable than a system using mechanical contacts which suffer from poor connections after prolonged use and eventually become unreliable. A further advantage of this technology is that it can be more easily integrated into the existing passport format. With the chip physically embedded inside the passport it is also thought that this will increase the security of the document and provide additional protection against forging. The

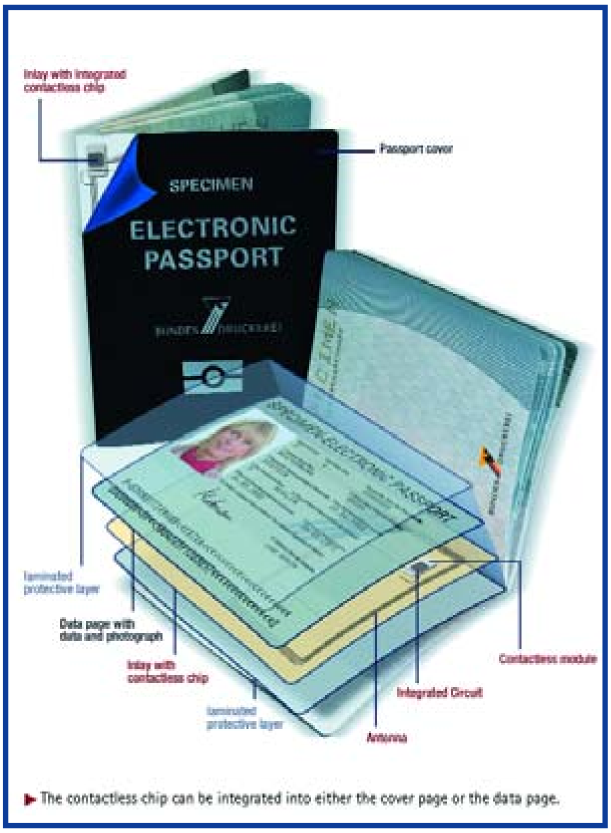


Figure 1. The Chip and aerial coil is mounted on an inlay. (Bild: Bundesdruckerei [8]).

ICAO allow many possibilities of positioning the chip in the passport so depending on which country issued the passport you may find it either inside one of the pages of incorporated in the passport cover.

The communication

Energy and data transfer to the secure card occurs using the same technique as normal RFID tags with an integrated antenna and a decoder circuit. The ISO/IEC14443 Standard defines the data transfer between these so called 'proximity cards' and the reader equipment. The maximum range of the card from the reader is 10 cm. This part of the specification (apart from the communication protocol) is identical to the industry standard Mifare® (**Figure 3**) interface system. The accumulated experience from more than 500 million of these Philips chips that are already in circulation indicates that this data transfer method has very good reliability.

Figure 2. The Smartcard controller is just 0.32 mm thick. (Philips).

Before any communication with the smartcard can begin a reader terminal emits a high frequency electromagnetic field which is detected by any smartcard in range. The 13.56 MHz carrier frequency induces energy in the smartcard aerial which it then stores to power the chip. The signal modulation method from the reader to the passport is 100 % Amplitude Shift Keying (ASK), information is conveyed by simply turning the carrier on and off. This modulation method can be very easily and reliably demodulated by the contact-less smartcard in the passport.

Data from the passport to the reader uses load modulation with subcarrier. The subcarrier frequency is 847 kHz (13.56 MHz / 16). Subcarrier Modulation is performed by switching it on and off. The data transfer rate is currently defined as 106, 212 and 424 kbit/s for passports. All communications are necessarily organised as a master/slave interchange where the reader plays the role of master.
ISO14443 specifies a signal field strength of 1.5 A/m to 7.5 A/m which will induce a power in the reader of around 5 mW at a distance of 10 cm to run the CPU and coprocessor of the P5CD072.

The chip hardware

The P5CT072 block diagram shown in **Figure 4** incorporates a few additional blocks that you would not usually find in a standard microcontroller; the RF interface, the CIU (Contact-less Interface Unit) and the CRC16 generator are all used for contact-less serial communication with the reader hardware. The CIU is a special contact-less ISO14443 UART.

The 3DES coprocessor can encode or decode a 3DES message of eight bytes in less than 25 µs with the help of its dedicated hardware. The 'FameXE PKI' coprocessor is a special mathematical coprocessor that is optimised to calculate some of the more popular asymmetric encryption algorithms such RSA (Rivest, Shamir and Adleman) and ECC (Elliptic Curve Cryptography). The processor and coprocessor work together when these ciphers are used, the processor can prepare registers to store intermediate values generated by the 32 bit coprocessor during calculation. A dedicated fast RNG (Random Number Generator) is also used during cipher calculation.

Access to the ROM, RAM and EEPROM is managed by the Memory Management Unit (MMU). This allows a real hardware firewall to be constructed between the operating system kernel and all the other program functions and application software. The processor supports two modes of operation; the kernel runs in *system mode* and has unlimited access to hardware while application specific operations such as communication routines, internal filing system, cipher calculations or passport functions run in *application mode* and can only access their dedicated areas of memory and have either no or limited access to the hardware. This prevents access to the memory and hardware either as a result of physical interference or from tampered software or even as a result of a software bug.

Hacker protection

There are also security features built into the hardware of the P5CT072; sensors constantly monitor the voltage, temperature and frequency limits of the chip, a light sen-

Can anyone skim your details?

You may have noticed that special passport protective covers are starting to appear on the market [5] they are usually made of aluminium and are designed to protect your passport from casual skimming of the RFID tag. These covers may look attractive and will help keep your passport looking pristine but they really offer little else. Provided the passport is kept shut it is protected by a 'Basic Access Control' (BAC) system which prevents tag skimming; before data can be read from the tag it is necessary for a customs official to open the passport and read information in the MRZ with an optical scanner, some of this information is then encoded to produce an 'authentication key' and sent to the RFID tag which tells it that it is at a genuine passport control desk and effectively unlocks communications with the tag. The passport control desk therefore requires both an optical reader to scan the Machine Readable Zone (MRZ) and also a contactless reader for the tag. This system is inherently more secure than a simple identification number associated with your passport, for example like the PIN you tap in when making a credit card purchase, here it is only necessary for a four digit code to be correctly entered before the sale is authorised.

Once communication with the tag is established information exchange begins and the data is encrypted using triple-DES (112 bit key length) [4]. This system presently gives a good level of security for the data exchange and effectively prevents any casual eavesdropping. The information exchanges also contain embedded checksums to prevent unauthorised data manipulation.

From 2007 it is proposed that fingerprint information will be added to the personal data stored in your passport. This additional personal information will be protected by an increased level of access control known as 'Extended Access Control' (EAC). The system uses public key cryptography to identify the customs control point and selectively bar the reader from accessing finger print information. The governing authorities issuing passports in each country will use EAC to control just how much personal data can be read by a customs officer at an overseas passport checkpoint.

sor is also used to detect any hacking techniques using powerful lighting.
Additional security in the hardware protects against code-crackers who use 'Simple Power Analysis' (SPA) and 'Differential Power Analysis' (DPA). These cracking techniques rely on the fact that when a CMOS gate inside the chip switches state from a 0 to a 1 the current drawn from the power supply is different to when it switches from a 1 to a 0. With the help of an oscilloscope and signal analysis it is possible to build up a 'current profile' of an unprotected circuit and gain some insight into the encrypted information. To counter these attacks the chip is designed to draw a constant current irrespective of internal data flow, in addition the processor and coprocessor perform dummy calculations to increase the apparent 'randomness' of processor activity.

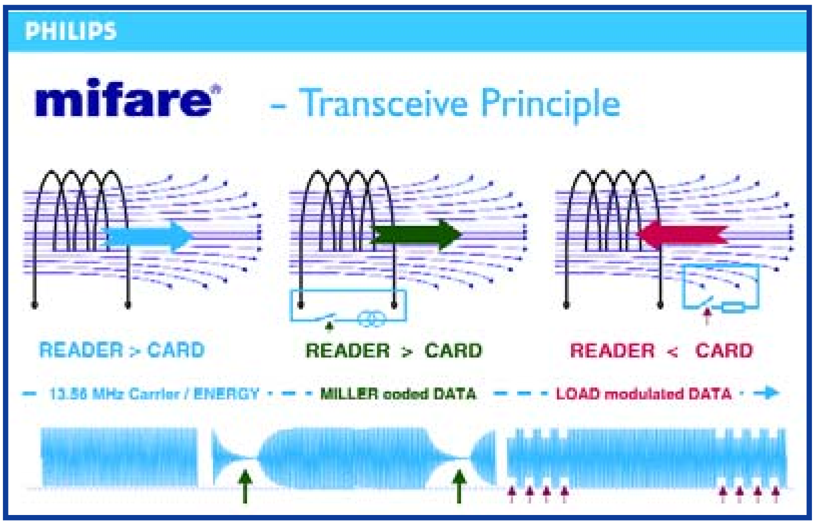
The smartcard layout is also designed to prevent unauthorised reading and data manipulation. Extensive use of 'glue logic' is used to distribute the processor components throughout the P5CT072 chip, it is not possible to identify a single area that is the CPU or the system bus, instead parts are scattered around the chip in an apparently disorganised arrangement. Likewise the address, data and control lines to the ROM, EEPROM and RAM are scrambled so that address locations are not contiguous but instead increment in an apparently random way; the memory cell addressed at 1001 does not necessary follow the cell at 1000. This arrangement provides some protection against simple memory dumping attacks. Each time the chip performs a power-on-reset memory cells in RAM have their addresses reallocated so that they do not have the same address as before.

The level of security offered by these smartcard ICs (and also the passport) is dependant on the absolute integrity of the manufacturing process of the chips and compilation of the passports themselves.

The operating system

The application software and operating system for the German passport system was developed by T-Systems, an offshoot of Telekom. The basic operating system is divided into the following categories: communication over the contact-less interface, program control com-

Figure 3. Reader and Smartcard communication using the Mifare® Principle. When reading the card modulates the reader signal by loading the resonant circuit. (Philips).



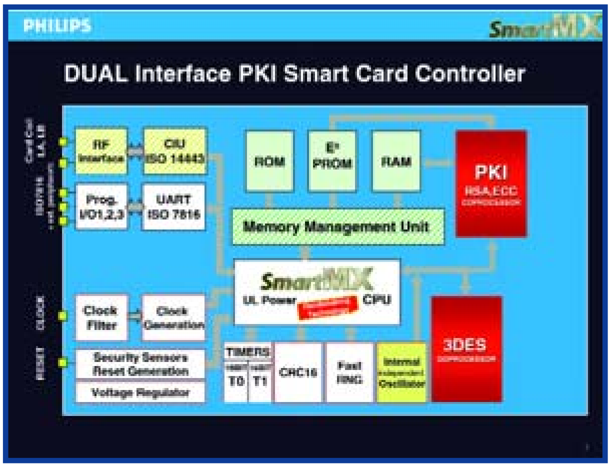


Bild 4. Block diagram of the Smartcard controller (Philips).

Is Big Brother watching?

During manufacture of each of the RFID chips and also contact-less Smartcard ICs a Unique Identification number (UID) is programmed into EEPROM. The UID allows the card reader to identify each individual card when several are presented to the reader at the same time. Communication with each card is selectively enabled so that data collisions from more than one card cannot occur (Anti-collision protection). However for a passport a fixed UID can provide a link to its owner, this relationship is forbidden for all EU passports so instead a random temporary UID (Random ID) is generated which is valid only for the duration of each session.

mands, file system management, application of cryptographic algorithms for data security.
The smartcard filing system is organised in a similar way to DOS files on a PC. The files are stored in the smartcard EEPROM and contain all the personal details. Once they are stored in the EEPROM the operating system ensures that no further write operations are allowed to overwrite this data.

The ICAO has also defined further security features for the electronic passport. The integrity and authenticity of the stored data is protected by a unique digital signature and its hash value [4] is stored in a dedicated file in memory. The digital signature certifies that the data was encoded by an authorised agency and has not been altered. Every passport issuing body has a digital certificate with a public key register stored by the ICAO, this ensures that the chip data can be authenticated by the digital signature issued only by the passport authority.

(060010-1)

Links

[1] www.semiconductors.com/products/identification/

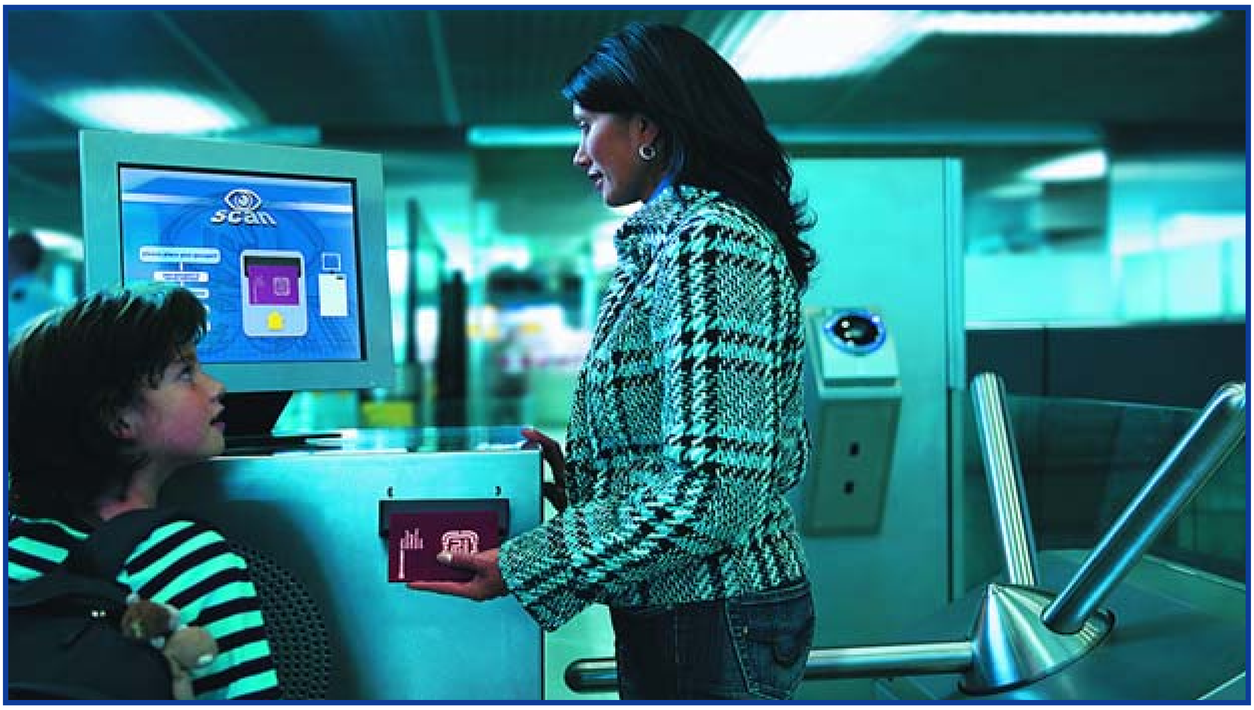
[2] www.infineon.com/security_and_chipcard_ics

[3] www.icao.int/mrtd/download/technical.cfm

[4] http://www.wikipedia.org

[5] https://shop.foebud.org/

[6] www.bundesdruckerei.de



The new ePassports could make miserable border guards a thing of the past…

RFID and Security

Paul Goossens

RFID tags are being used in an increasing number of places. For instance, they are used in the payment systems of public transport services in several cities and as library cards. In this article, we examine some security and privacy issues related to RFID tags.

An RFID tag is a combination of a special IC (chip) and a small antenna. When such a tag comes within range of a corresponding reader, the RFID chip is powered by the energy transmitted by the reader. The reader and the chip can use these radio waves to communicate with each other in both directions.

RFID tags can be used for many different purposes due to the fact that they are wireless devices. A tag can communicate with a reader without even having to be visible. That also creates a few disadvantages. Users of RFID tag usually do not notice that their RFID tags are being read, and they will be equally unaware if other persons eavesdrop on the communications between a tag reader and their tag.

Downside

Suppose you're shopping at the grocer's and you put a nice cut of beef (with its own RFID tag) in your trolley. When you pass by the wine section, your trolley (fitted with a reader) tells you which wine fits best with your meat. That's a pretty harmless scenario, but other scenarios are less so – for instance, suppose someone else could read and copy the information in your passport without your knowledge, or charge a petrol purchase to your account? In such situations, you naturally don't want to unwittingly let yourself be victimised by malicious persons or companies.

Various groups of people are now busy publicising hazards of this sort in order to make it clear that caution must be exercised in using this new technology and that security is a very important aspect that manufacturers and organisations must take into account.

For instance, a group of students hacked the RFID system of the Exxon Mobile Speed Pass, which is used in a payment system for American filling stations operating under the Exxon brand name. The RFID tags for that system are fitted with a cryptographic system, but that wasn't enough to prevent the students from making a purchase using a DIY RFID tag copied from a genuine tag. They used a homemade device to receive the communications between an RFID payment card and the associated reader at a distance (and thus without being noticed). After analysing the communications, they were able to crack the protection and copy the RFID card. As an experimental test, they then filled up with petrol and successfully used their copied RFID card to automatically pay for the purchase. Of course, the RFID payment card they copied belonged to one of the group, so what they did could not be treated as a criminal act.

Since then, the first RFID virus has been developed by one of the members of a research group at the Free University of Amsterdam. That virus was written for the group's own RFID system, which is not a system that is used commercially. Nevertheless, it clearly shows that it's necessary to pay attention to the potential hazards associated with RFID technology.

Melanie Rieback

The person who created the virus, Melanie Rieback, did so to draw attention to issues related to the security of RFID systems. In her opinion, the privacy and security risks are not only a problem for consumers, but also for companies that want to use this technology. The number of items that have been published about this virus certainly suggest that she achieved her objective. As a result of this attention, several companies have approached Melanie to ask her to help them improve the security of their RFID software. Unfortunately, a few companies in the RFID business responded very negatively to the virus and regarded it as a tempest in a teapot.

Besides the previously mentioned hacking of the Exxon Mobile Speed Pass, Melanie mentioned that the new Dutch passport is not entirely secure against hacking. A company in Delft named Riscure has shown that the proposed RFID technology is not sufficiently secure. They managed to crack the key to such a passport in a few hours, which then put them in the position to read the birth date, passport photo and fingerprint data from the new passport without that being noticed. In response to this, the Dutch Ministry of Internal Affairs announced that the security of this technology would be improved.

The Dutch passport is not the only one to suffer problems from the security of its RFID tag. The American passport is also drawing sharp criticism. At the recent Computer, Freedom and Privacy conference, a member of the American Civil Liberties Union demonstrated that the new American passport could be read at a distance of a metre, while the manufacturers stated that it could only be read within a distance of a few centimetres.

Worrisome

Given these examples, Melanie wonders whether the industry has actually learned anything from them. 'Cars are tested exhaustively before they're allowed on the road, so why isn't there adequate testing for technologies that pose a threat to privacy?' How can people be

Viruses threaten RFID tags

expected to trust and accept these new products if it turns out that they haven't been adequately tested? Up to now, it's only been research institutions that have cracked RFID technology, but who's to say that people with malicious intentions can't or won't do the same? Once enough RFID systems are put into use, it's simply a question of time until the real test comes: the practical test. Unfortunately, by then it's too late.
Even RFID chips used instead of barcodes can be used to collect privacy-related information. Every RFID chip with an embedded serial number can be used to trace where people go, monitor their purchasing behaviour, and so on. For several years already, several organisations have been warning about these undesirable effects of RFID systems. The opinion of the industry regarding reports of this sort is that intended to cause a general boycott of RFID technology, which they do not regard as a particularly serious threat.

Solutions and barriers

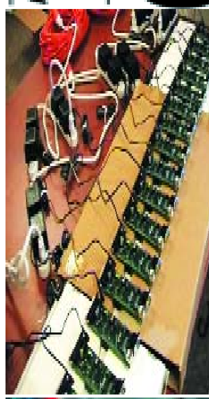
Fortunately, there are also ways to counter these hazards. For instance, there are RFID jammers that are designed to interfere with communications between RFID tags and RFID readers. If someone is carrying such a jammer, it is not possible to read RFID tags in his or her immediate vicinity. Melanie is a member of a research group that is working to develop what they call the 'RFID Guardian', which is more sophisticated in operation than a jammer.
The RFID Guardian will allow the user to personally select which RFID tags can be read and which cannot be read. It will be able to analyse queries from RFID readers and decide from the result of the analysis whether to permit or deny communication. That would make it possible, for example, to allow your public transport card to communicate but block all other RFID tags. Such a system is comparable to the firewall in your computer.

A say

According to Melanie, it's important for consumers to voice their opinions and demand a higher level of security. Tests with enhanced security in RFID chips have already been made, but they are only laboratory exercises. A lot of money will have to be invested to make this level of security available on a large scale. As long as consumers are willing to put up with relatively low security, manufactures will probably have little interest in investing a lot of money in additional security.
Several committees are presently drawing up standards for RFID systems. It is to be hoped that these standards establish more stringent requirements for RFID security that is presently the case. Of course, manufacturers of RFID chips are also represented on these committees. They are dead set on being able to use their current technology, because otherwise they will have to invest a lot of money in improving their products.

Retort

Based on these results, we asked Philips (one of the world's largest manufacturers of RFID devices) for their response to this issue.
Philips said that they were aware of the hazards related to RFID technology. They consider it important to keep track of developments of this sort, and they are also interested in seeing what sorts of hazards RFID technology is exposed to. However, Philips remarked that was is important to know how the virus was tested and that the case in question involved a system that was specifically set up to serve as a target for cracking.
Philips said that risk with reports of this sort is that they are also read by people who are not so well informed about the method that was used. That can lead to a mistaken interpretation of the facts and generate a false impression among consumers.
According to Philips, the RFID tags they have developed for use in passports and payment systems are so well protected that they are safer than payment transactions on the Internet. For instance, Philips supplies RFID tags to Visa (among others) for their banking cards. The tags were thoroughly tested by Visa before they were approved for use in their payment cards.
They also said that the security used in a system depends entirely on the type of application for which RFID is used. For instance, Philips has supplied more than 500 million Mifare RFID chips since 1994, which among other things are used in a payment system for public transport. Up to now, they are not aware of any of these RFID chips ever being cracked.



Conclusion

RFID tags are poised to play an increasingly important role in our society. The extent to which that will cause security problems is presently guesswork, but it's perfectly clear that this issue must be examined critically. Particularly if we start carrying around banking information, medical data and other sensitive information in our RFID tags, it is important to screen this information against unauthorised persons.
On the one side, we see the RFID manufacturers, who promise us even more luxury and convenience from using RFID technology. On the other side, there are groups of people who regard the coming of RFID as the prelude to the apocalypse. Which of these two sides will turn out to be right? As usually happens, the truth will most likely lie somewhere in the middle. In any case, you can expect *Elektor Electronics* to keep a close eye on these developments.

(060174-1)

Web links
http://rfidanalysis.org/
www.rfidvirus.org/
www.riscure.com/
www.rfidjournal.com

Scopemeters

All in one hand

Jan Steen

A while ago, we tested a large number of USB oscilloscopes for *Elektor Electronics*. As a sort of follow-up to that, here we subject ten 'scopemeters' to a careful examination.

Scopemeters are primarily designed for portable use. Like USB oscilloscopes, many of them are multifunction instruments. Although some models can only be used as oscilloscopes, most of them can also be used as multimeters or (in some cases) FFT analysers. Some models also include additional functions that are relatively easy to integrate into an instrument of this sort thanks to the current state of technology, such as a frequency counter or a function generator. The options and measurement ranges vary from one instrument to the next, and they are naturally related to the price.

Although scopemeters are a good deal larger than digital multimeters, they are generally small enough to hold in one hand, which leaves your other hand free for making measurements. The dimensions of the LC display vary from one model to the next, but it is generally a good deal larger than the display of an 'ordinary' digital multimeter so the measured signals can be displayed clearly. Relatively expensive models usually have somewhat larger displays, and some of them have colour displays. We even had the opportunity to admire a model with a touchscreen display.

Application areas

It's not particularly difficult to put your finger on the application areas for scopemeters. Although certain models are ideally suited for a fixed working environment or workstation, these instruments are of course primarily intended to be used in the field. Their limited size and weight, combined with independence from an AC power source thanks to internal batteries, make them an ideal choice for service applications in many different areas. In addition, they are very easy to transport. If you have to fly to a foreign country to make measurements 'in the middle of nowhere', it's naturally easier to take along a scopemeter than a normal oscilloscope. Several models thus come with a protective case with space for the measuring accessories.

Professional versus semi-professional

For the sake of convenience, we used the purchase price as the criterion for this distinction. We classified everything under £ 700 (€ 1000) as semi-professional, and thus everything above £ 700 (€ 1000) as professional. That doesn't mean a scopemeter costing £ 350 (€ 500) (for example) cannot be used for professional purposes. It's possible to imagine situations in 'professional' environments where it would be useful to graphically display a particular signal without actually placing any requirements on the accuracy of the measurement. In many cases, it's sufficient to know that a particular signal is actually present somewhere, instead of making all sorts of exact measurements or analysing waveforms. The more expensive instruments generally have larger and nicer displays, and they naturally offer more features along with a larger measurement range and/or a higher sampling rate.

Sampling

The sampling rate indicates how often actual measurements are made in a given time interval so they can subsequently be displayed. A waveform is thus built up from individual samples. The instrument 'joins' the individual points so they can be displayed graphically. However, a high sampling rate is of little use if the LCD screen has a low resolution (number of pixels). These two parameters must be in balance. In addition, there's nat-

urally a relationship between the sampling rate and the maximum measurable frequency. The input signal must be sampled with at least two measurements per period of the input frequency. The software can then construct the waveform from the samples by interpolation, but in that case only a sine wave will be displayed, even if the input signal has a completely different shape. A much larger number of samples are necessary for proper reproduction of the waveform – at least 8 to 10 samples per period of the input signal – and a lot more than that are necessary if you want to see the details.

In practice, you can use the rule of thumb that the maximum measurable frequency of a sampling oscilloscope is approximately one-tenth of the maximum sampling rate. In case of an instrument with 1 billion samples per second (1 Gs/s), that yields an analogue bandwidth of 100 MHz. However, you can easily use such an instrument at frequencies up to 500 MHz if you are only interested in tracing a signal.

When using a digital oscilloscope, you should always make sure that the input signal does not contain any frequency components that are higher than half the sampling rate, as otherwise aliasing products will be generated – and they can cause some very strange waveforms to be displayed.

Practical test

For this test, we requested samples of ten currently available scopemeters from manufacturers and suppliers. They were tested in a practical environment, with primary attention being given to using the various features and options of the instruments. Brief descriptions of the individual instruments are given on the following pages.

ScopeMeter™

The term 'scopemeter' is popularly used to refer to a small, portable oscilloscope. That's actually incorrect, because 'ScopeMeter' is a trademark of Fluke and can only be used properly with reference to Fluke instruments. All other instruments should thus be called 'portable oscilloscopes' or 'portable scopes' instead of 'scopemeters'.

For your information, Fluke and Philips jointly developed the first portable oscilloscope in 1990 and marketed it under the name ScopeMeter. This product is still being produced, with new models being developed regularly.

Velleman HPS40

The first thing we noticed about the HPS40 was its remarkable simplicity. Aside from the four menu navigation buttons, there are only a few buttons on the front panel. That ease of use is more or less typical of most of the scopemeters we examined. The average remote control unit of a TV or VCR is considerably more complicated. The HPS40 is a handy, compact unit. There are three connectors at the top: a BNC connector for the probe, a connector for the AC adapter, and an optically isolated RS232 port. The AC adapter is not included as standard, but it is available as an option. The HPS40 has a maximum sampling rate of 40 Ms/s.

There is also a simpler model, the HPS10, with a sampling rate of 10 Ms/s. The resolution of the LCD screen is 112 x 192 pixels, and it has a backlight that switches off automatically after a certain length of time.

Practical experience

There's not a lot that needs to be said about using the instrument. The HPS40 is a simple measuring instrument. It is also 'just' an oscilloscope, with no other measuring functions on board. Operation is entirely problem-free. It is a user-friendly instrument. Of all the scopemeters we tested, this is certainly one of the simplest instruments. That means you can't expect any wonders from this Velleman unit. Simple AC signals were displayed quite nicely, but the limitations imposed by the sampling rate are quite evident.

Conclusion

Not an 'electrifying' instrument. However, it does have an attractive design. It is a relatively simple instrument with average specifications. The sampling rate (40 Ms/s) is also not especially impressive. The range of uses is thus distinctly limited. It's a perfectly good choice for routine measurements and hobby use, and it is priced accordingly.
The HPS40 is the least expensive scopemeter that we tested (£ 240 (€ 350) with VAT). For that amount, you receive the meter, an RS232 cable, a probe, and a plastic storage case for the lot.

Wittig Multiscope 20 Ms/s

Like the Velleman HPS40, the Multiscope is a relatively simple instrument in terms of its specifications and thus certainly not suitable for all applications. However, it is a two-channel model, and it is supplied complete with a plastic case, an AC adapter/charger, two probes, an RS232 cable and PC software on a CD-ROM for transferring stored readings to a PC. The sampling rate is 20 Ms/s per channel. It draws power from six AA cells. It is also a true 'handheld' instrument that is relatively narrow at the base and wider in the LCD area. As a result, the screen has modest dimensions and a resolution of 128 x 64 pixels. Naturally, as with all scopemeters, it also includes a backlight. The Multiscope is only an oscilloscope and does not have any other measuring functions. However, the measured value (RMS, etc.) is shown on the display alongside the waveform.

Practical experience

The Multiscope is reasonably easy to use, which is actually the case for all the scopemeters we tested. In terms of design, it's a bit of an odd man out with a numeric keypad of the sort found on mobile phones. However, we didn't have any significant problems as long as we kept the manual within easy reach, and it's also easy to use the navigation buttons above the numeric keypad to page through the menus. The button in the middle provides access to the menu.

Conclusion

You shouldn't expect all too much from an instrument such as the Multiscope. It has distinct limitations in terms of specifications, and it is only intended to be used for making simple measurements. Aside from that, it's a nice bit of gear, and it comes with an attractive case with space for all the accessories. A nice gadget for field use, but with limited measurement capability and a price to match. The Multiscope costs only £ 240 (€ 350) ex VAT.

Just before we finished testing the instruments, Wittig advised us that this model has been discontinued and will soon be replaced by a new model.

Wens 700S

Our first impression was quite positive. This instrument has a robust appearance, with a blue-grey front panel and a grey sleeve that protects it against impact. It's a bit on the large side, but still fairly easy handle. Power is provided by an NiMH battery pack with two 3.6 V / 2100 mAh cells.

It has a rotary selector switch, as do some of the other instruments (such as the Merconet). Besides being an oscilloscope, the Wens 700S (like most scopemeters) has practically all the functions you will normally find in a digital multimeter, with a function generator and frequency counter as bonuses. The maximum sampling rate is 25 Ms/s. The upper frequency limit of the integrated frequency counter is an impressive 1.3 GHz. The function generator can produce sine-wave, triangular and rectangular waveforms over the range of 40 Hz to 1 MHz. The scope can be connected to a PC via an RS232 port.

Practical experience

With a bit of playing around, we managed to accomplish quite a bit without the manual. However, it took a bit of searching to figure out how to switch on the display backlight – it's not so easy to find. The manual is also in German, because we obtained this meter directly from the German supplier ELV. Fortunately, the user interface of the instrument is relatively intuitive, so the average technical type shouldn't have any problems with it.

When you switch on the scope function, you are rewarded with a rather generous display in the graphic area. The overall dimensions of the display are 63 x 63 mm. The visibility of signal details is reasonably good.

Conclusion

Certainly a very attractive instrument to look at, with a robust, solid appearance. Easy to operate, but with a limited range of uses with regard to its specifications. Not the first choice for measuring high-frequency signals. The dimensions are relatively large, but that's compensated by the rather large display.

All in all, a nice (and above all affordable) instrument with several extra functions on board.

Seintek S2405

The Seintek S2405 is the 'big brother' of the S2401. It is a relatively simple instrument with matching specifications. It provides a sampling rate of 25 Ms/s if you use both channels or 50 Ms/s in single-channel mode. That's a fairly reasonable sampling rate, but it is too low for measuring signals such as video signals. This sort of specification is suitable for simple measurements on signals such as audio signals or other waveforms with reasonably low upper frequencies.

The screen has a resolution of 132 x 128 pixels and is monochrome (like all meters in this price class). However, it is quite legible, and it naturally has backlighting. The instrument is easy to use, with large buttons and a (removable) rubber bumper. The standard accessories included with the scopemeter are an AC adapter, two probes with 'normal' banana plugs, two test leads for ordinary measurements, an RS232 cable, and a floppy disk with software. As far as we're concerned, that could just as well be a CD-ROM, because floppies are out. All of this is fitted in a nice nylon carrying bag.

Practical experience

You don't need a doctorate to use this instrument. There's also not a lot that has to be said about it. It's all a piece of cake, and we managed quite nicely without consulting the manual. The manual (in English) is well written. The measured signals are presented nicely. The menus are easy to understand and well organised. You can store images and transfer them to a PC if you wish. In short, there's nothing complicated about this instrument.

Conclusion

Not exactly something to set the world on fire. This instrument is clearly intended to be used for routine measurements without especially high requirements in terms of results. The rubber bumper gives the S2405 a solid, robust appearance, although it appears a bit cheap without it. It is also relatively cheap: £ 275 (€ 400) (ex VAT) may seem like a tidy sum, but this sort of instrument is still at the lower end of the scale for scopemeters.

Metex MS-2000

Metex supplied two scopemeters for our test, one of which was the MS-2000. This 'Handyscope' is a single-channel instrument that can also be used as a multimeter, logic tester and frequency counter (with 5-digit resolution). The measurement range of the frequency counter extends to around 10 MHz. In terms of specifications, the scope portion is not especially impressive. The sampling rate is only 10 Ms/s. That's not exactly a giddy number. The LCD screen has a reasonable size for an instrument in this class, as well as a quite respectable resolution. The overall dimensions can be described as 'average'. The standard accessories include a probe, an RS232 cable, test leads, a banana-plug to BNC adapter, and a floppy disk with software. Like the Seintek instrument, the Metex instruments come with a nylon carrying case with a place for each of the accessories.
You can also use this Metex instrument to measure resistors, capacitors and diodes 'graphically'.

Practical experience

This is starting to seem a bit repetitive. All the scopemeters we've examined so far are easy to use, and all the manufacturers deserve a compliment in that regard. The Metex also held no surprises for us. The display is very easy to read. Particularly in meter mode, the numbers on the display are enormous, so you certainly don't have to sit with your nose against the screen. Sometimes you can clearly hear a relay click inside the instrument when you select a range, which is noticeable but otherwise not disturbing.

Conclusion

A complete instrument. Nice, solid design and construction with a removable bumper. Attractive carrying case. Easy to understand and pleasant to use. Can be used as a scope, multimeter or frequency counter, but the specifications are not very impressive. The sampling rate (10 Ms/s) is the lowest of all the units we tested. The frequency counter says goodbye at 10 MHz. All in all, that makes it an outstanding choice for low-frequency measurements. The price of this Metex model is £ 280 (€ 410) ex VAT.

Velleman APS230

This Velleman model is of a different class than the HPS10 and HPS40. It has a lot more to offer than the HPS series.
To start with, this is a two-channel instrument with two separate BNC connectors. It also comes standard with two proper probes.

The design is completely different from the HPS series. You can't really call it a 'handheld' instrument – it's a bit too bulky for that – but that doesn't present any particular problems for portable use. The performance is respectable. The maximum sampling rate for each channel is 240 Ms/s. The LCD is generously sized and has a resolution of 128 x 192 pixels.

Practical experience

A splendid instrument to work with. The APS230 is an oscilloscope pure and simple and does not include multimeter, function generator or frequency counter functions. Naturally, the scope also makes measurements and displays readings on the screen, such as peak-to-peak and RMS. The APS230 is easy to use, in part thanks to the user-friendly buttons on the front panel. Their operation is clear and intuitive in most cases, and you end up exactly where you want to be. However, attaching the included probes takes a bit of getting used to, because there's no way to feel how far you should tighten them. Of course, the BNC connectors are suitable for all types of probes. The two channels can be displayed together in a single screen, but they can also be displayed in two separate screens side by side or above and below, with or without a grid. Screenshots can be sent to a PC via the RS232 port.

Conclusion

We have pretty positive opinion of this portable scope, certainly in light of its price of £ 325 (€ 470) (ex VAT). It comes complete with probes, an RS232 cable, and plug adapters for the AC adapter. If you're looking for a handy, not especially expensive portable oscilloscope at a reasonable price, this is certainly a good choice – naturally assuming that the specifications and/or measurement ranges of this instrument are suitable for the things you want to measure.

Merconet VK06

This scopemeter is not really intended to be used for electronics applications. As Merconet says, it is a 'electrical mains quality meter' that is mostly used to measure AC mains voltages in houses and commercial buildings. Nevertheless, the sampling rate is a tidy 20 Ms/s. A nice bonus is that the scope can be used to display the voltage versus current characteristics of various types of electronic components.

The colour is a rather flashy light green. The measurement range is selected using a rotary switch. This instrument does not have a BNC connector, but that isn't really necessary for its intended use. The LCD screen has an oblong vertical format and isn't all that large. The VK06 is powered by six NiCd AA cells, which are charged by the included AC adapter.

Practical experience

The VK06 is a user-friendly instrument, although the 'scope' portion, which means the part that provides the graphic display, occupies a rather small part of the LCD screen. The overall dimensions of the screen are reasonable for this type of scopemeter, but the area used for the graphic display is only 2 x 3 cm. That is actually too small to properly display any details, but as we already mentioned in the introductory comments, this instrument is designed for a specific application where the oscilloscope function plays a secondary role. The graphic display of the voltage waveform is actually a sort of indicative visual aid in support of the 'normal' measurement.

Conclusion

This Merconet instrument is very pleasant to use. Anything that we couldn't discover by experimenting with it was easy to find in the user manual. The instrument we tested actually has a different type number, which turned out to be the original designation of its manufacturer (TPI), but Merconet distributes as the 'VK06'. This instrument is quite suitable for making measurements at relatively low frequencies, but it is more of a multimeter with a scope function than a true scopemeter.

Metex DSO 20

The second Metex product in our test clearly belongs to a different class than the MS-2000 with regard to specifications as well as price. This Metex unit is one of the larger units in our test, but it also has significantly more features than most of the others. To start with, it is a two-channel model. It provides a sampling rate of 20 Ms/s. The DSO 20 also has standard multimeter functions, and like the MS-2000, it has a frequency counter with an upper frequency limit of 20 MHz. Again like the MS-2000, it has a logic tester function. The LCD screen is generously sized, and although it's monochrome, it is nice and clear. The resolution is 320 x 240 pixels. This Metex model also comes with a nylon carrying case, a manual in English, an AC adapter, and two test leads. The optional accessories include a logic probe, an analogue probe, an RS232 cable, and software.

Practical experience

Operation is not exactly crystal-clear. We had to consult the manual regularly to figure out how to use all the features. That's actually not so surprising, because this is an instrument with significantly more features than the average scopemeter. It also has a lot more controls. That means it's somewhat more complex to operate, but you can get used to it fairly quickly by experimenting a bit with the manual close to hand. One of the cute features is the rotary encoder. That's a knob you can use to scroll through various settings or parameters. The encoder of the Metex unit controls everything – time base, input sensitivity, cursors, and so on. It's a nice feature, and this is the only meter in the test that has it.

Conclusion

Given its features and price, this is an attractive midrange instrument. We could almost put it the pro class. It's a pity that the sampling rate isn't a bit higher – they should really do something at about that at Metex so they could offer an excellent instrument at a nice price. It's also a versatile instrument, but unfortunately that doesn't apply to the standard accessories. However, the importer (DDS) includes an extra probe as a little present.

Fluke 199C

The Fluke 199C is without question a top-class instrument. The specifications are more than respectable. This instrument can handle signals up to 200 MHz. The sampling rate is 2.5 Gs/s, which is the highest of all the instruments we tested. Even after using it for only a short time, we recognised that we had a professional instrument in our hands. The 199C can also be used as a recorder or an ordinary multimeter.

This instrument is somewhat larger than the average scopemeter, but for that you get outstanding specifications and a large display (almost as large as with a normal scope). The backlight is quite bright, which helps make the display especially easy to read. The presentation makes very attractive use of colour. The manual is supplied on CD-ROM in ten languages.

Practical experience

As the saying goes, good wine needs no bush. We found the manual completely unnecessary for making ordinary measurements. Naturally, we did need it occasionally to check out all the features. The Fluke 199C is an especially pleasant instrument in use. Besides its versatility, the display is a real treat for the eye, partly due to the different colours on the screen. Cursor measurements, zooming, you name it – everything is smooth and easy. Besides being suitable for portable use, this instrument is also quite suitable for use in a stationary workstation, and it's certainly just as good as a 'normal' scope.

Conclusion

Absolutely top quality. It's difficult to avoid resorting to superlatives when testing equipment of this sort. The Fluke 199C is a professional instrument with outstanding specifications, and it can be used in practically every application area. It is clearly designed for professional users. That can also be seen from the price of this top-end instrument: £ 2600 (€ 3800) ex VAT. For that amount, you receive the instrument together with a robust case, two probes, test leads, an RS232 cable, and two CD-ROMs that hold the manuals and software.

Metrix ScopiX OX7104-C

This instrument and the Fluke 199C form the top class of our test. Besides being an oscilloscope, it is a also a multimeter, recorder and analyser. Like the Fluke unit, it has quite respectable specifications. The OX7104 has a sampling rate of 1 Gs/s (real time) or 50 Gs/s for repetitive signals. On top of that, the ScopiX has four input channels and a 12-bit A/D converter. Like the Fluke, it has a large, very attractive colour display with the extra bonus of touchscreen operation.

You can do a lot of things directly on the screen, such as positioning cursors for making measurements or using the pull-down menus. Naturally, controls for all the usual functions are also present on the front panel. Here as well, as with the Fluke, the dimensions are somewhat more generous than in the less expensive class.

Practical experience

Intuitive operation was somewhat more difficult at first than with the Fluke, because several buttons have symbols instead of text labels. Most of the symbols are self-explanatory, but it still took us a bit of searching to get the instrument to do what we wanted. We managed to figure out quite a lot during half an hour of experimenting. Working with the touchscreen display was a real treat. Just as with the Fluke, the screen has outstanding backlighting, and everything is clearly displayed. The nicest detail is the ultrabright LED fitted in each of the intelligent Probix probes. That's really handy when you have to look for a measurement point in a cabinet or some other dimly lit space. It's certainly a plus point.

Conclusion

The ScopiX OX7104 is a first-class instrument that has a lot to offer in terms of characteristics and features. Quality with excellent specifications. A professional instrument for inside and outside the lab. It comes with a robust case and an extensive set of accessories: two probes, test leads, adapters, test clips, software and a manual on CD, RS232 cables, etc. This top-end quality comes at a corresponding price: approximately £ 2900 (€ 4200) ex VAT, including all the accessories.

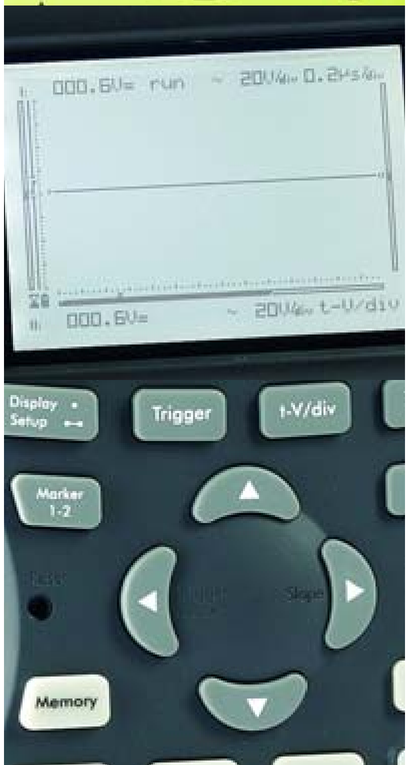
Model	Channels	Screen resolution (pixels)	Max. sampling rate	Input range (min/max & div)	Extra functions	PC link & software	Power source	Max. operating time from battery	Standard accessories	Price (ex VAT)
Velleman HPS40	1	112 x 192	40 Ms/s	0.1 mV–160 V	–	RS232/No	5x NiMH Adapter/charger	Up to 20 hrs (standby)	Probe AC adapter RS232 cable Hard case	£ 203 (€ 294)
Wittig Multiscope 22-321	2	128 x 64	20 Ms/s	2 mV–40 V	–	RS232/Yes	6x AA Adapter/charger	6–16 hrs	Test leads Oscill. module AC adapter Software	£ 240 (€ 350)
Wens 700S	1	160 x 160	25 Ms/s	10 mV–200 V	Multimeter Frequency cntr Function gen. Logic tester	RS232/No	NiMH pack Adapter/charger	6 hrs	Test leads Soft case AC adapter	£ 268 (€ 388)
Seintek 2405	2	132 x 128	25 Ms/s 2 chan. 50 Ms/s 1 chan.	50 mV–500 V	Multimeter	RS232/Yes	4x NiMH Adapter/charger	3 hrs	AC adapter Test leads Test clips Software	£ 275 (€ 400)
MS2000	1	160 x 160	10 Ms/s	0.1 V–100 V	Multimeter	RS232/Yes	4x NiMH Adapter/charger	Not specified	Probe RS232 cable Test leads Adapter plug Software	£ 285 (€ 410)
Velleman APS230	2	128 x 192	240 Ms/s	1 mV–20 V	–	RS232/No	NiMH pack Adapter/charger	Not specified	2 probes RS232 cable AC adapter Adapter plugs for adapter/charger	£ 325 (€ 470)
Merconet VK06	1	160 x 240	20 Ms/s	0.1 V–1000 V	Multimeter	RS232/Yes	6 x NiCd Adapter/charger	Up to 3.5 hrs	Test leads AC adapter Software	£ 337 (€ 489)
DSO20	2	320 x 240	20 Ms/s	5 mV–2 V	Multimeter Frequency cntr Logic analyser	RS232/Yes	NiMH pack	Not specified	Test leads Soft case Hard case Probe (from DDS)	£ 545 (€ 790)
Fluke 199	2	Not specified	2.5 Gs/s	2 mV–100 V	Multimeter Recorder	RS232/Yes	NiMH pack Adapter/charger	4 hrs	Probes Test leads RS232 cable AC adapter Hard case Software	£ 2620 (€ 3800)
Metrix Scopix OX7104-C	4	320 x 240	1 Gs/s	2.5 mV–200 V	Multimeter Recorder FFT analyser Recorder	RS232/Yes	NiMH pack Adapter/charger	2.5 hrs	Probes Test leads RS232 cable AC adapter Hard case Software Test clips	£ 2900 (€ 4200)

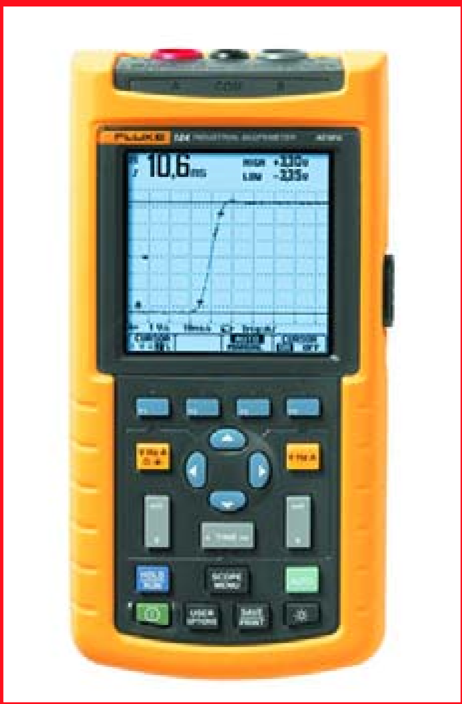
Summary

Testing these scopemeters was a natural and enjoyable follow-up to the USB oscilloscope tests published in the September issue last year. Both types have their specific uses, of course, but they basically provide the same functions. Naturally, a USB scope is not something you take with you in the field. Scopemeters, by contrast, are specifically designed for that purpose. The prices and specifications of the units we tested cover a wide range. Generally speaking, you can find scopemeters starting from £ 240 (€ 350) and ranging up to several thousand pounds. The most expensive one we were able to test was the ScopiX OX7104C, with the Fluke 199C a close second. These instruments sell for the tidy sums of £ 2900 (€ 4200) and £ 2600 (€ 3800), respectively (ex VAT), but you naturally get the cream of the crop at that sort of figure. They are very professional instruments. Incidentally, with both of these instruments we tested the most expensive models of a family of several models. There are also models with lower sampling rates or fewer input channels. The Fluke 190 series starts at around £ 1700 (€ 2500), while the Metrix series starts at around £ 1300 (€ 1900).

If you don't necessarily need to measure very high frequencies with a scopemeter or don't really need the

Manufacturer	Model	Internet address of manufacturer	Distributor/dealer UK
Fluke	Fluke 199	www.fluke.nl	see www.fluke.co.uk
Merconet (TPI)	VK06 (Scope Plus 440)	www.merconet.nl (www.testproductsintl.com)	Farnell Electronics Components (http://uk.farnell.com)
Metex	DG Scope 20 MHz (DSO20)	www.nostek.co.kr	Conrad International www.conrad.com
	MS2000		–
Metrix	Scopix OX7104-C	www.chauvin-arnoux.co.uk	Conrad International www.conrad.com
Seintek	2405	www.seintek.com	–
Velleman	HPS40 APS230	www.velleman.be	Conrad International www.conrad.com
Wens	700S	www.wens.co.kr	–
Wittig	Multiscope 22-321	www.wittig-technologies.de	Farnell Electronics Components (http://uk.farnell.com)





Not tested

Two instruments are missing from this test, but we want to mention them for the sake of completeness. The first is the Fluke 120 series, which is the 'junior' version of the 190 series. That is a very interesting instrument that is available in two models, with prices of £ 900 (€ 1300) and £ 1050 (€ 1500). Unfortunately, Fluke was unable to provide us with samples for testing in time for our schedule, but it would certainly be worth considering them if you are contemplating buying a scopemeter.

In addition, Tektronix sells scopemeters in the THS700 series with prices ranging from £ 2150 (€ 3100) to £ 2500 (3600). Unfortunately, Tektronix said they were not interested in participating in our test. That's a missed chance in our opinion, because a comparison with the Fluke and Metrix instruments could have been very interesting.

robustness or features of a Fluke or Metrix instrument, they are a bit over the top, since you can find quite respectable instruments at less than £ 350 (€ 500). Naturally, your choice will depend primarily on what you need to measure. It's striking that nearly all relatively inexpensive scopemeters have a sampling rate somewhere between 20 Ms/s and 40 Ms/s. That's adequate for measuring signals up to a few megahertz, and you should keep that well in mind when purchasing such an instrument. The only exception in that regard is the Velleman APS230 with a sampling rate of 240 Ms/s, and that at a very affordable price.

When you're purchasing a scopemeter, you may also want to look at all the additional functions offered by the various models. If you're looking for a sort of all-in-one 'minilab' instrument, you can manage quite well with a scopemeter that includes a function generator, frequency counter and multimeter functions, such as the Wens 700S. However, you'll also notice that the ultimate choice of a particular scopemeter is strongly dependent on personal wishes.

Finally, we have a few general remarks. All the scopemeters were quite easy to use. Of course, the more complex ones required a bit more time and nosing around in the manual, but their operation was never really complicated. Anyone with a technical bent will have no trouble mastering it quickly. The manuals are generally well prepared. Some of manuals are only in one language, but given the international character of such instruments, it seems to us that it would be good to make them multilingual (easy to do with a CD).

Almost all of the instruments can be linked to a PC. In some cases, the PC software is supplied on a floppy disk. That's outdated. We don't think it would be a capital crime for the manufacturers to put the software on a CD-ROM together with the manual.

Extensive information about instruments of this sort, including specifications and suppliers, is of course available on the Internet. The tables on these pages list the websites of the manufacturers and several suppliers, along with key specifications.

(060054-1)

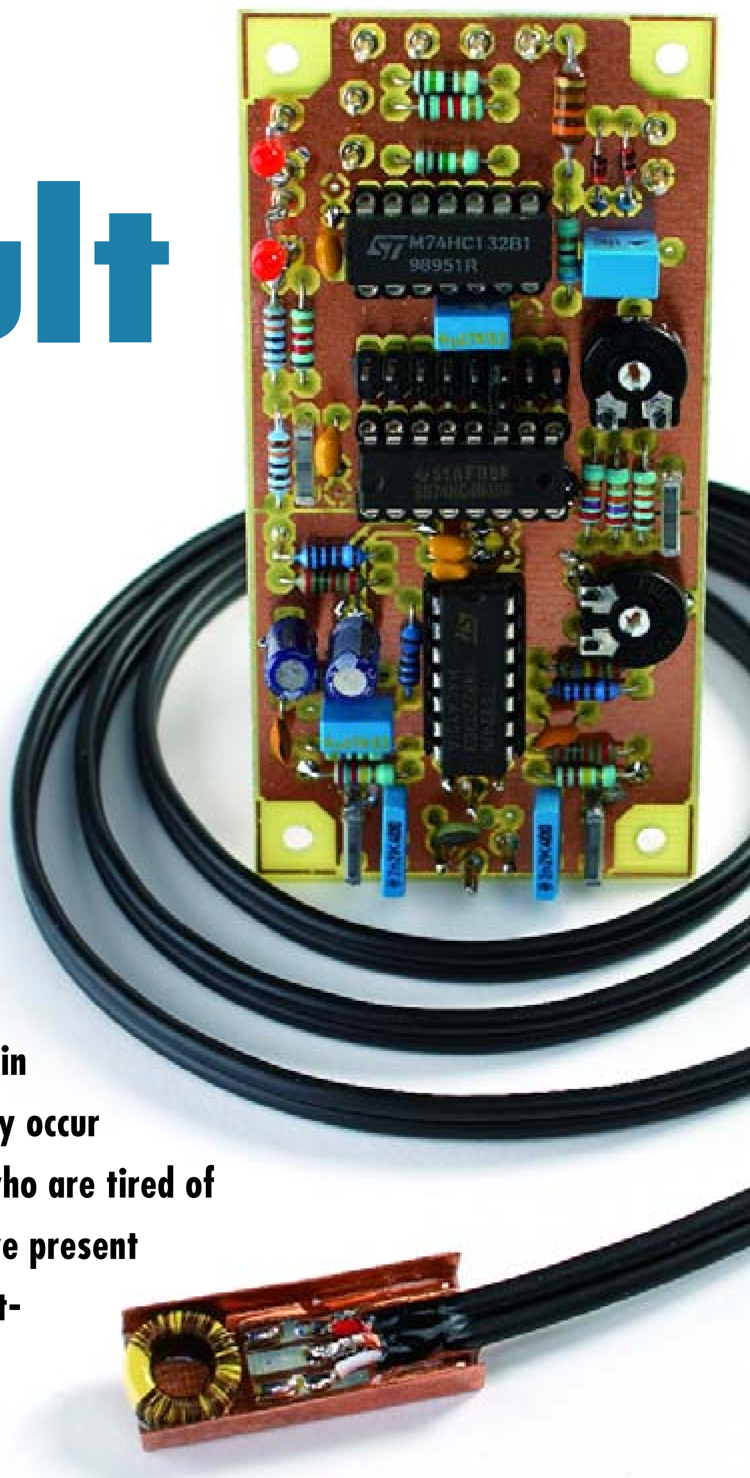
We would like to thank the following companies for making instruments available for testing:

Chauvin Arnoux – Conrad – DDS Electronics Europe B.V. – ELV
Fluke – Merconet – Velleman – Wittig Technologies

Find the Fault

Audible short-circuit finder

Ton Giesberts



Even the most experienced electronics engineer will undoubtedly come across these: short-circuits in places where they don't belong. And they naturally occur at times when they're least welcome. For those who are tired of scanning around a PCB with a magnifying glass, we present here a handy circuit that makes searching for short-circuits on homemade PCBs or already assembled boards a piece of cake.

When working with fine pitch electronics all manner of things can go wrong. When etching a circuit board, for example, small pieces of copper can be left behind so that there is a connection somewhere that shouldn't be there. Or a fault has appeared in a board that has already been built. In both these cases the circuit described here provides a way out. With this short-circuit finder the fault can be hunted down in a very straightforward manner.

Principle

The principle of the circuit is simple. An unwanted current can flow in that part of the circuit near where the short-circuit is. Grateful use is made of this fact in our circuit. By injecting a current at the relevant place on the PCB a magnetic field is generated. This field can be detected, of course. The current, and therefore also the field, are present up to the short-circuit. The short-circuit finder sounds a tone while the field is sensed. An LED flashes at the same time, but this is intended more as a check for the correct operation of the circuit. In practice it will be easier to listen to the sound and not watch the LED. When

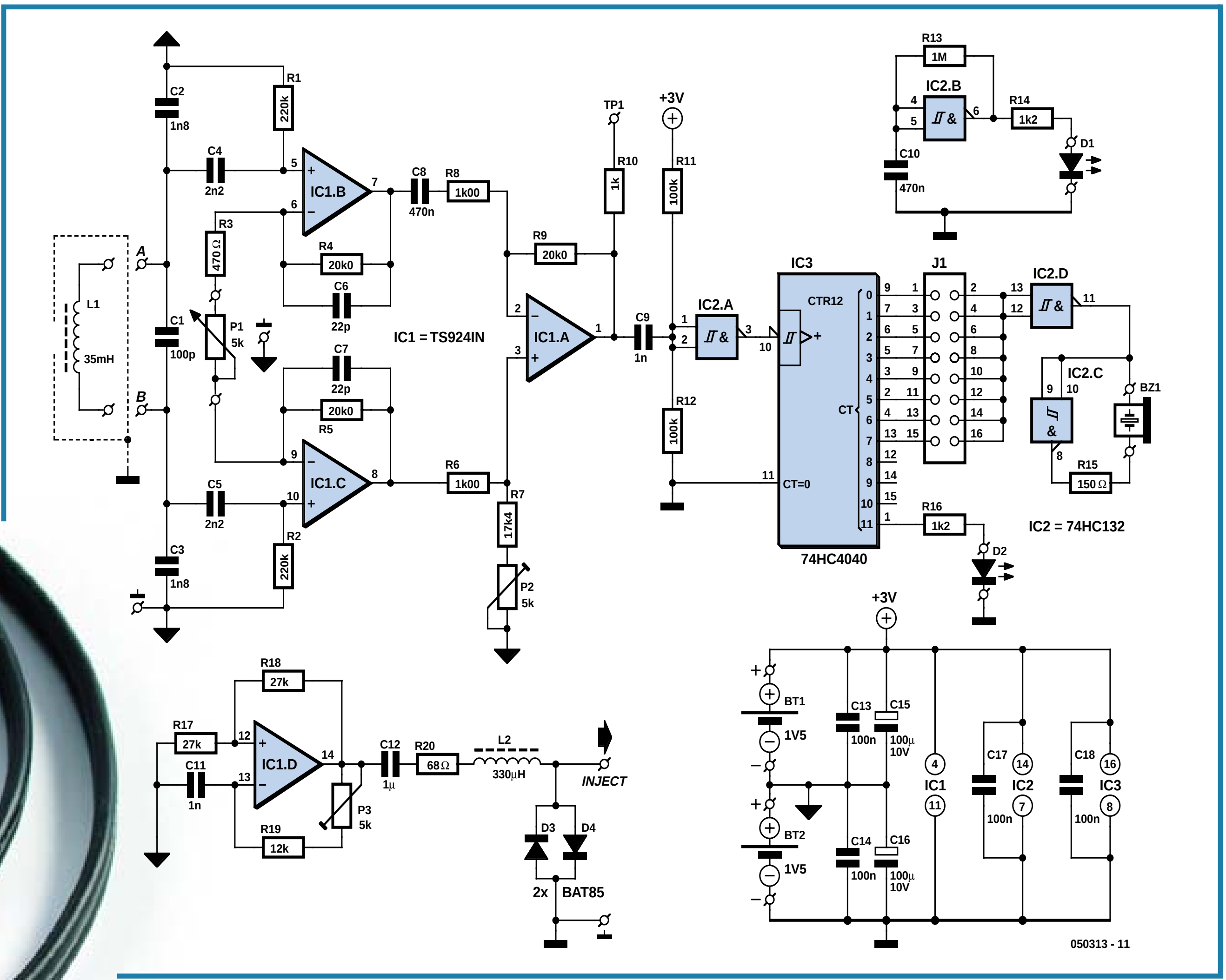


Figure 1. The schematic can be divided into two parts. One part provides the generation of the test signal, the other part detects and amplifies the picked-up signal.

the sound disappears you have found the short-circuit. In the box we deal with some of the details in a little more depth.

The design

To describe how the circuit works from the electronic perspective, we explain, with the aid of **Figure 1** what happens. The signal is picked up by coil L1 that we wind ourselves. To make the detection more sensitive we selected a frequency that is just outside the audible frequency range (about 29 kHz). To make this frequency audible, the signal that is amplified by IC1a through IC1c, is routed via a digital Schmitt-trigger (IC2a, a 74HC132) to a divider IC3 (74HC4040). P1 adjusts the gain. The first eight outputs are available on the outside. You select the frequency of the sound that can be reproduced well with an AC-buzzer using jumper JP1.

To maximise the volume of the sound a little bridge amplifier is made with two gates from IC2 (IC2c and IC2d). The buzzer is connected to the pins that are marked ‘BZ1’. R15 limits the current to a safe value (< 20 mA).

The last divider output of IC3, pin 1, is used to drive LED D2. When the signal is sufficiently high, it will flash with a frequency of 29 kHz/$2^{12} \approx$ 7 Hz. If there is no signal the LED can be either continuously on or off. This depends on the state of the counter when it stops.

As a power supply indicator we chose, because of the battery power supply (see later on in the article) a flashing LED. This saves power and immediately after power on you have an idea whether everything is in order or not. This indicator is built around the last gate in IC2 as a standard Schmitt-trigger oscillator (also sometimes called a multivibrator with Schmitt-trigger input). The frequency is set with R13 and C10 to about 2 Hz. Both D1 and D2 are, for the sake of minimum current consumption, powered with a current of only 1 mA. Therefore good, low-current LEDs have to be used here.

We designed the current injector around the fourth opamp in IC1. In principle this is also a multivibrator with Schmitt-trigger input (in this case sometimes also called a multivibrator with comparator). The hysteresis is set with R17 and R18. C11 and R19 + P3 determine the frequency, which of course also depends in the size of the hysteresis. With equal values for R17 and R18, the frequency for this oscillator is about 2.2 x C11 x (R19 + P3).

In theory the frequency is therefore adjustable from about 26.7 to 37.9 kHz, but the range can be easily modified by changing R19 and/or C11.

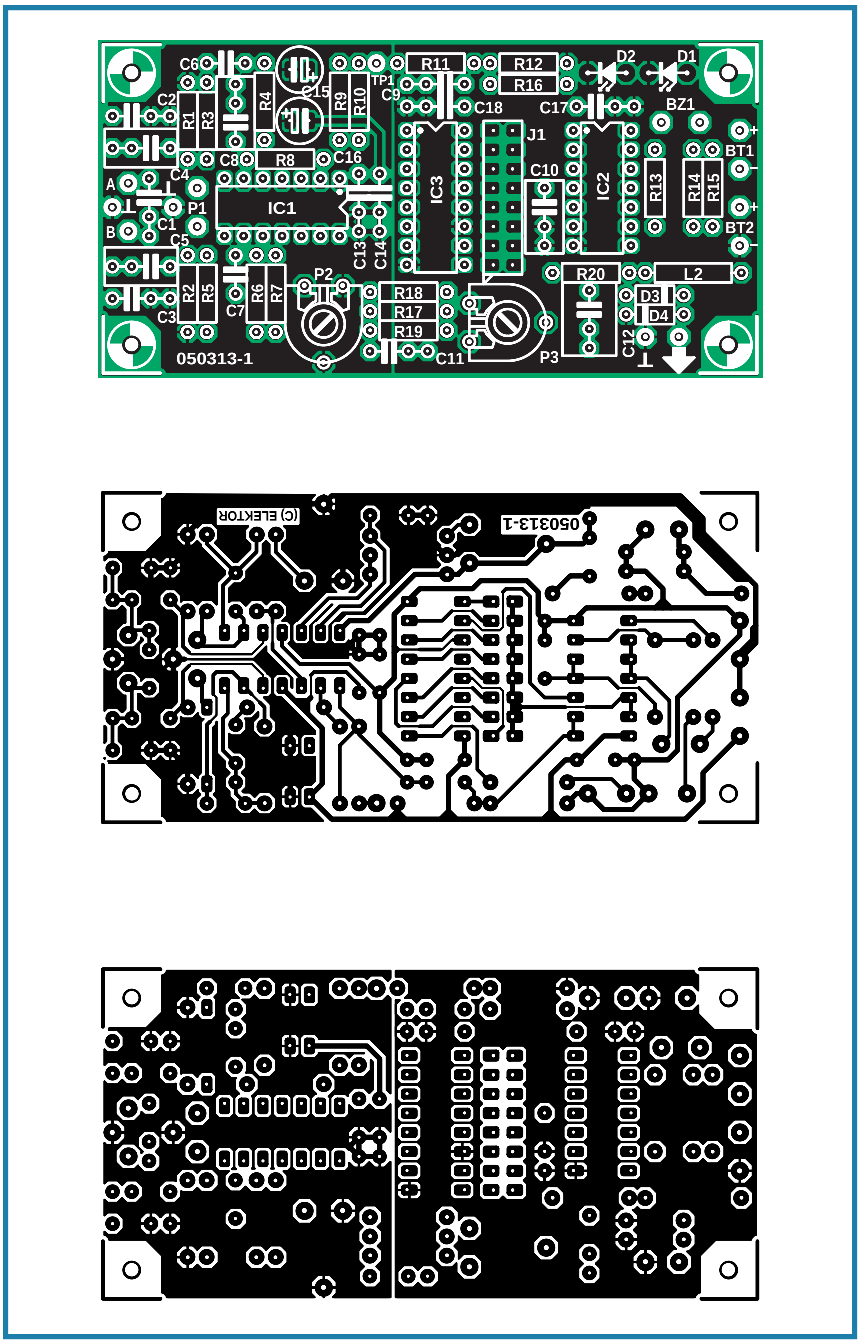


Figure 2. The PCB is double-sided with sizable ground planes to reduce sensitivity to noise.

COMPONENTS LIST

Resistors
R1,R2 = 220kΩ
R3 = 470Ω
R4,R5,R9 = 20kΩ0
R6,R8,R10 = 1kΩ00
R7 = 17kΩ4
R11,R12 = 100kΩ
R13 = 1MΩ
R14,R16 = 1kΩ2
R15 = 150Ω
R17,R18 = 27kΩ
R19 = 12kΩ
R20 = 68Ω
P1 = 5kΩ linear law mono potentiometer, small model
P2,P3 = 5kΩ preset

Capacitors
C1 = 100pF
C2,C3 = 1nF8 MKT
C4,C5 = 2nF2 MKT
C6,C7 = 22pF
C8,C10 = 470nF
C9,C11 = 1nF MKT
C12 = 1µF MKT, lead pitch 5 or 7.5mm
C13,C14,C17,C18 = 100nF ceramic
C15,C16 = 100µF 10V radial

Inductors
L1 = 35 mH, 100 turns 0.1 mm ECW on Ferroxcube core TL10/6/4-3E5 (Farnell # 3056960) or 92 turns 0.1 mm ECW on Epcos core B64290-L38-X38 (Schuricht # 331648)
L2 = 330mH

Semiconductors
D1,D2 = LED, low-current
D3,D4 = BAT85
IC1 = TS924IN (ST), rail-to-rail I/O (Schuricht # 648226)
IC2 = 74HC132
IC3 = 74HC4040

Miscellaneous
J1 = 16-way pinheader, 1 jumper
BZ1 = AC buzzer
BT1,BT2 = 1.5-V battery with holder
Double-pole switch (power on/off)
PCB, ref. 050313-1 from The PCBShop

The current detection works with only a single frequency. It is therefore essential to limit the harmonics of the injection current. Note that the output signal from IC1d is a square wave. That is why coil L2, acting as a low-pass filter, is placed in series with the output. To prevent a DC current in the coil, C12 is connected in series with L2 and the output.

The opamp that has been selected (IC1) is a TS924IN. This rail-to-rail opamp can deliver an output current of no less than 80 mA and operate off a power supply voltage from 2.7 to 12 V. In our case the high output current capability means that no final output stage is required for the current injector because the opamp is easily able to deliver the necessary current. We have assumed a maximum current of about 20 mA peak.

The circuit operates off 3 V, so two penlight (AA) batteries will suffice for the power supply. On the PCB there are two connections for each of the batteries, because half the supply voltage is necessary as a virtual earth (see also the PCB layout, **Figure 2**). You can use either two single battery holders or a holder for two batteries. With the latter you will have to tap into the link between the two batteries. This can then be connected to the appropriate point on the PCB. The current consumption at two times 1.5 V is 15 mA and this remains reasonably constant.

Practicalities

What now remains is the construction of the sensor. Here our preference was

Development and background

In this box we explain a little more how the circuit came together and the technical background. The first thing we started with was naturally enough the sensor. We carried out many experiments with various coils. These included several SMD-variants some including a metal screw. You can never tell what will work well in the end. Ultimately the choice became a small toroidal core (diameter 10 mm). With 100 turns of 0.1 mm enamelled wire a large enough signal can be measured. For our prototype we used a TL10/6/4-3E5 from Ferroxcube, because we happened to have one handy. In the parts list a more readily available type from Epcos is indicated. In this case the number of turns has to be reduced to 92. This causes a slight reduction in sensitivity, but that is not really a problem. To increase the sensitivity, the coil is part of a resonant circuit. A nice benefit of this is that it reduces the sensitivity to interference. At a peak current of 20 mA a peak voltage of 10 mV was measured.

As a compromise between bandwidth and amplification we finally selected a resonance frequency of about 30 kHz. That means that with a reasonable amplification the bandwidth of the amplifier stage does not have to be all that large and the Q-factor of the circuit is good. There is therefore a good resonant gain. The injector delivers enough current to over-drive the amplifier stage of the detector when there is no return current to oppose the field. The amplifier stage has to amplify the incoming signal sufficiently to exceed the Schmitt-trigger threshold of IC2a. The hysteresis for a 74HC132 with a power supply voltage of 3 V is about 0.6 V, but could also be nearly 2 times larger or smaller. That is why it is desirable for the amplifier to provide a little more gain than what appears necessary. To make the measurements as accurate as possible a symmetric amplifier stage was selected. The sensor signal is only a few millivolts in magnitude after all. To influence the Q-factor of the circuit as little as possible, the input impedance cannot be too low. That is why we picked 220 kΩ for each input. The disadvantage of this is that the sensitivity to interference increases.

The capacitor for the parallel resonant circuit is split in two and consists of C2 and C3. This way the impedance for common-mode interference is smaller. C1 completes the resonant circuit and suppresses any differential RF interference. The total capacitance of the resonant circuit consists of the series combination of C2 and C3 added to the value of C1 and therefore amounts to 1 nF.

Because the test frequency is 29 kHz the corner frequency can be quite high, which suppresses mains related frequencies. However, the corner frequency cannot be too high, otherwise the tolerance of the capacitors can negatively affect the symmetry of the inputs. The corner frequency at the input is now at about 330 Hz (C4/R1 and C5/R2).

With R3 to R5 and P1 the gain of the opamps IC1b/IC1c can be adjusted from about 7 to 85. C6 and C7 limit the sensitivity to RF noise. The asymmetric output signal is supplied by difference amplifier IC1a. This opamp amplifies the signal another 20 times. The total gain can therefore be adjusted from about 150 to 1700.

During testing, the offset of the input stage was found to be too high however. C8 prevents the amplification of the input-offset. Unfortunately this means a worsening of the common mode suppression at 500 Hz by about 23 dB, but that has otherwise no consequences for the amplifier as a whole. P2 has been added to allow for the possibility of adjusting the common-mode suppression, but in practice the tolerances tend to almost negate the effect of this. The potentiometer can just be set to the centre position. The amplified sensor signal is coupled with C9 with a reasonably high corner frequency (3.2 kHz). This is low enough not to cause any additional attenuation. The sensitivity is now not influenced by IC2a.

The bandwidth of the amplifier at maximum gain appears to be about 34 kHz. We therefore loose a little bit of sensitivity at maximum amplification, but this is still plenty.

Testing of already assembled PCBs is possible if the signal voltage of the test signal is limited. In this way nothing can fail because of a test signal that is too large. For this purpose two Schottky-diodes (BAT85) are placed in anti-parallel at the output. Also, the magnitude of the current, with a maximum of 17 mA, is too small to cause defects and in the case of a short-circuit there is practically no voltage anyway.

for something manageable with a shield, because the effective signal is of the order of millivolts. For the connection to the PCB a thin two-conductor screened cable can be used. A cheap, standard audio cable is enough. The metal case that houses the PCB can be fitted with a 3- or more-way connector (2.5 or 3.5 mm jack or similar). Another option is to take a cable of sufficient length and connect it straight to the PCB. In this case a strain relief where the cable passes through the case is essential. The latter solution is preferable because a connector can cause trouble over time.

The actual sensor consists of a small wound toroidal core, the shield and the cable. For the shield we made a small rectangular 'box' from 0.3 mm thick copper sheet (see **Figure 3**). The inside dimensions are 5 mm high, 30 mm long and 11 mm wide. The wound core fits exactly in there. To fix the core in place we used two-component epoxy glue. Place a thin piece of plastic underneath the core to prevent a possible short-circuit if the windings are damaged. This also reduces the parasitic capacitance somewhat. For this we 'peeled' a thin layer from a PCB.

After mounting the coil in the shield and connecting the cable, the tester has to be calibrated again. In our case the frequency shifted from 29 kHz to 27.5 kHz. This was mainly caused by the length of the screened cable (1 m) that we used to connect the sensor to the PCB. With a cable capacitance of, for example, 100 pF per meter the extra capacitance that is connected in parallel amounts to 50 pF. This by itself is sufficient to detune the circuit by 2.5%. The core is positioned so that it protrudes from the shield by at most about 1 mm. To fix the ends of the winding in place, a small piece with three strips of copper is glued next to the core. The middle strip is soldered with a short bit of wire to the shield. This then becomes the connection for the cable screen. The other two strips are connected to the ends of the winding and the signal conductors of the cable. The free end that is still inside the shield can be used to glue the cable, so that there is no strain on the solder connections.

In the photo of **Figure 3** you can clearly see that first a U-section was made into which the sensor and cable are mounted. After that, the other side can be soldered or glued to it. The process of winding the coil is not difficult. It only requires some patience and a steady hand, because the wire is 0.1 mm think (or thin) and is easily broken. So be careful when winding the toroid. The winding is divided into two halves to prevent it becoming damaged where it protrudes from the shield. Halfway, a section that corresponds with that part of the core that protrudes, has to be kept free (this can be clearly seen in the photo of **Figure 3**). If you wind tidily and tightly a hundred turns will fit on one layer. It is easier to glue the core if the winding is flat. A length of wire of 1.5 m is easily enough.

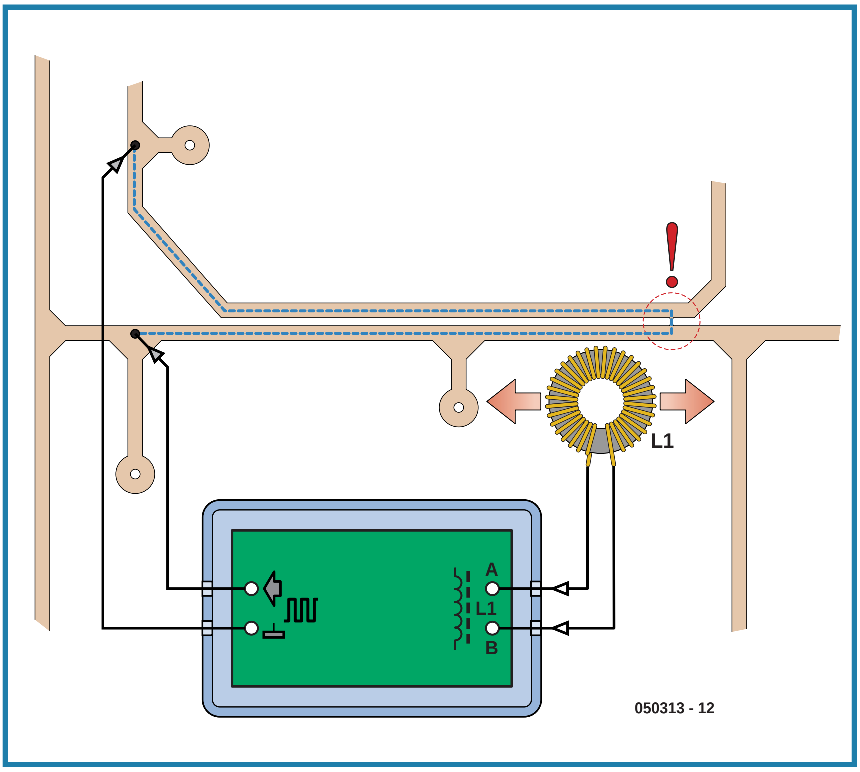
When building the circuit into an enclosure you need to take into account the dimensions of the PCB, the AC-buzzer, the batteries with holder(s), the positions of the LEDs and the double-pole on/off switch. Use screened cable for the connection to potentiometer P1. For this purpose there is a connection to virtual ground on the PCB next to the two connections for the potentiometer. Note carefully: the '–' of the 3-V power supply is therefore *not* the signal ground of the sensor or the screen for the potentiometer. On the PCB there are two large ground planes on the component side, between which there is clearly a separation. A connection between these two would short out battery BT2!

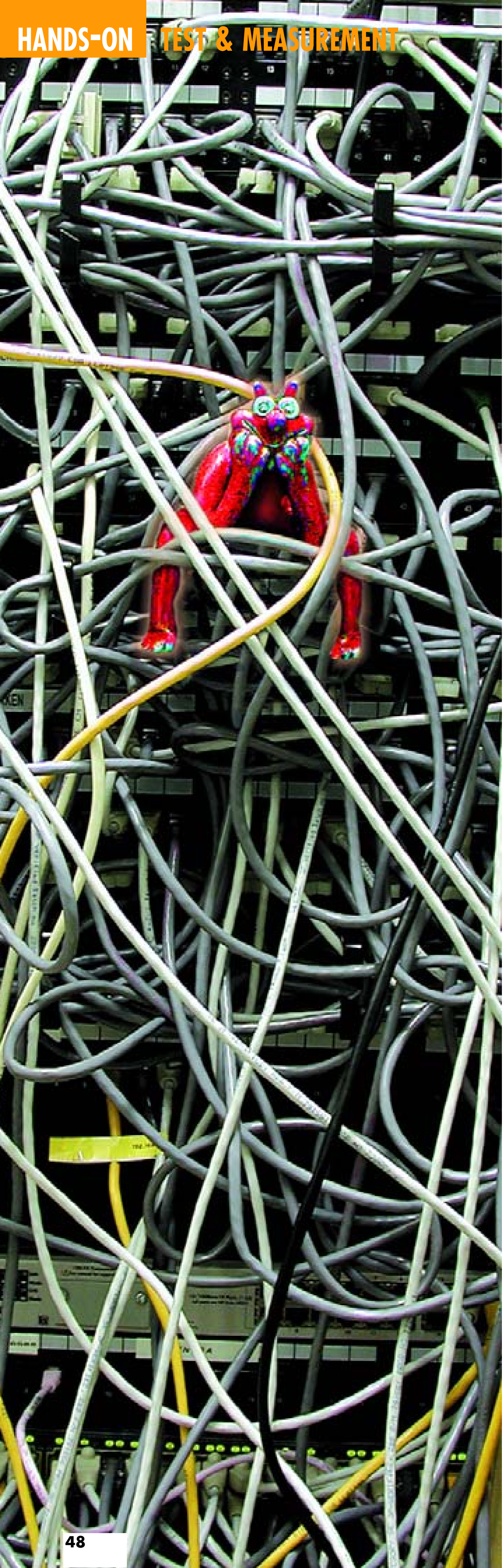
Figure 5 finally shows how the circuit is used in practice. The output signal from the generator is connected to the two print traces that you suspect are shorted together. With the sensor you can then follow the trace from the beginning. In this way you will quickly find at which point the current 'jumps' from one trace to another. This is the location of the short-circuit! When tracing you can adjust the sensitivity with P1. Do not adjust this too high, this will make locating the short-circuit easier.

(050313-1)

Figure 3. This is one way to implement the sensor. The copper enclosure provides sufficient shielding from interfering sources.

Figure 4. The circuit in actual use.





Network

for Gigabit / 10

Help! The network is down! What's wrong? Is it the cable? The NIC? The patches? The plugs? A gremlin in the patch bay? Cable and connector faults are relatively common and this simple tester will help you find the culprit in no time. The tester is suitable for Gigabit, 10BASE-T and 100BASE-T cables, with the ability to check Gigabit crosswire cables, too.

The initial purpose of this circuit design was to implement a simple Gigabit cable tester that supports both straight-through and crossover UTP/STP cables with the ability of selecting which pair(s) to test and detecting the defective pair(s) if any. Each pair is represented by an LED that flashes whenever the corresponding pair is properly connected; otherwise it remains off. A switch selects between straight-through and crossover (a.k.a. crosslink) modes and a pushbutton initiates the testing process. Once done the systems goes to sleep.

As the design evolved, it was realized that Gigabit cables are really no more than a logical follow-up to the earlier 10BASE-T and 100BASE-T standards, so provision was made to test these 'slower' cables too. However, 10BASE-T / 100 BASE-T crosslink cables can not be tested.

Because it has to be used in less accessible places like a patch bay of large network, the little instrument is portable and powered by a 9-V battery. The tester needs to be connected to the RJ45 plugs at either end of the cable under test and performs a simple continuity test using a pulse transmitted over wire pairs in the cable under suspicion. Sure, a continuity test is also possible with an ohmmeter or similar but then those thin con-

Cable Tester

BASE-T / 100BASE-T

Majdi Richa

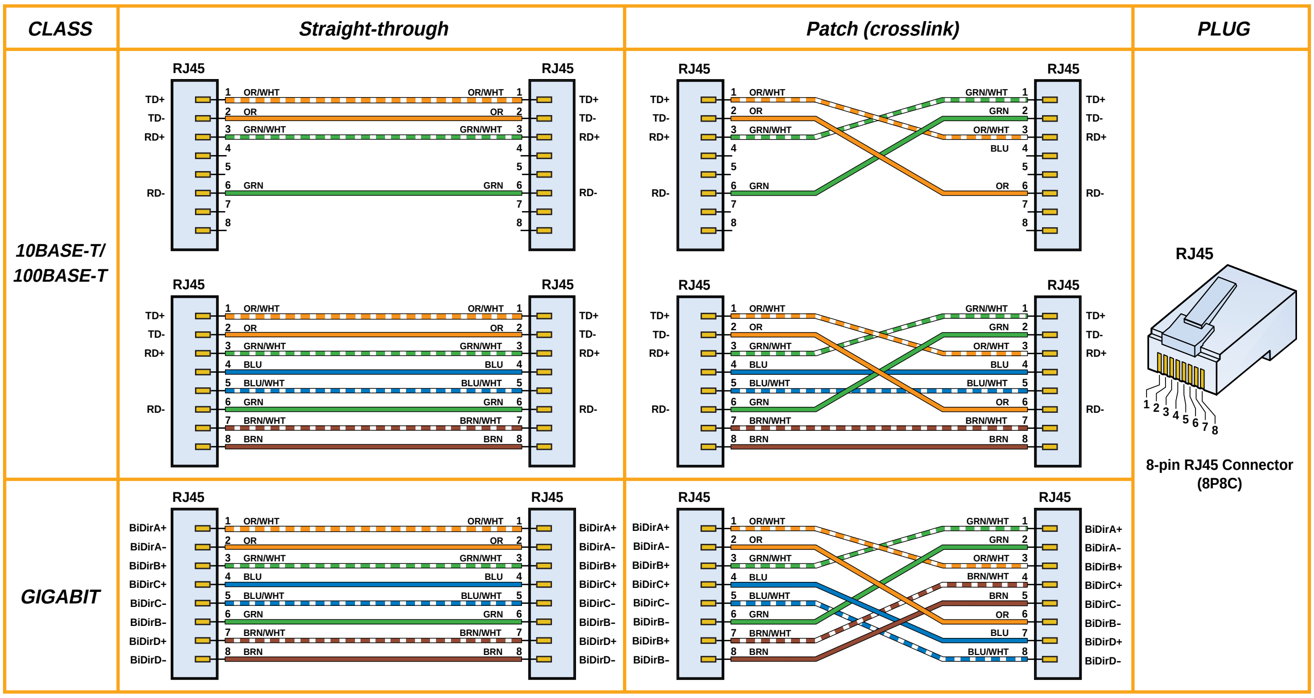


Figure 2. Circuit diagram of the Cable Tester for 10/100BASE-T and Gigabit Cables.

nector contacts on an RJ45 plug are difficult to reach individually with a test probe. Also, you have to do a lot of counting up and down the contact row to positively identify a contact number — twice over so you soon wish you had two pairs of eyes, infrared vision and three hands. A nice job for a microcontroller.

The cable standards

Computer network cable can be supplied off the reel, cut to length and fitted with press-on RJ45 connectors. That' how most professionals do their cable installation work in large offices. Most home users however will buy standard lengths of these cables (usually CAT-5) with the connectors ready fitted. CAT-5 cable has eight wires and is suitable for data speeds up to 100 Mbit/s. Inside the cable the eight wires are organized as four pairs of two (usually twisted) wires. The wire colours are usually, but not always, to the U.S. T568B standard.

A crosslink or 'patch' cable is only required between two computers that have to talk to each other directly, or between two telecom-related equipments with the same functionality. Crosslink cables are rarely seen in lengths greater than 5 m or so. They may be compared to the 'zero-modem cable' for the now slightly antiquated RS232 standard. In the traditional star-like configuration with several PCs connected to a common router, straight-through network cable is used and this by far the commonly seen.

For reference purposes, **Figure 1** shows an overview of commonly found cables of the straight-through and crosslink variety. All employ the RJ45 connector, which is shown along with the pin order on the plug. Note that the colour coding is not obligatory and that our tester is not compatible with 10/100BASE-T crosslink cables.

Practical circuit

The circuit diagram of the Cable Tester is given in **Figure 1**. A PIC 16F874 with machine code ticking inside is reading the configuration set on DIP switch S1, as well as the status of pushbutton S2 and mode switch S3. In response to all this user input, it generates pulses to travel over the wire pairs connected between RJ45 sockets K1 and K2 to which the cable under test is connected. The PIC of course checks the arrival of the pulse and acts accordingly by making an LED light if the wire pair is okay for continuity. No dynamic test is performed on the cable. For reference, **Table 1** shows the

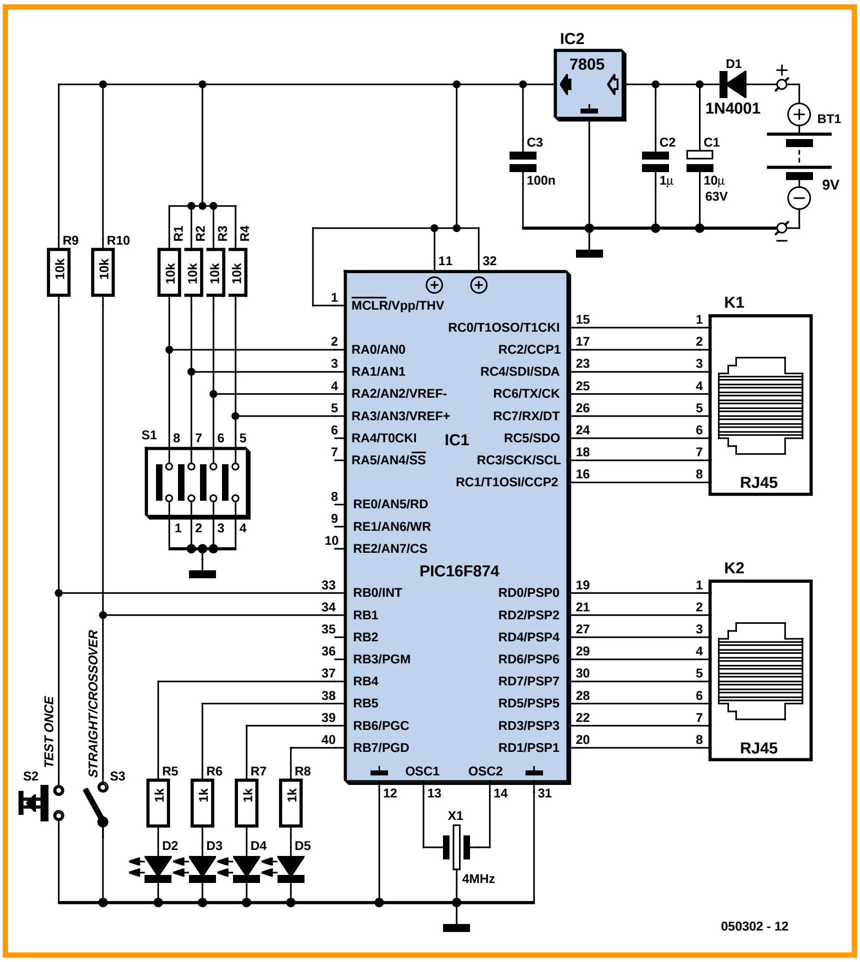


Figure 2. **Circuit diagram of the Cable Tester for 10/100BASE-T and Gigabit Cables.**

relation between the connector and PIC pins for a Gigabit crosslink cable.

The circuit has a conventional 5-volt power supply based on a 7805 voltage regulator complete with its usual decoupling capacitors — there's C2 and C3 to combat high-frequency noise and C2 to keep low-frequency ripple to a minimum and improve the general stability. Pull-up resistors R1-R4 keep the RA0-RA3 inputs of the PIC at a default level of +5 V. The same goes for R9 and R10 for the RB0 and RB1 inputs connected to S2 and S3 respectively.

The PIC oscillator section ticks at 4 MHz using ceramic resonator X1 as the external frequency determining element.

The PIC is capable of driving LEDs D2-D5 directly using 1-kW current limiting resistors. Low-current LEDs have to be used, though.

Software

Less hardware means cleverer software. The object code to run in the PIC was written in the C language and compiled using the CCS C compiler (www.CCSinfo.com). The software was coded using an interrupt-based technique, i.e., the processor remains in sleep mode (reduced power consumption). It is woken up by a logic Low on the RB0/INT line (refer back to Figure 1). The interrupt service routine initiates the testing process depending on cable type defined by the setting of switch S3. If the designated wire pair is OK, the corresponding LED will blink for a short time. **Table 2** shows an overview of functions implemented in the software, along with short descriptions.

Both the PIC source code and hex object code files are available free of charge from our website as archive file **050302-11.zip**. These files allow readers with suitable assemblers/compilers and programmers to burn their own PIC for the project. As a bonus, the 050302-11.zip archive also contains files you can use to simulate the circuit using Proteus. [A section of] the C program listing is shown in **Figure 3**. Those without access to PIC programming tools can buy the programmed controller from the Publishers, the order code is **050302-41**.

Construction

The design for the printed circuit board is shown in **Figure 4**. The board is single-sided with generous copper pour areas as a ground plane helping to keep stray radiation to a minimum.

As only through-hole components are involved, construction is a doddle provided you are in the clear regarding your choice of the enclosure for the tester as that will determine the height at which the DIP switch, LEDs and pushbutton are fitted above the board surface. Do not make the mistake of fitting these parts as close as possible to the board surface and only then starting to look for a suitable enclosure — you'll find that you have to remove and refit the relevant parts one by one which is a waste of time, not even mentioning the danger of damaging the board. We recommend using a good quality socket in position IC1 as it will hold the valuable PIC micro. Finally, there's four wire links which must not be overlooked while populating the board.

Practical use

On power-up, the LEDs blink once sequentially. Connect the cable to the

Table 1. Gigabit crosslink cable connections

K2 pins		K1 pins	IC1 pins		
1—2	→	3—6	15—17	→	27—28
3—6	→	1—2	23—24	→	19—21
4—5	→	7—8	25—26	→	22—20
7—8	→	4—5	18—16	→	29—30

Table 2. Main functions in microcontroller program

Function	Parameter(s)	Description & returned value
int1 TestSTPair(**int8** p)	An 8-bit number representing the wire pair to test	Function takes the wire pair number of a straight-through cable and returns 1 (Boolean) if OK
void TestSTCable()	None	Void function that scans and tests all selected wire pairs of a straight-through cable using the above mentioned function
int1 TestCOPair(**int8** p)	An 8-bit number representing the wire pair to test	Function takes the wire pair number of a crosslink cable and returns 1 if OK
void TestCOCable()	None	Void function that scans and tests all selected wire pairs of a crosslink cable using the above mentioned function
void EXT_isr()	None	External Interrupt service routine that initiates the testing process according to the selected cable mode
void main()	None	Main function of the software. It holds all initializations, port directions and interrupt enabling

Figure 3. Part of the C program written for the project. Also useful for the PIC fuse settings.

```
///////////////////////////////////////////////////////////////////////////////
void TestSTCable()                // Test straight-through cable
{
   int8 pair;
   PORTD = 0;
   PORTB = 0;
   for (pair = 0; pair < 4; pair++)        // scan pairs
   {
      if (TestSTPair(pair) && bit_test(PORTA,pair)) // selected & connected?
         bit_set(PORTB,pair+4);      // turn on LED
      delay_ms(500);        // wait a bit
      PORTB = 0;
   }
}
///////////////////////////////////////////////////////////////////////////////
int1 TestCOPair(int8 p)           // Test crossover pair p
{
   switch (p)
   {
      case 0:  bit_set(PORTD,0);          // test High
               if (!bit_test(PORTC,4))
                  return 0;
               bit_clear(PORTD,0);        // test Low
               if (bit_test(PORTC,4))
                  return 0;
               bit_set(PORTD,2);        // test High
               if (!bit_test(PORTC,5))
                  return 0;
               bit_clear(PORTD,2);      // test Low
               if (bit_test(PORTC,5))
                  return 0;
               break;
      case 1:  bit_set(PORTD,4);          // test High
               if (!bit_test(PORTC,0))
                  return 0;
               bit_clear(PORTD,4);        // test Low
               if (bit_test(PORTC,0))
                  return 0;
               bit_set(PORTD,5);        // test High
               if (!bit_test(PORTC,2))
```

COMPONENTS LIST

Resistors
R1,R2,R3,R4,R9,R10 = 10kW
R5,R6,R7,R8 = 1kW

Capacitors
C1 = 10mF 63V radial
C2 = 1mF MKT lead pitch5 or 7.5mm
C3 = 100nF

Semiconductors
D1 =1N4001
D2,D3,D4,D5 = LED, red, low current
IC1 = PIC16F874-20/P, programmed, order code **050302-41** *
IC2 = 7805

Miscellaneous
X1 = 4MHz 3-pin ceramic resonator
K1,K2 = PCB mount RJ-45 socket, Molex # 95009-2881 (Farnell # 257102)
S1 = 4-way DIP switch
S2 = pushbutton with tactile feedback, 1 make contact, footprint 6x6mm
S3 = switch, on/off, 1 make contact, chassis mount
BT1 = 9V battery with holder (and optionally an on/off switch)
4 wire links
PCB, order code **050302-1** *

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

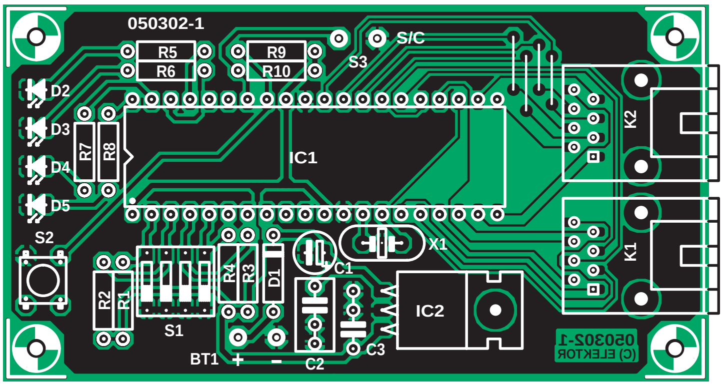
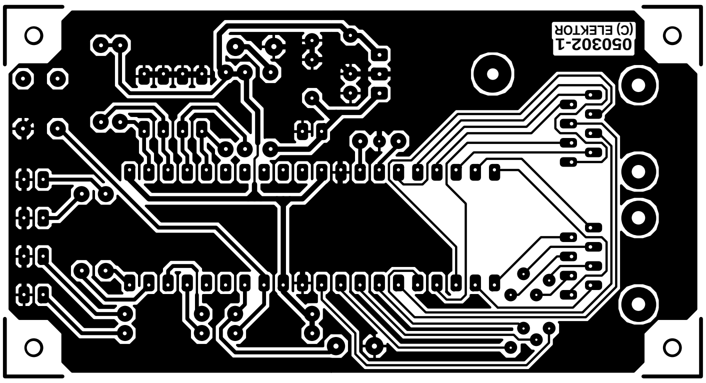


Figure 4. Copper track layout and component mounting plan of the PCB deigned for the network cable tester.



instrument and use the DIP switch to select the wire pairs you do *not* want to test (the selection is inverse). Next, select between straight-through and crosswire mode (the latter for Gigabit cables only) and then press the TEST ONCE button. If the pair passes the test, the associated LED will light. If not, the LED remains off. Simple but very useful!

To prevent the battery being drained when the instrument is not is use, it should be disconnected by removing the clip-on lead. Alternatively, wire an on/off switch into the +9-V line. The current consumption during standby is about 5 mA, while 10 mA is briefly drawn when pulses are being transmitted across the cable.

Note that on (old) 10BASE-T cables not all wire pairs may be present or connected to pins as only two are required functionally. These cables are now rare and should not be used for new installations.

(050302-1)

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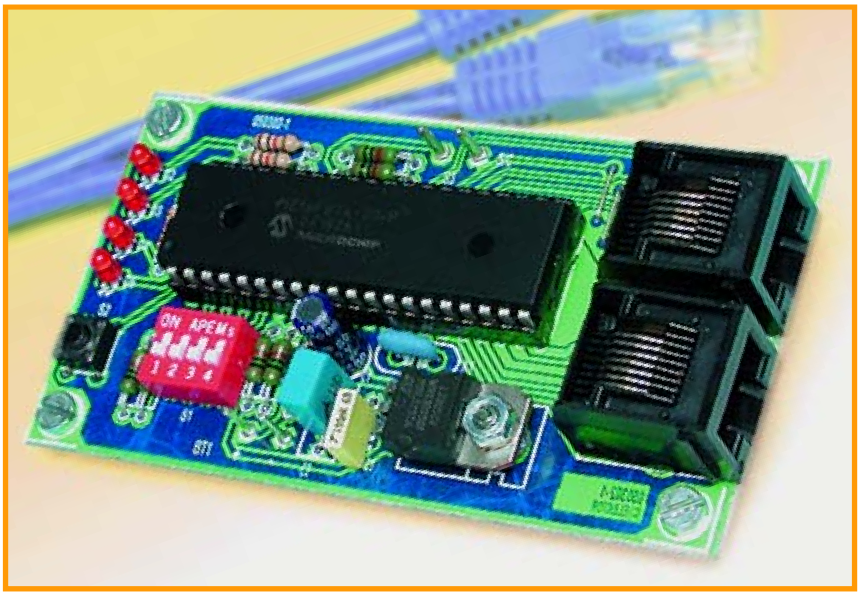
Further reading

1. Gigabit Crossover Cable, Elektor Electronics July/August 2005,
2. Home Network for ADSL, Elektor Electronics July/August 2004.
(both articles available as downloads from our website)

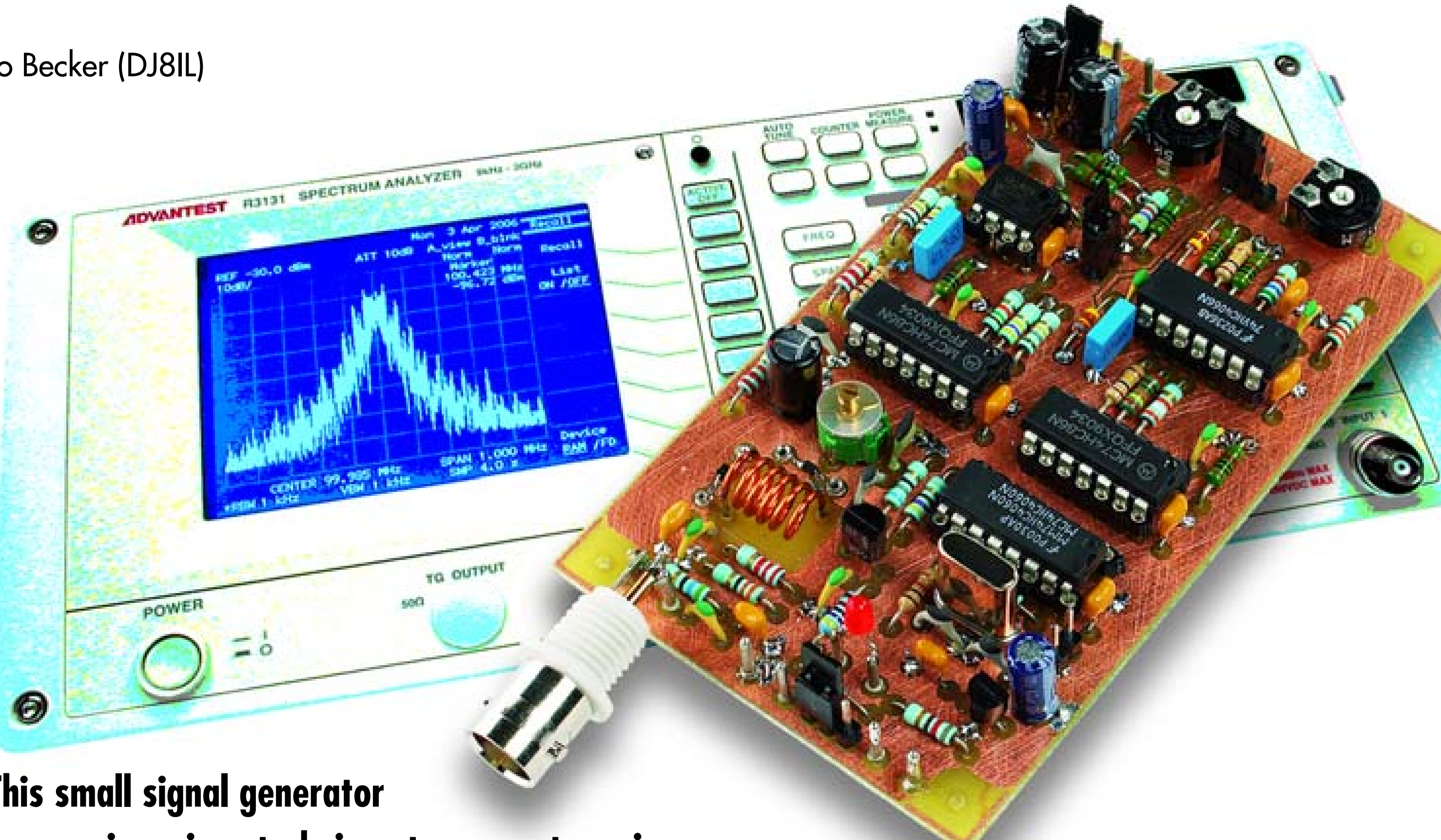
Figure 5. Our prototype of the tester.



FM Stereo Test Tran

VHF FM and audio test signals

Jo Becker (DJ8IL)



This small signal generator uses an ingenious technique to generate a sine wave with very low distortion, a mono (L+R) baseband signal and an FM stereo signal.

This test signal generator is particularly notable not just because of its high precision, but also because of the original method it uses to produce its waveforms. The many features are listed in the 'Output signals' text box. Rather than using special-purpose ICs, whose exact internal workings would be hidden from view, this design just uses ordinary HCMOS logic. All audio-frequency signals are produced using binary counters and combinatorial logic from a crystal reference of 9.728 MHz. The audio output can be switched between the tone and the baseband signal. It can deliver a maximum of 2 V_{pp} from its relatively low impedance short-circuit proof output. The FM oscillator is free-running, but is very stable in frequency at around 100 MHz in the VHF FM broadcast band. The frequency can be adjusted over the FM band by changing a capacitor value, and a trimmer offers fine adjustment over a range of ±300 kHz. The RF output level, at 12 mV_{eff} into 50 Ω, is more than adequate to drive a connected receiver and obtain its maximum signal-to-noise ratio.

Digital sine wave

The method used to generate the audio signal is particularly interesting. **Figure 1** shows how a divider chain made from flip-flops and some exclusive-OR gates can be used to produce a quantised signal with the various contributions being summed in such a way that the third and fifth harmonics are both absent. Only the very weak harmonics from the seventh upwards need to be filtered out. This idea has the advantage that phase relationships, for example between the pilot tone (at 19 kHz) and the 38 kHz subcarrier, remain precisely fixed. The required amplitude ratio of $(1+2^{1/2})$:1 appears in the circuit diagram (**Figure 2**) as the resistance ratios R3:(R4+R5) and R6:(R7+R8).
The seventh harmonic of the pilot tone

nsmitter

Output signals

- Sine wave test signal at 594 Hz with less than 0.06 % distortion for testing audio amplifiers;
- Multiplex stereo (L and R) signal for measuring and minimising crosstalk;
- Sum (L+R) signal for adjusting balance;
- FM signal, modulated by the multiplex signal, for testing FM stereo receivers and wiring;
- Audio/multiplex output impedance: 1.8 kΩ to 3 kΩ;
- Audio/multiplex output level: maximum 2 V_{pp};
- RF output impedance: 50 Ω;
- RF output level: 12 mV_{eff} into 50 Ω.

is at 133 kHz, above the third harmonic of the 38 kHz subcarrier at 114 kHz, and will surely not cause interference in a receiver. The 594 Hz audio test signal (whose phase is not important) is filtered by C3 and the following active low-pass filter at a total of 18 dB per octave. This reduces the theoretical distortion level from 21 % to below 0.05 %. For comparison, if we had started with a square wave instead, the residual distortion would have been thirty times greater. In the *Elektor* Electronics laboratory we measured a distortion of 0.055 % on the prototype with total harmonic distortion plus noise at –86 dB. The output amplitude can be altered by changing C3.

The multiplex (MPX) signal

For FM stereo transmissions the carrier is frequency modulated by the so-called multiplex signal, or MPX. The multiplex consists of three components:

- the sum signal, L+R (the normal mono signal), from 30 Hz to 15 kHz;
- the difference signal, L-R, which is modulated onto a 38 kHz subcarrier (the subcarrier itself is suppressed);
- the 19 kHz pilot tone.

The three parts of the multiplex test signal can easily be generated. The 594 Hz audio tone directly gives us the mono signal. The 594 Hz signal, modulated by the 38 kHz signal, would produce either a pure left-channel or a pure right-channel signal, depending on the polarity of the 38 kHz signal with respect to the phase of the pilot tone, if the 38 kHz signal were a sine wave. However, the on-off modulation used is equivalent to multiplying by a square wave, and so the sidebands produced are correspondingly wider, and it is necessary to mix in a small amount of tone signal with the opposite phase to compensate. This is done using R14 and P1. IC5 serves as the switching modulator, the switching phase being determined by IC3.A (pin 3 of IC3) and IC2.B (pin 6 of IC2).
At the summing point (pin 2 of IC4) the 19 kHz pilot tone is mixed in. The pilot can be removed from the multiplex by removing jumper JP1 to allow the multiplex modulation to be checked using an oscilloscope. Unadjusted (with P1 set to around 10 kΩ) a channel separation of around 35 dB to 40 dB is observed, which is adequate for most purposes. Using a TCA4500A as a test decoder for the stereo signal, a channel separation of up to 50 dB has been

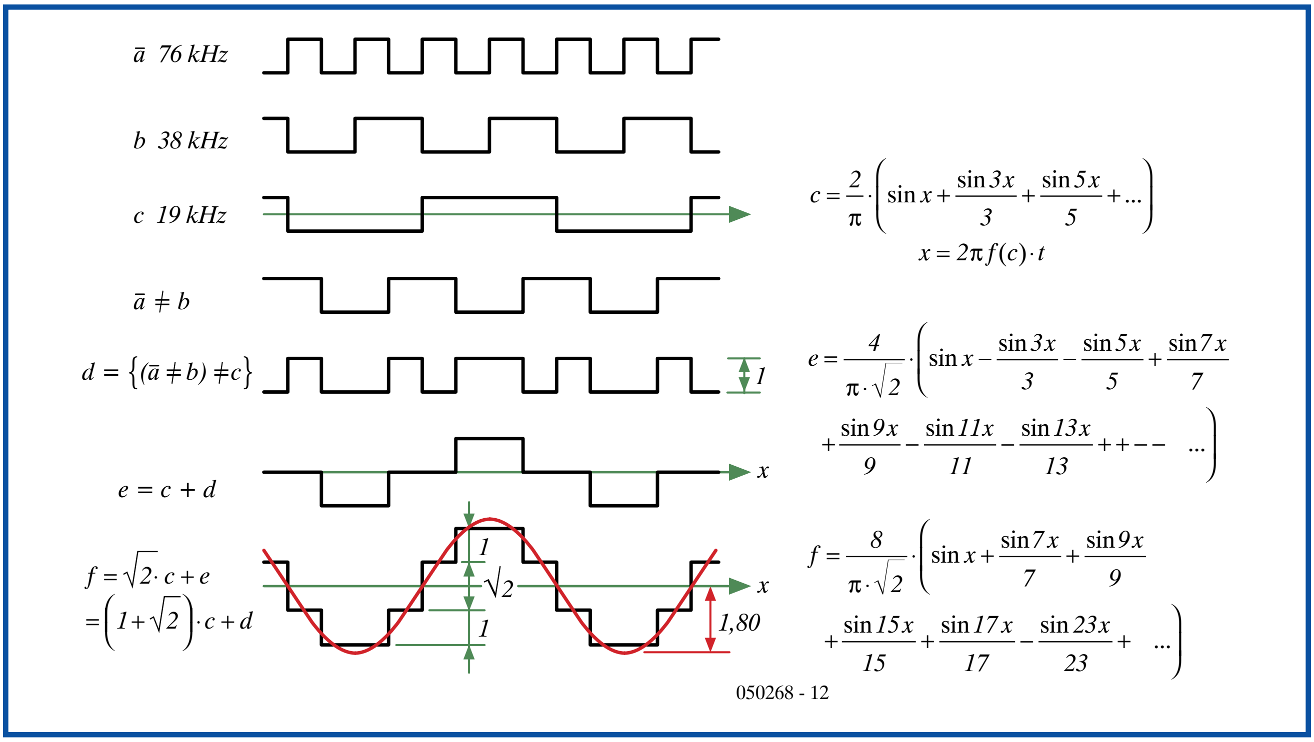


Figure 1. Waveforms and Fourier series of the signals in the quasi-digital sine wave generator.

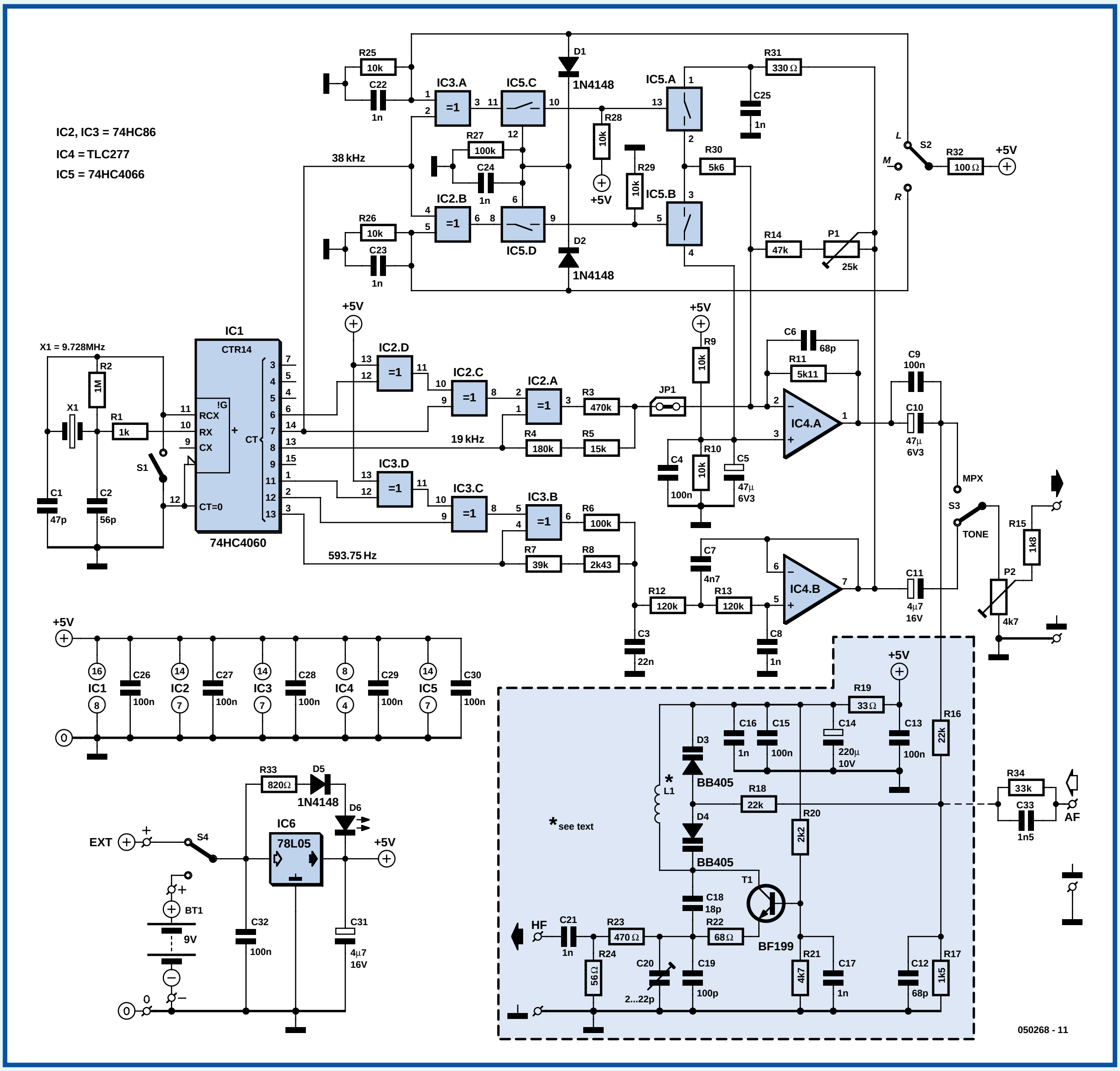


Figure 2. Circuit diagram of the stereo test transmitter. The FM transmitter itself is the highlighted area around transistor T1. The remainder of the circuit produces the modulating signals which are available at the audio output (via R15). An optional external modulating signal can be coupled in via C33 and R34.

FM transmitter

The FM stereo test transmitter consists of a signal generator that produces the baseband signals (test tone, pilot tone and multiplex signal) and a small FM transmitter that is modulated by these baseband signals. The FM transmitter itself is shown in the highlighted part of the circuit diagram in Figure 2 and is built around a single-transistor oscillator circuit. If you wish to construct a mono FM transmitter, only this part of the circuit is required and the rest can be dispensed with (even R16 is no longer needed). The RC-network consisting of C33 and R34, shown dotted, allows an external modulating signal to be connected, which can be any audio frequency signal with a level of up to around 200 mV.

This RC-network applies so-called pre-emphasis, which is necessary to emphasise higher frequencies for correct modulation according to national standards. In Europe an RC time constant of 50 μs is used; in the USA 75 μs is used. This is easy to arrange: the resistor R17 is already given, and so simply use a value of just 33 nF for C33 (rather than 4.7 μF) and we have a high-pass filter with the wanted time constant of 50 μs. To change the sensitivity of the modulation input we can adjust R34, although we then also need to change C33 so that R34 times C33 remains equal to 50 μs. A potentiometer (4.7 kΩ or 10 kΩ) can also be fitted at the input.

And be sure to observe the remarks at the end of the main article text before switching the oscillator on!

obtained by adjusting P1: only 6 mV_{pp} of crosstalk on a 2 V_{pp} signal. C6 and C25 remove spikes from the tone and multiplex signal, and C6 also reduces the distortion in the residual crosstalk signal.

Bits and pieces

The printed circuit board (**Figure 3**) has a ground plane over the whole of the component side. Details of construction can be seen from the component mounting plan and from the photograph of our final laboratory prototype (**Figure 4**). The only coil (L1) should be mounted without a gap between it and the circuit board.

The current consumption of the test transmitter is only 12 mA and so a 9 V alkaline PP3-type battery should give several years of occasional use. The state of the battery is indicated by LED D6 using an original circuit which takes advantage of the voltage drop across the 5 V voltage regulator IC6 and which does not itself consume extra current. The LED lights as long as the voltage drop across the regulator is at least 2 V to 2.5 V. If the battery voltage falls to 7.5 V or 7 V, the LED will go out, indicating that the battery should be changed. The circuit will operate happily on voltages from 6.7 V to 12 V, over which range the oscillator frequency, if set to 98 MHz, will vary by about 100 Hz. Over a period of 10 minutes the frequency should drift by no more than 1 kHz.

For occasional laboratory use there is no need to put the circuit in an enclosure. To this end the connections for switches S1 to S4 have been brought out to headers so that jumpers can be used instead of the switches. For the same reason potentiometer P2, which adjusts the signal level at the audio/multiplex output, is a trimmer mounted on the circuit board. A BNC connector for the FM output can be soldered directly to pins on the board (near R24). In other words, when the device is used without an enclosure, everything except the battery is securely attached to the board.

When we built our prototype in the *Elektor Electronics* laboratory we substituted ordinary radial electrolytics for the tantalum types specified by the author, without measurably impairing the performance of the circuit. It would therefore seem not essential to use tantalum types.

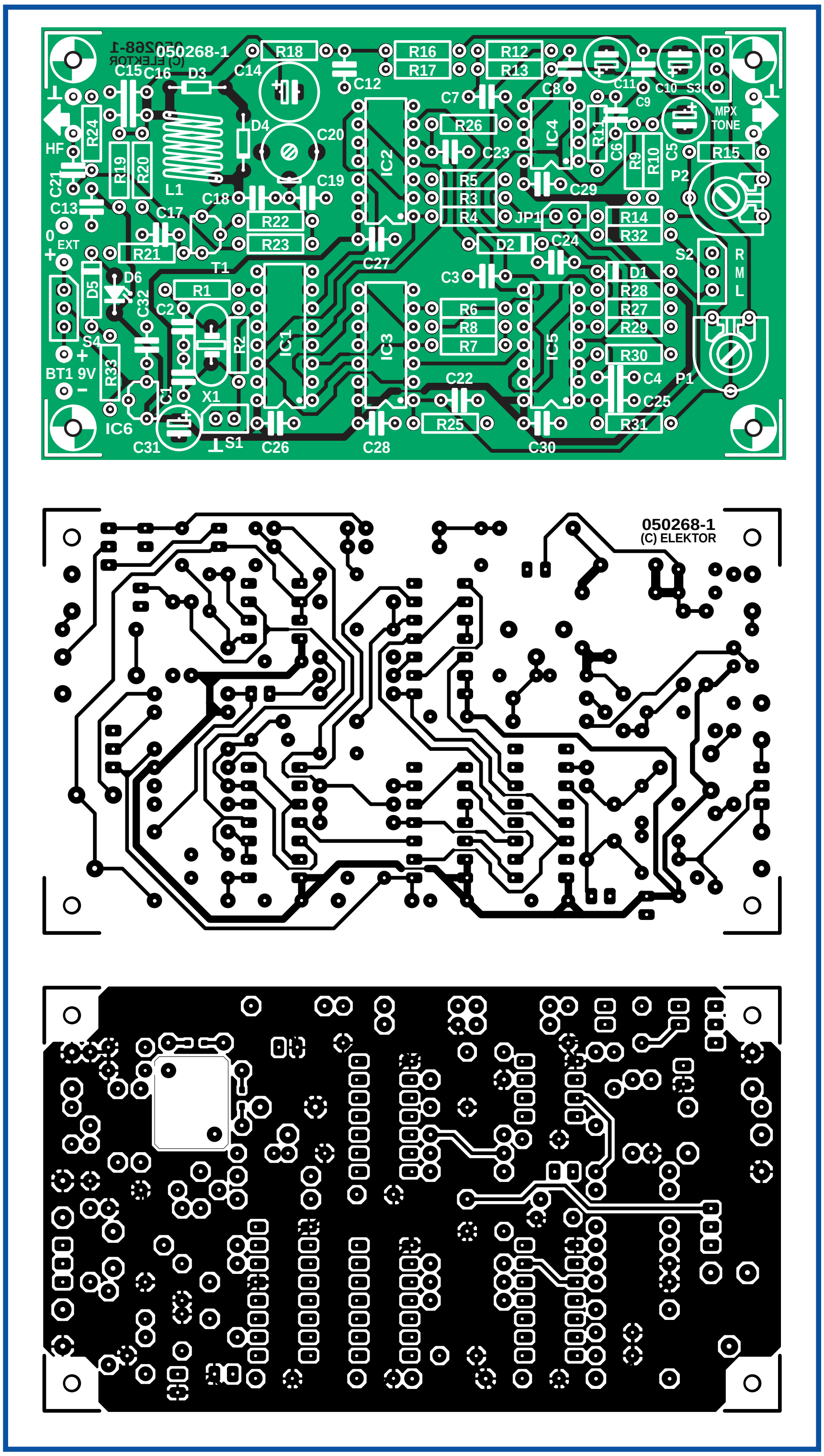


Figure 3. The double-sided printed circuit board, whose holes are not plated through.

As we have already mentioned, it is possible to adjust the oscillator frequency over the FM band by changing the value of C18. Of course, the frequency also depends on the inductance of coil L1 and on the capacitance of varicap diodes D3 and D4. On our prototype board we used a value of 18 pF for C18 and found that we had to compress the coil somewhat to obtain an operating frequency of 102.7 MHz. The author used a value of 15 pF for C18 and obtained a frequency of slightly over 108 MHz. The difference may have been due to the fact that we used slightly thicker silver-plated wire (1.3 mm) for L1.

As with most varicap diodes, the BB405

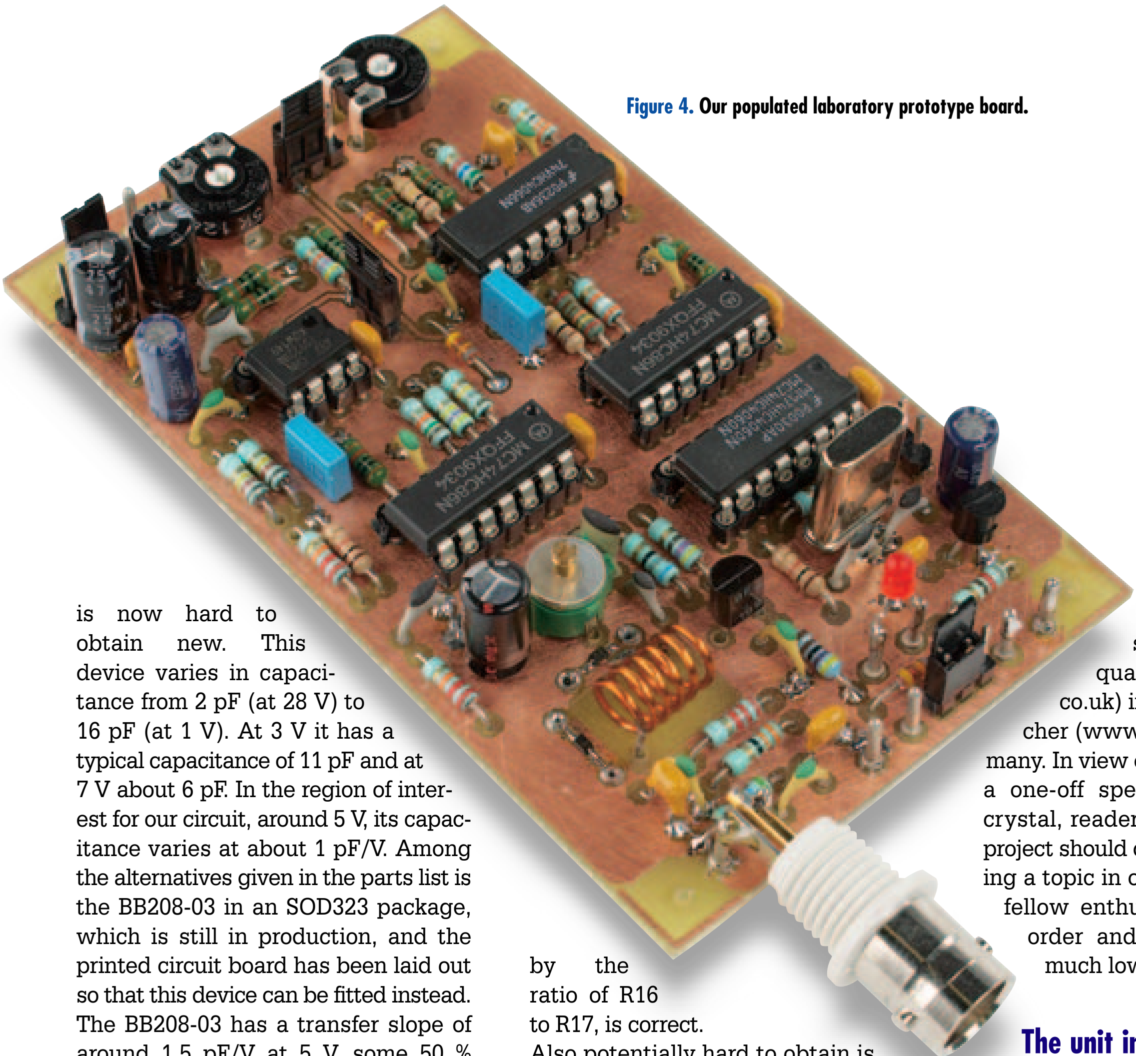


Figure 4. Our populated laboratory prototype board.

is now hard to obtain new. This device varies in capacitance from 2 pF (at 28 V) to 16 pF (at 1 V). At 3 V it has a typical capacitance of 11 pF and at 7 V about 6 pF. In the region of interest for our circuit, around 5 V, its capacitance varies at about 1 pF/V. Among the alternatives given in the parts list is the BB208-03 in an SOD323 package, which is still in production, and the printed circuit board has been laid out so that this device can be fitted instead. The BB208-03 has a transfer slope of around 1.5 pF/V at 5 V, some 50 % higher than the BB405; the value of R17 must therefore be changed to 1 kΩ so that the modulation level, determined by the ratio of R16 to R17, is correct.

Also potentially hard to obtain is a quartz crystal with a frequency of 9.728 MHz, which is not a standard value. Custom crystals can be obtained from sources such as Euroquartz (www.euroquartz.co.uk) in the UK or Andy Fleischer (www.andyquarz.de) in Germany. In view of the of the high cost of a one-off special frequency quartz crystal, readers wishing to build the project should definitely consider posting a topic in our online Forum to find fellow enthusiasts, place a larger order and get the crystal at a much lower price.

The unit in operation

The audio output can be switched between the multiplex signal and the 594 Hz sine wave test signal using S3.

COMPONENTS LIST

Resistors
R1 = 1kΩ
R2 = 1MΩ
R3 = 470kΩ
R4 = 180kΩ
R5 = 15kΩ
R6,R27 = 100kΩ
R7 = 39kΩ
R8 = 2kΩ4 (or 2kΩ43 from E96 series)
R9,R10,R25,R26,R28,R29 = 10kΩ
R11 = 5kΩ1 (or 5kΩ11 from E96 series)
R12,R13 = 120kΩ
R14 = 47kΩ
R15 = 1kW8
R16, R18 = 22kΩ
R17 = 1kΩ5
R19 = 33Ω
R20 = 2kΩ2
R21 = 4kΩ7
R22 = 68Ω
R23 = 470Ω
R24 = 56Ω
R30 = 5kΩ6
R31 = 330Ω
R32 = 100Ω
R33 = 820Ω
P1 = 25kΩ preset
P2 = 4kΩ7 preset

Capacitors
C1 = 47pF
C2 = 56pF
C3 = 22nF MKT, lead pitch 5mm
C4,C9,C13,C15,C26-C30,C32 = 100nF ceramic, lead pitch 5mm
C5,C10 = 47µF 6V3 tantalum or radial electrolytic
C6,C12 = 68pF
C7 = 4nF7 MKT lead pitch 5mm
C8,C16,C17,C21-C25 = 1nF, lead pitch 5mm
C11 = 4µF7 16V tantalum or radial electrolytic
C14 = 220µF 10V radial
C18 = 18pF
C19 = 100pF
C20 = 22pF PTFE trimmer capacitor
C31 = 4µF7 16V radial

Inductor
L1 = 6 turns 0.8mm ECW or CuAg, internal diameter 5mm

Semiconductors
D1,D2,D5 = 1N4148
D3,D4 = BB405 (alternatives: BB205, BB505, BB208-03)
D6 = LED, red, low current
T1 = BF199
IC1 = 74HC4060
IC2,IC3 = 74HC86
IC4 = TLC277 (TS922IN)
IC5 = 74HC4066
IC6 = 78L05

Miscellaneous:
JP1 = 2-way pinheader w. jumper
S1 = on/off switch (and/or 2-way pinheader w. jumper)
S2 = 1-pole, 3-way switch (and/or 3-way pinheader w. jumper)
S3, S4 = changeover switch (and/or 3-way pinheader w. jumper)
X1 = 9.728MHz quartz crystal, HC-49/U, fundamental frequency, parallel resonance, load capacitance 30 pF, ±10 ppm, (see text)
BT1 = 9V battery with clip-on leads
BNC socket 50Ω (optional)
PCB, order code 050268-1

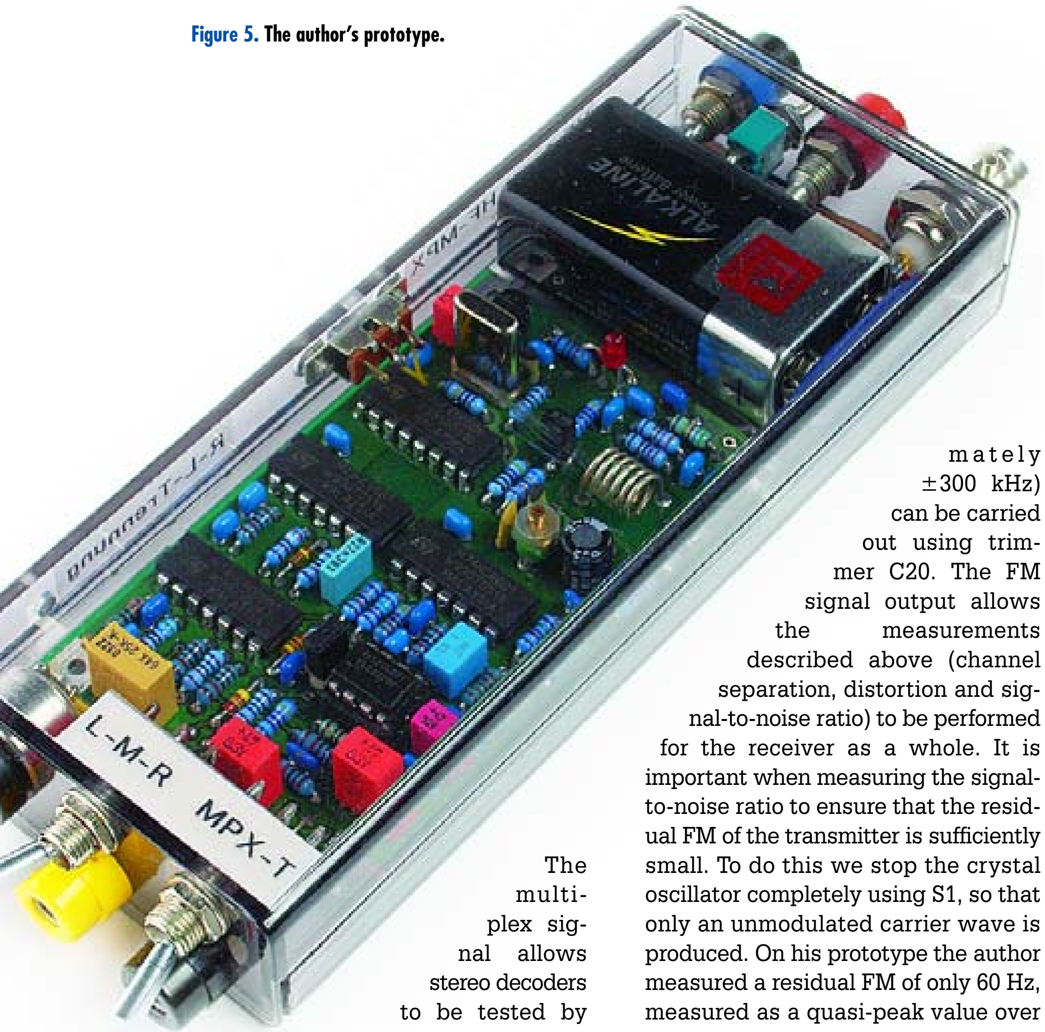


Figure 5. The author's prototype.

The multiplex signal allows stereo decoders to be tested by connecting the output of the generator to the MPX input of the decoder. We discussed above the adjustment of P1 to obtain good channel separation, while P2 allows the level of the test signal to be adjusted. Using the MPX signal as an input to the decoder allows measurement not only of its output channel separation, but also of its output signal-to-noise ratio and distortion. S2 selects whether the test tone is output on the right or left stereo channel. With the switch in the middle position the tone is at equal amplitude in the two channels, allowing balance to be tested.

With S3 set to 'TONE' the 594 Hz sine wave is routed to the output. The low distortion of this signal makes it ideal for measuring the distortion of audio amplifiers.

The RF output of the test signal generator can be connected directly to the antenna input of an FM stereo tuner or receiver. We have already discussed the adjustment of the carrier frequency, and fine adjustment (approximately ±300 kHz) can be carried out using trimmer C20. The FM signal output allows the measurements described above (channel separation, distortion and signal-to-noise ratio) to be performed for the receiver as a whole. It is important when measuring the signal-to-noise ratio to ensure that the residual FM of the transmitter is sufficiently small. To do this we stop the crystal oscillator completely using S1, so that only an unmodulated carrier wave is produced. On his prototype the author measured a residual FM of only 60 Hz, measured as a quasi-peak value over the audio band from 20 Hz to 23 kHz, which is a negligible level of interference. Note that you will be broadcasting the FM output of the test signal generator, at least to the extent that what you have connected to the output forms an antenna. The operation of radio transmitters in the UK is regulated by Ofcom, and operating an unlicensed transmitter can incur a fine of up to five thousand pounds or even a spell in prison. Ofcom has facilities for monitoring radio transmissions and does prosecute offenders: only licensed radio amateurs are allowed to use their home-built equipment within strictly allocated parts of the radio spectrum (which does not include 88-108 MHz). Despite the low RF output power of the device (only 3 µW), it is still necessary to ensure that no FM signal leaks out of the system, and that the oscillator itself does not act as a transmitter. If you use a screened cable, ideally coax, to connect the transmitter to the receiver there should be no difficulty as the device is operating as a signal generator for test and measurement purposes rather than as a radiating transmitter.

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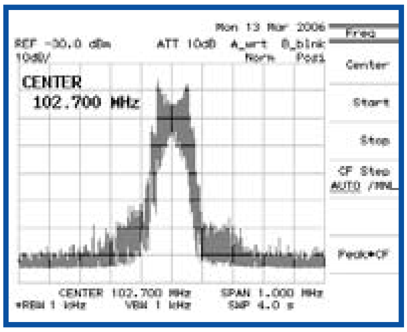


Figure 6a. Spectrum of the RF output signal in mono operation. The carrier frequency is 102.7 MHz.

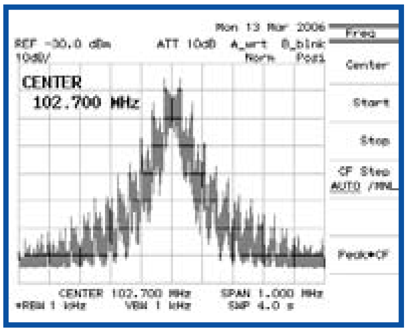


Figure 6b. As Figure 6a, but here in stereo operation.

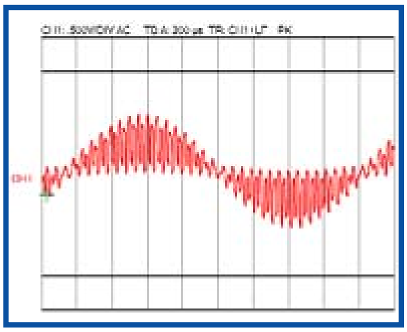


Figure 6c. The multiplex signal at the audio output (S2 set to L or R).

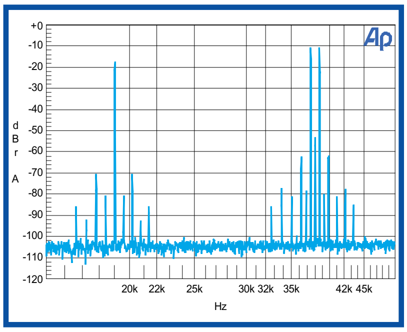


Figure 6d. Spectrum of the signal in Figure 6c (stereo multiplex signal). Frequency modulation of the 38 kHz subcarrier is clearly visible.

FPGA Course (3)

Paul Goossens

This month we'll use the FPGA to construct a simple microcontroller system using a (free) 8052 microcontroller core. The microcontroller drives various peripheral elements of the prototyping board, including the I²C interface. Finally, we'll use it to build a four-channel multimeter.

This instalment uses an 8052 core derived from the T51 open-core design. We modified it slightly to make it easier to use in our FPGA module.
The internal operation of the microcontroller falls outside the scope of this course. However, we'll show you how to use the microcontroller and how to connect it the peripheral digital logic. That will be illustrated by building a four-channel voltmeter.

Cores

Our example here is built from various pieces of digital logic. You'll find the example project in the 'ex9' folder of the software for this instalment (060025-3-11). After opening the project file in that folder, you will see a schematic diagram as shown in **Figure 1**. The circuit is built around the block labelled 'T8052', which represents the 8052 microcontroller.

The associated files are located in the 'T51' and 'Altera Cyclone' folders. This microcontroller is derived from an 8052 core design that can be found at www.opencores.com. We modified the core slightly so it would use the internal memory of the FPGA more efficiently. We also added a wishbone interface. We'll have more to say about those changes in next month's instalment.

The important aspect of this microcontroller is that it has 8 KB of program memory and 4 KB of XRAM. It is also compatible with a standard 8052, so you can use regular 8052 development tools with it.

PLL

In this example, we operate the 8052 at a clock rate of 25 MHz. This clock signal could be generated using the 50-MHz clock on the board and a flip-flop. However, we decided to use the two PLLs in the FPGA for this example. The PLLs can be used to generate clock signals at frequencies that differ from the 50-MHz signal provided by IC7.
In the Quartus package, Quartus provides IP cores under the 'Megafunctions' designation that allow you to use the PLL. These megafunctions can be used as symbols via the same symbol toolbox that contains the input pins and so on. Refer to the Quartus manual if you want to know more about using megafunctions.

Part 3: Cores & System on Chip

In this case, the megafunction is configured to accept a 50-MHz input clock and generate a 25-MHz clock. When you use the PLL, you have to allow it a bit of time to generate a stable clock. The 'locked' output goes to '1' when the PLL output is stable.

8052

The 8052 in our circuit is clocked by the 25-MHz signal. Its reset input is a logic OR function of the 'switch1' input and the inverted 'locked' output of the PLL. That ensures that the microcontroller will be in the reset state if the PLL is not supplying a stable clock signal. The microcontroller can also be reset by pressing button S1 on the prototyping board.

The two external interrupt lines are tied to ground ('0') because they are not used in this example.

I/O ports PO–P3 require a bit more explanation. In a standard 8052, these ports can act as inputs as well as outputs. The pins are thus bidirectional. In an FPGA, it's often impossible to use bidirectional pins. For that reason, each port of the 8052 has an 8-bit input and an 8-bit output.

Unused inputs are simply connected directly to the corresponding outputs of the same port. For example, if bit 0 of port P3 is not used as an input, it must be connected to bit 0 of the output of port P3

The final thing that deserves mention is the XRAM_AC input, which forms part of the wishbone bus. We'll discuss that bus in next month's instalment.

I²C

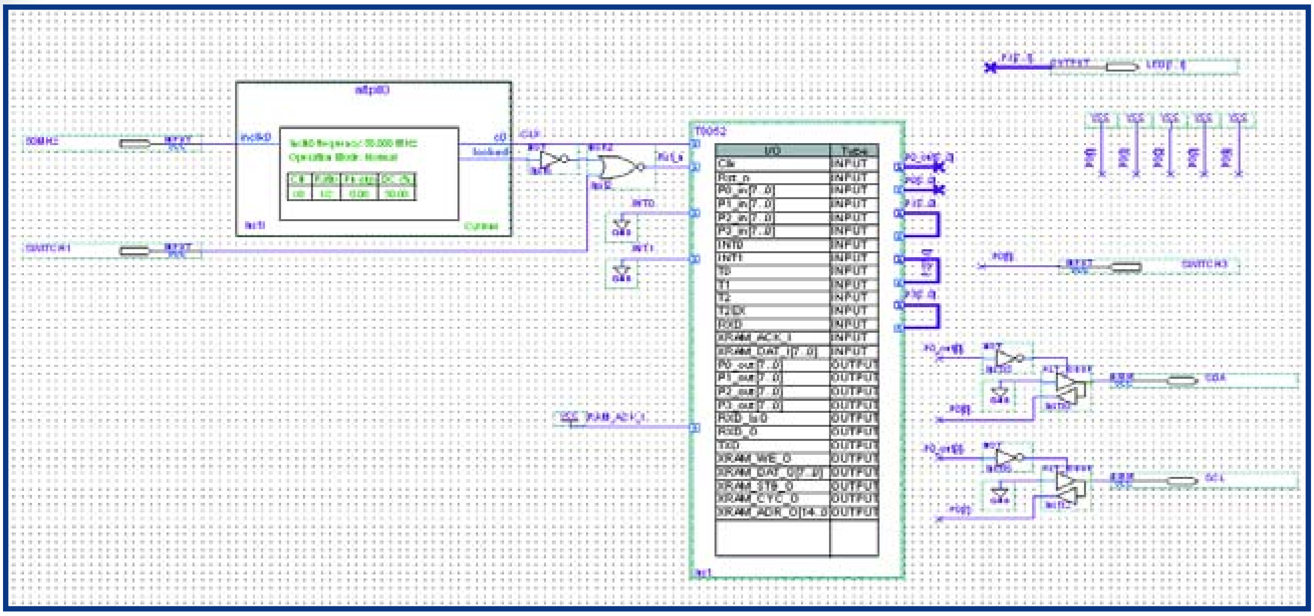
The I²C bus requires two bidirectional signal lines. As we just mentioned, it's usually not possible to use bidirectional signal lines with an FPGA. Fortunately, the type of FPGA used here does allow I/O pins to be used for bidirectional signals. Two such pins are shown in the schematic drawing. These bidirectional pins are located in the same list as the input and output pins, with the designation 'bidir'.

We also need a bidirectional buffer in order to use these bidirectional pins. In this case, we used the 'ALT_OPBUF' symbol, which consists of an output buffer with an Enable input and an input buffer. When the Enable input is set to '1', the outputs can source or sink current according to the signal levels at the buffer inputs. The outputs are in a high-impedance state if the Enable input is '0'. In that state, an external device can drive the pin with a high or low level without causing a short-circuit condition.

The outputs of the input buffer can be used to read back the states of the pins, regardless of whether the output buffer is enabled.

As you already know, the I²C lines must be connected to open-collector

Figure 1. Schematic diagram of the embedded system.



I²C bus

The prototyping board includes an I²C bus that can be used to drive various ICs. The ICs that provide the digital and analogue I/O signals on connectors K3 and K5 communicate with the FPGA via this bus, and the IC that drives the LCD uses the same I²C bus.

The general structure of the I²C signals is shown in the adjacent figure. There you can clearly see that all ICs connected to the bus drive the SDA and SCL lines via open-drain outputs. In other words, an IC can pull the level of a signal line to ground, but it can never connect it to the supply voltage. The pull-up resistors cause the level to be the same as the supply voltage when none of the connected ICs is pulling the line low.

Each communication is initiated by a 'Start condition', which can be recognised by a falling edge on the SDA (data) line while the SCL (clock) line is high. After that, the SCL line also goes low. The end of the communication is indicated by a 'Stop condition', which consists of a low-to-high transition on the SCL line followed by a high state on the SDA line. These two conditions are the only cases where the SDA line can change levels while the SCL line is high.

After a Start condition, the master first sends an I²C address. That is an 8-bit value, with the final bit indicating whether the communication is a read operation or a write operation. It is '1' for a read operation. The other seven bits are used to address a particular IC.

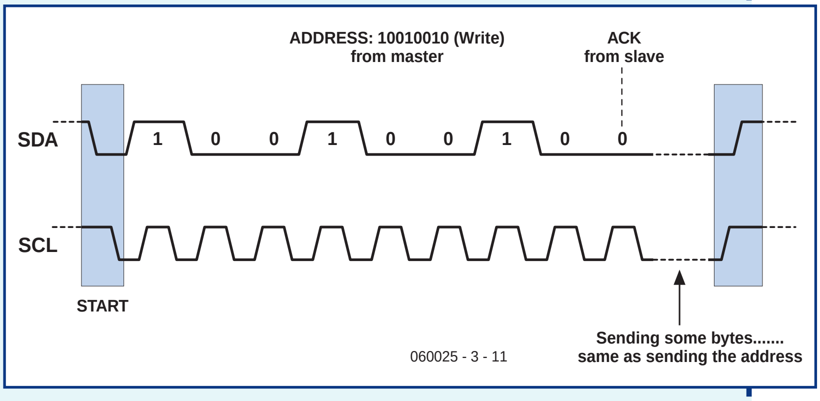
The IC that recognises its address will pull the SDA line low on the ninth clock pulse as a sign that it has been addressed. This is called 'ACK', which is short for 'Acknowledge'.

If the eighth bit is a '1', the master will then start sending its first data byte. It does this by placing the most significant bit of the first byte on the SDA line and then issuing a clock pulse. It then places the next bit on the SDA line and issues the next clock pulse. That process is repeated up to and including the least significant bit. On the ninth clock pulse, the slave pulls the SDA line low again as an ACK signal. After this, the master can send another byte if desired or terminate the communication with a Stop condition.

The situation is different with a read operation. In that case, the master generates a Start condition and then sends the address of the desired IC with the least significant bit set to '0'. The addressed slave device generates an ACK, just as before.

Next, the slave places the first bit (most significant bit) of the byte to be sent on the SDA line. The master then generates a clock pulse and receives that bit. After the master receives the eighth bit, it generates an ACK. The master can then decide to receive another byte or terminate the communication with a Stop condition.

It's important to bear in mind that the master always generates the clock signal. However, the slave can affect this by delaying the clock. That works as follows: after the master returns the SCL line to the high-impedance state, it must wait until the level on the SCL line goes high. The slave can hold the SCL line low during this interval if it needs extra time, for instance for processing data. The slave can thus use this mechanism to slow down communications.



outputs. That means the ICs connected to the lines are only allowed to sink current in order to pull the signal lines to a low level. For that reason, the input of the output buffer is connected to ground (GND) in the example. The signal line can then be pulled to ground by setting the Enable input to '1'.

Here the Enable line for the SDA signal is connected to the inverted bit-0 output of port P0. The Enable input will thus go to '1' when that bit set to '0', which will cause the SDA line to be pulled low.

The state of the SDA signal line of the I²C bus can be sensed at any desired time via bit 6 of the input buffer of port P0.

The SCL line is handled in the same way, but using other bits of port P0. This arrangement allows the I²C protocol to be implemented in software.

Firmware

By now, you may be wondering where the program for the microcontroller is located.

The program memory is incorporated in the T8052 core. This memory is also a megafunction. During compilation, the megafunction uses the 'firmware.hex' file in the 'firmware' folder to populate the program memory. The firmware can be modified quite easily, as you will soon see.

We used the free SDCC compiler to generate the firmware for this example. You can find the compiler on the home page of SDCC. You will need this compiler if you want to modify the firmware according to your own wishes. After downloading the compiler software, run the setup program. We recommend leaving the standard settings unchanged. When the installer asks whether you want to install SDCC using the default path, confirm this by clicking on 'Yes'.

The firmware for this example is located in the folder under 'ex9/firmware'. That folder also contains a file named 'make.bat'. To

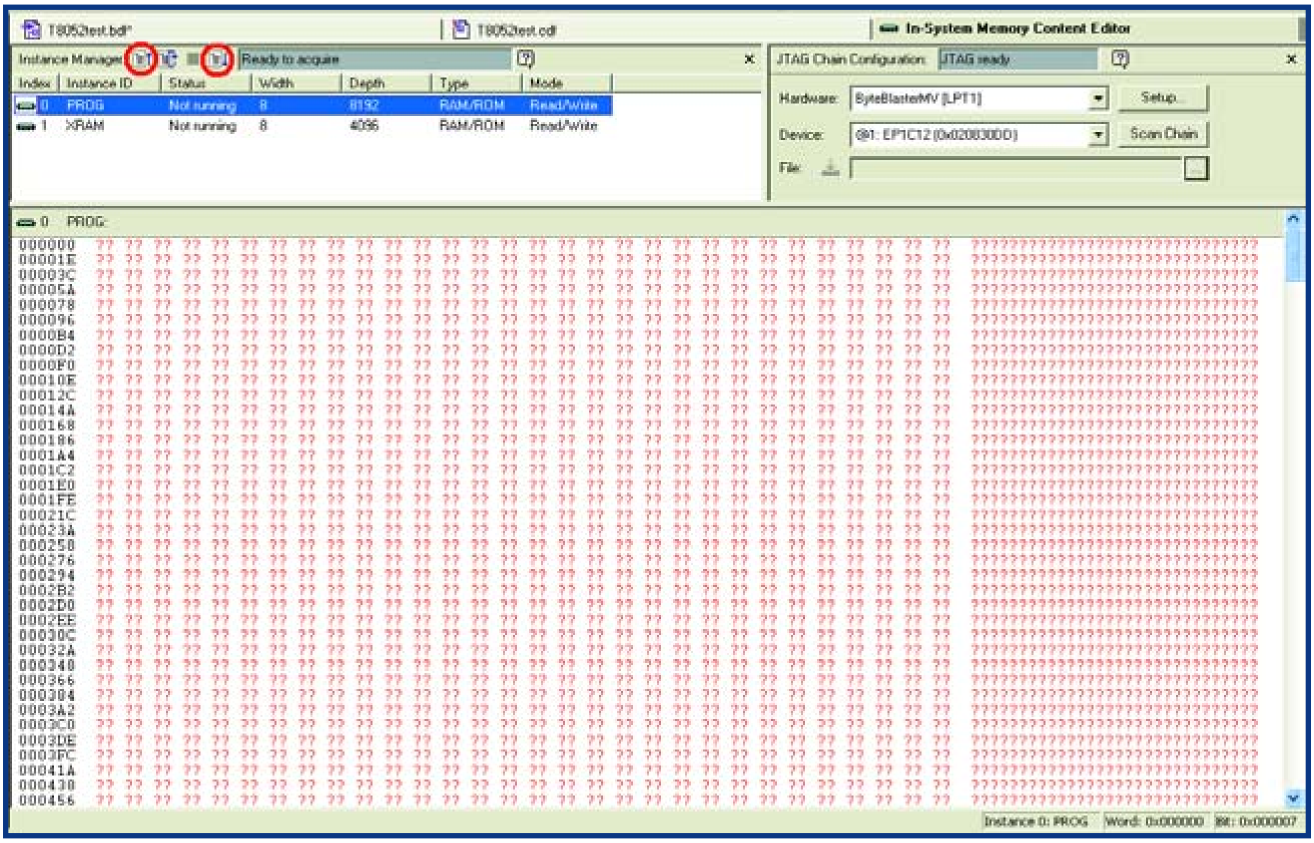
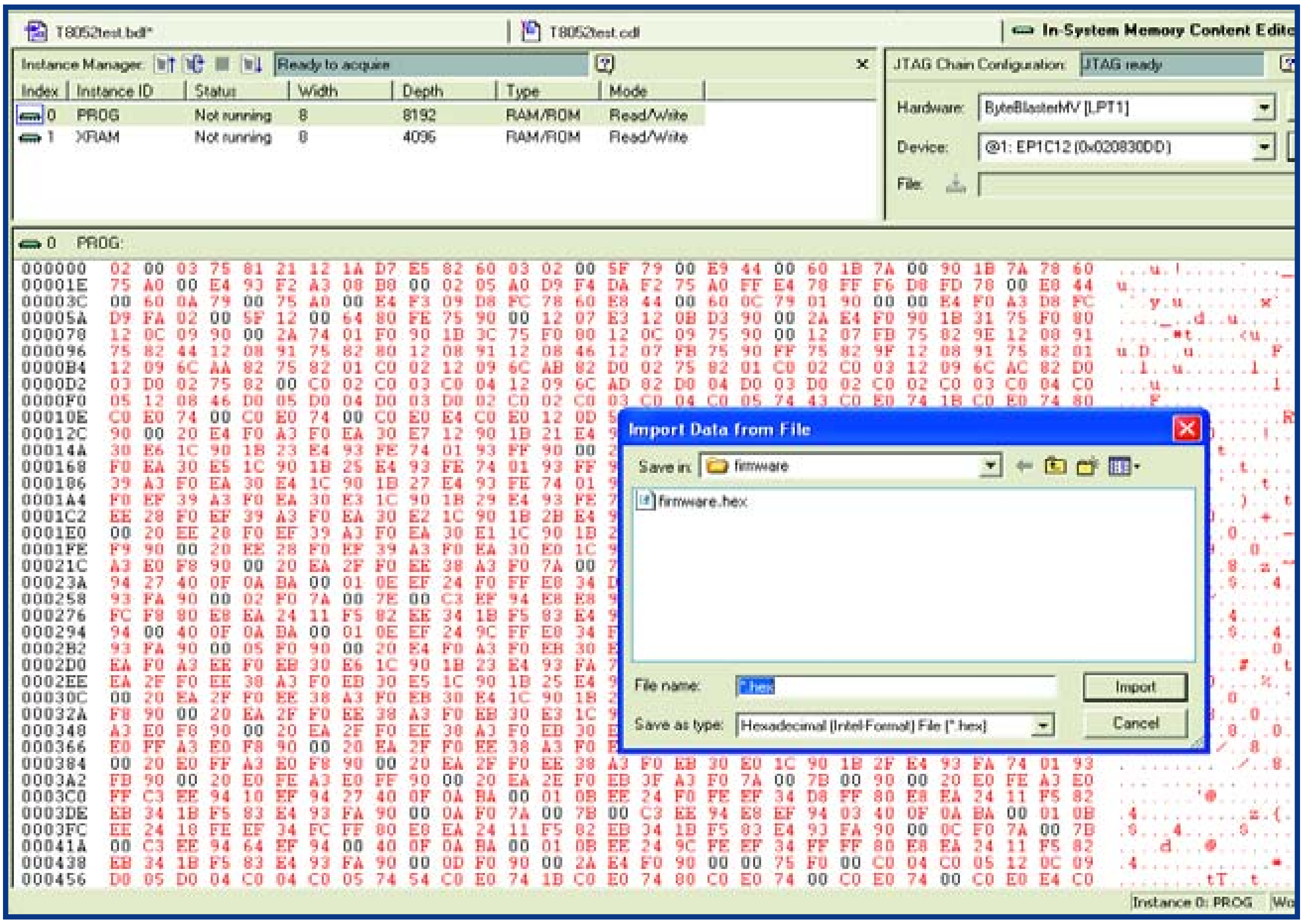


Figure 2. Memory peeking via JTAG.

Figure 3. Downloading new firmware.



recompile the firmware, simply double-click on the 'make.bat' file.

All the intelligence of the circuit is contained in the firmware. Among other things, it looks after driving the I^2C bus, the A/D converter and the LCD module. The source code is relatively simple and should not present any problem for anyone with a reasonable knowledge of C.

Hands-on

Start the program and configure the FPGA using the example project for this instalment, which you will find in the 'ex9' folder. After you configure the FPGA, you will see a welcome message on the LCD. Starting around 4 seconds later, the LCD will continuously display the voltages measured at the four analogue inputs of the prototyping board. Congratulations – you just built a four-channel multimeter!

As you know, the FPGA now contains a microcontroller with program memory and working memory. Thanks to the modifications we made to the microcontroller, you can use Quartus to view and modify the memory contents.

In the 'Tools' menu, click on 'In-System Memory Content Editor'. That will open a new window as illustrated in **Figure 2.** Two memories are listed at the top left, with the names 'PROG' and 'XRAM'. PROG contains the firmware that is executed by the 8052. At this point, Quartus does not know the content of that memory. Consequently, the contents of the memory locations shown in the box under 'PROG' are filled with question marks. Select the program memory by clicking on the word 'PROG'. You will see 'Instance manager' somewhere near the top of the window, with several buttons next to it. Click on the leftmost button (an icon showing a document with an upward-pointing arrow next to it), which is called 'Read'.

Quartus will read in the content of the program memory and display it in the box below. That all happens without causing any problem for the 8052. In fact, there's no sign of any sort of slowdown.

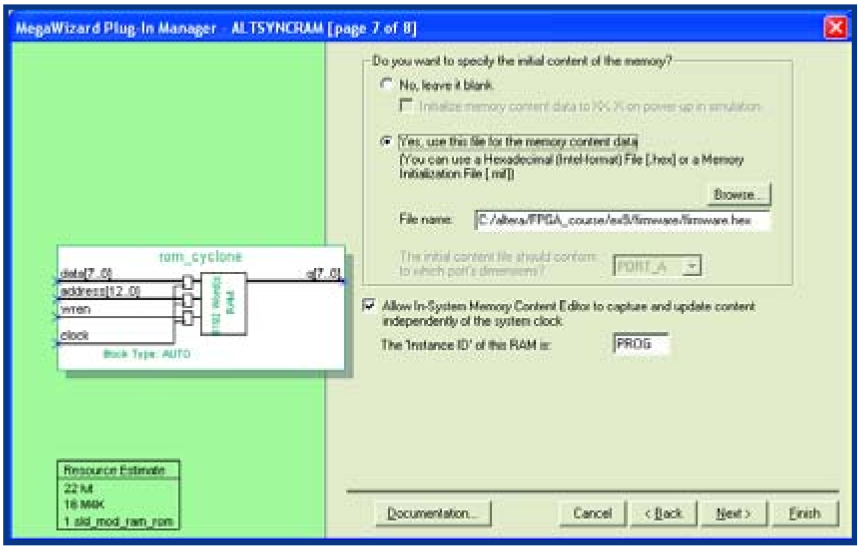


Figure 4. Specifying the location of the firmware on the hard disk.

New firmware

The next exercise is to try making changes to the firmware. For example, you can change the string in line 57 to 'Test'. Save this change, and then double-click on 'make.bat' in the previously mentioned folder in the Windows Explorer window. SDCC will recompile the program and generate a new 'firmware.hex' file.

Return to the Memory Content Editor window and position the mouse cursor somewhere in the data area. Now right-click with the mouse and select 'Import Data from File…' in the popup menu. Navigate to the 'firmware' folder and select the new 'firmware.hex' file. The program will now load the content of the selected hex file into the memory buffer. A warning message will also be displayed to indicate that the length of the hex file is not the same as the length of the memory buffer. You can simply ignore that message.

Next, press button S1 on the prototyping board to reset the microcontroller in the FPGA. While holding this button depressed, click on the 'Write' button on the screen. You can recognise it by its icon (a document with a downward-pointing arrow). That causes the program to transfer the content of the memory buffer to the FPGA memory via the JTAG interface.

Now you can release the reset button. The welcome message on the LCD will be different now, which proves that the new firmware has been loaded into the 8052.

On your own

While you're waiting for the next instalment, it's a good idea to work on your own to acquire more experience with the 8052. The easiest approach is to copy the 'ex9' folder to a new folder. You can then experiment to your heart's content with the copied version.

Don't forget that the compiler expects to find the firmware at a particular location, but it's easy to change that location. In the Project Navigator window, select the 'Hierarchy' tab. Click on the + sign next to 'T8052'. A list will be displayed underneath, with among other things the entry 'rom_cyclone'. Double-click on this entry. That will bring up a 'MegaWizard' window. Click on 'Next' to proceed to the next window of the wizard. Keep going in the same way until you reach window 7 (**Figure 4**). In this window, enter the exact location and name of the hex file you want to use for the firmware. Finally, click on 'Finish'. Be sure to leave all other settings unchanged. Now you can recompile the design, and the program memory will contain the firmware you want to use.

(060025-3)

Web links

www.opencores.com
www.sourceforge.com
http://sdcc.sourceforge.net

Earlier in this series

Versatile FPGA Module, Elektor Electronics March 2006.

FPGA Prototyping Board, Elektor Electronics March 2006.

FPGA Course (1), Elektor Electronics April 2006 (with free downloads).

FPGA Course (2), Elektor Electronics May 2006.

STD_LOGIC

Starting with part 1 of this course, we have been using signals of type STD_LOGIC. That signal type can have various states, but up to now we have only used the '1' and '0' states.

Signals of type STD_LOGIC can also have other states, of which 'Z' and '-' are the most important. The 'Z' state indicates that the signal is in a high-impedance state. An example of where that can happen is the output of a buffer with an Enable input. It is recommended **not** to use this state if you are generating a design to be implemented in an FPGA, because most FPGAs cannot generate internal high-impedance signal states. However, most FPGAs (including the one we use) can generate high-impedance states on their I/O pins. It is thus possible to use the 'Z' state for such signals.

Another state is '-', which is called 'don't care'. If you set a signal to '-' in a particular case, you effectively tell the compiler that you don't care whether the output is '1' or '0' and it has no effect on the overall operation of the design. That allows the compiler to simplify functions where possible, with the result that the circuit may take up less space in the FPGA.

We used an ALT_IOBUF in Quartus for the I^2C interface. That is a buffer with an Enable input, which means that the buffer outputs go to a high-impedance state when the Enable input goes to '0'. The level on the output (I/O pin of the FPGA) can be read via a second buffer.

Open cores

This 8052 core we used here is derived from the T51 core. That core is available free of charge from the www.opencores.com website. We modified the T51 core slightly to suit our purposes.

All cores (which are also called 'IP', which stands for 'intellectual property') on this website are free. That means they can be used without paying any licence fee. We made a few modifications to the 8052 core, primarily to enable it to work properly with the internal memory of the Cyclone FPGAs.

We don't intend to describe the internal operation this 8052 here. That's anyhow not particularly relevant with a core (aside from the educational value). A designer can simply regard a core as a black box that performs a particular function. It's the same as with an IC – you need to know how you can use it, but the details of its internal operation are not important.

We placed all the necessary files for this core in the 'T51' subfolder. The VHDL files in that folder collectively constitute an 8052 microcontroller. The top-level document for this core is the 'T8052.vhdl' file, and that is the only file you have to use directly. It's not particularly difficult to use this core in a new design (such as your own design). Nevertheless, we recommend that you copy the 'ex9' folder to a new folder if you want to use it in your own designs, after which you can modify the copied files as you see fit.

Most of the signal names of the 8052 core are self-explanatory, but the ones that start with 'XRAM' need a bit of explanation. These signals collective form what is called a 'wishbone bus', and that's something we'll explain in the next instalment. For now, it's quite important to know that the 'XRAM_ACK' signal must always be set to '1' if this bus is not used, since otherwise the microcontroller can hang unexpectedly.

Wireless switches controlled via your PC

These are the units that we'll use. There are four mains sockets, of which one can be used as a dimmer, bundled with a remote control unit.

Modding for Home

Wireless mains switches can be very useful: a remote control is used to turn an electrical device on or off. But when nobody's at home, during the holidays for example, things become more difficult. In those circumstances this mod will come in handy. It could be turned into an inexpensive burglar deterrent quite easily. This mod is also very useful for those of you who are too lazy to search for the remote control when they're sitting in front of their PC.

Many computer hobbyists who have an interest in expanding their system would like to use their PC to turn mains equipment on and off. Others with an electronics background would also find it useful if they could easily control 230 V equipment via their PC, for example as part of a home automation project, a burglar deterrent, or just for fun. At first sight this doesn't seem very difficult. You can go a long way using the parallel port, a few transistors and a relay.

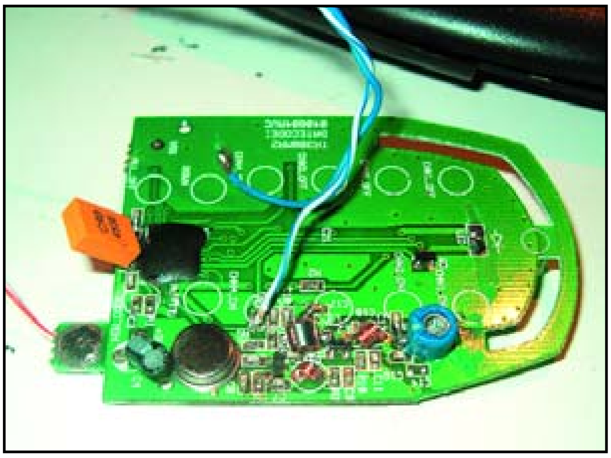
But it turns out that this solution does have a few disadvantages.

Easy

First of all, the PCB used for the controller has to be connected directly to the mains. This isn't an insurmountable problem of course, but it does introduce an element of danger. And secondly, you always need to run a cable between the PC and the device that needs to be controlled, which is difficult if they're not in the same room.

Since this circuit is only temporary (Fig. 1) it is built straight onto the DB9 plug without using a circuit board.

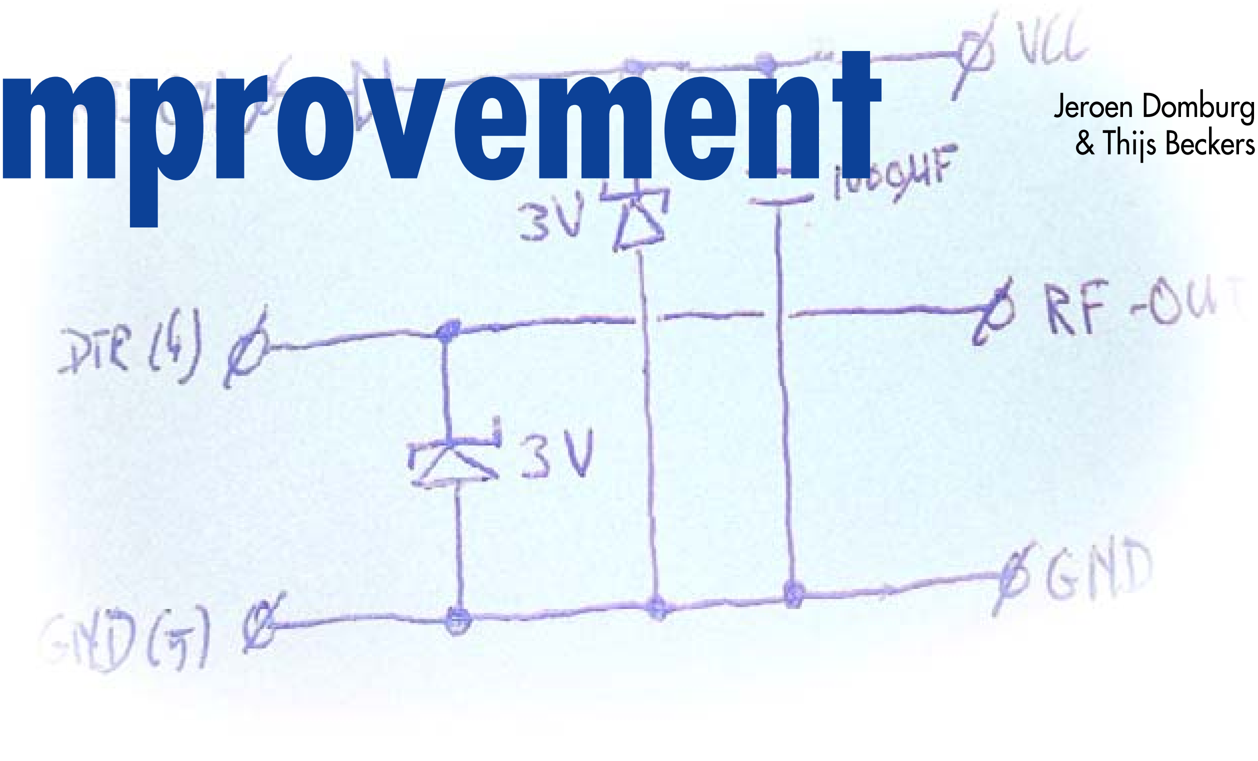
The transmitter. This is used to control the four outputs and the dimmer function. There is also a master switch that can turn all outputs on or off at the same time.

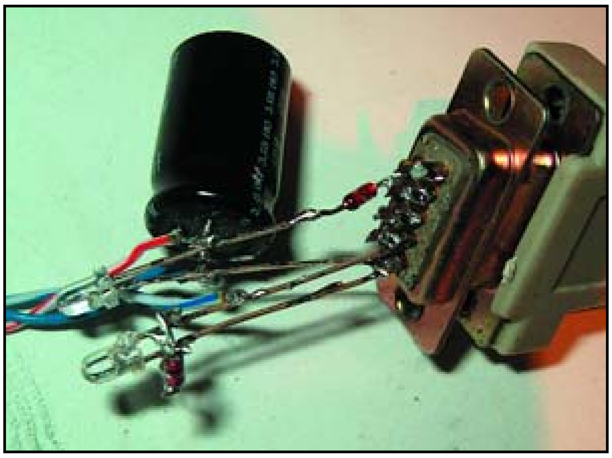


In this way we can tap into the signal from the control IC to the RF transmitter. The orange/white wire supplies power to the whole unit.

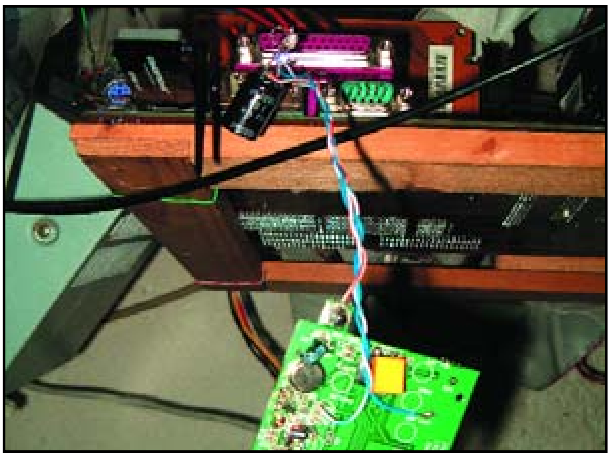
Improvement

Jeroen Domburg
& Thijs Beckers





Once Lirc has read all the buttons, the final circuit (Fig. 2) is also built directly onto the plug. The zeners have been replaced with UV LEDs that the author had lying around.



And this is how the complete circuit is connected to the author's server. If the circuit is placed on the floor it would make sense to house it in a box.

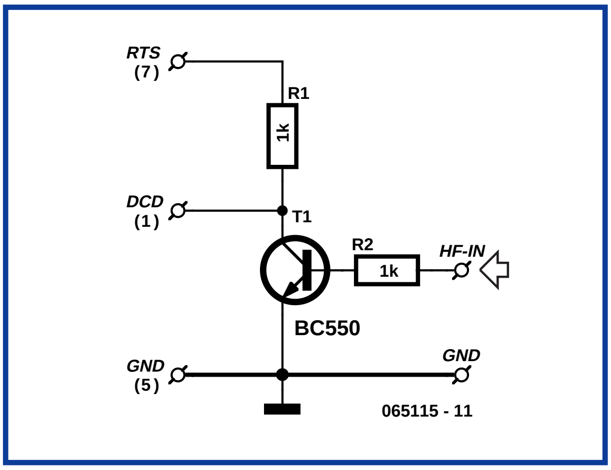


Figure 1. The circuit used by Lirc to learn the remote control signals. The BC550 can be replaced by virtually any low-power NPN transistor that you have lying about.

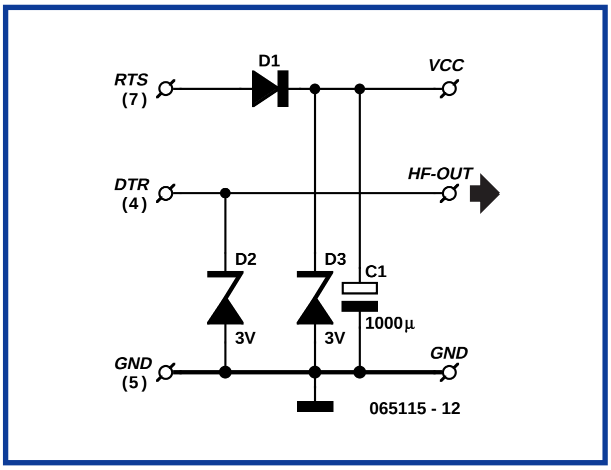


Figure 2. The final circuit with which the computer can control everything.

Both these problems can be solved at the same time if you use a wireless link between the PC and the relay. The disadvantage of this is that you need to be a lot more knowledgeable to design such a project: at the transmitting side the signal has to be encoded and converted into RF, and on the receiving side the opposite process has to take place. This quickly brings us into the realm of microcontrollers and not everybody knows how to use these, let alone have a few in their spares box.

But all is not lost: a few clever chaps have already solved these problems for us. From many DIY stores you can buy small devices that go between the mains socket and electrical appliances and which can turn the appliance on and off via radio waves. Some types even have a dimmer function built in. These devices usually work using radio waves in the 433 MHz band. There is no longer a need for a cable connection and a wall (or two) between the transmitter and receiver doesn't affect the operation.

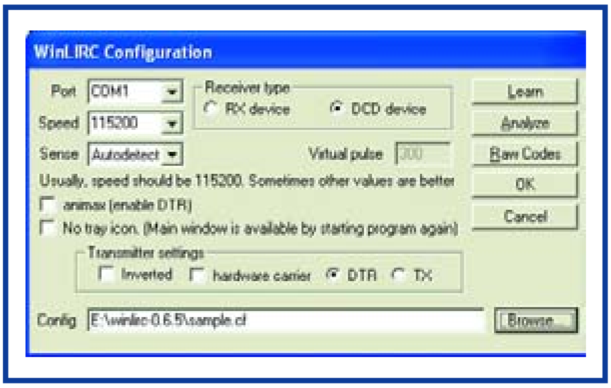


Figure 3. The program isn't really that big. The Linux version (600 KB) is twice as large as the Windows one.

Seen it before?

We have previously covered these devices in *Elektor Electronics*. The October 2005 issue had a circuit with which devices that 'listened' to these remote controls could be turned on and off automatically ('Remote Control Operator'). In this case, the remote control unit was controlled with the help of electronic switches that shorted the individual buttons.

This method can of course also be used when a PC is used for the control. It is possible to use the parallel port and a handful of transistors to simulate the pressing of buttons. This method has the disadvantage that it requires a fair number of components and can only control a maximum of four devices. On top of that, it probably won't work with every type of remote control. It only works when the buttons are scanned in a particular way.

Not the same then

Fortunately, there is a better way. From an electronic point of view such a remote control has just three sections: the buttons, an IC that scans these buttons (and passes a signal to the transmitter when a button is pressed) and the transmitter itself. These sections can be easily found when we open the remote control. The IC that takes care of the encoding is usually underneath a black epoxy blob, with tracks going out to the buttons. Sometimes it is an ordinary SMD IC or even a DIP version. There are many PCB tracks that go from this IC to the buttons, and a single track that goes to the RF transmitter. The RF transmitter is often easily recognisable: it is usually built using a large number of analogue components, whereas the rest of the board doesn't have much more than the single IC and some parts for interference suppression. The transmitter usually takes nothing more than the supply and the encoded signal from the IC. This signal line often has an LED connected to it, to indicate when the remote control is transmitting.

The encoded signal line is of particular interest to us in this case. As the signal from this line is sent over a 433 MHz connection, it won't have a very high frequency. It can also be assumed that a burst will appear on this line whenever a button on the remote control is pressed. If we could record this burst and reproduce it later, it becomes possible to control the wireless switches remotely.

Software

Fortunately there already is a (free) application that does exactly what we want. (For those of you who aren't clear on this: we need to store the pulse-trains and play them back later.) This program is called Lirc [1], which stands for Linux Infrared Remote Control. The program was originally written for Linux, but there also is a Windows version: WinLirc [2]. This program was really written to interface a computer with an infrared remote control and let it communicate with devices that react to these infrared signals, but it can also be used for our project. The program can, using extra hardware of course, receive, process and transmit infrared signals. The infrared signal is, just as our signal, a single line that goes high and low at certain times.

Construction

We first have to teach Lirc which signals have to be sent to control a specific mains socket. Depending on the model used, it's possible that somebody has done this already and that the configuration is available [3]. If that is the case, you can skip this step. If you can't find a ready-made configuration you will have to build the circuit shown in **Figure 1**. With this Lirc can learn what codes are sent by each button. You have to put Lirc in its learn-mode and follow the instructions. It won't be a problem if you need to control more devices than you have buttons for on the remote control. First program a set of buttons, then change the channel number of the remote control and program another set. You can repeat this until you have programmed enough buttons to control all units.

Once all buttons and their signals have been read in, we have to get Lirc to transmit them again. The cheapest method, and the most successful, is to use the transmitter built into the remote control. Build the circuit shown in **Figure 2**, break the track between the encoding IC and the RF transmitter and connect the output of our circuit to the track at the RF side (which is the input to the RF transmitter). The supply is also taken care of, so you can remove the batteries from the remote control. The zener diodes in the circuit have been chosen for use with a remote control that has a 3 V supply. Should the supply voltage for your remote control be different you have to change the values of the zener diodes to provide the correct voltage. And that is it: the computer is now ready to control the wireless mains switches.

And finally...

When you download Lirc you will also get information on how it should be used on the computer. Linux users can use the program 'irsend' that is included with Lirc; WinLirc users get a file called 'transmit.cpp' with their download. This gives a short example how Lirc can be used from Windows.

And just a final remark: instead of wrecking your remote control you could use a licence-exempt, type-approved 433 MHz transmitter module. This should be connected in the same way as the RF transmitter from the remote control. But first make sure that you've changed the values of the zeners so you have the correct supply voltage for the transmitter module.

(065115-1)

Web links

[1] www.lirc.org/

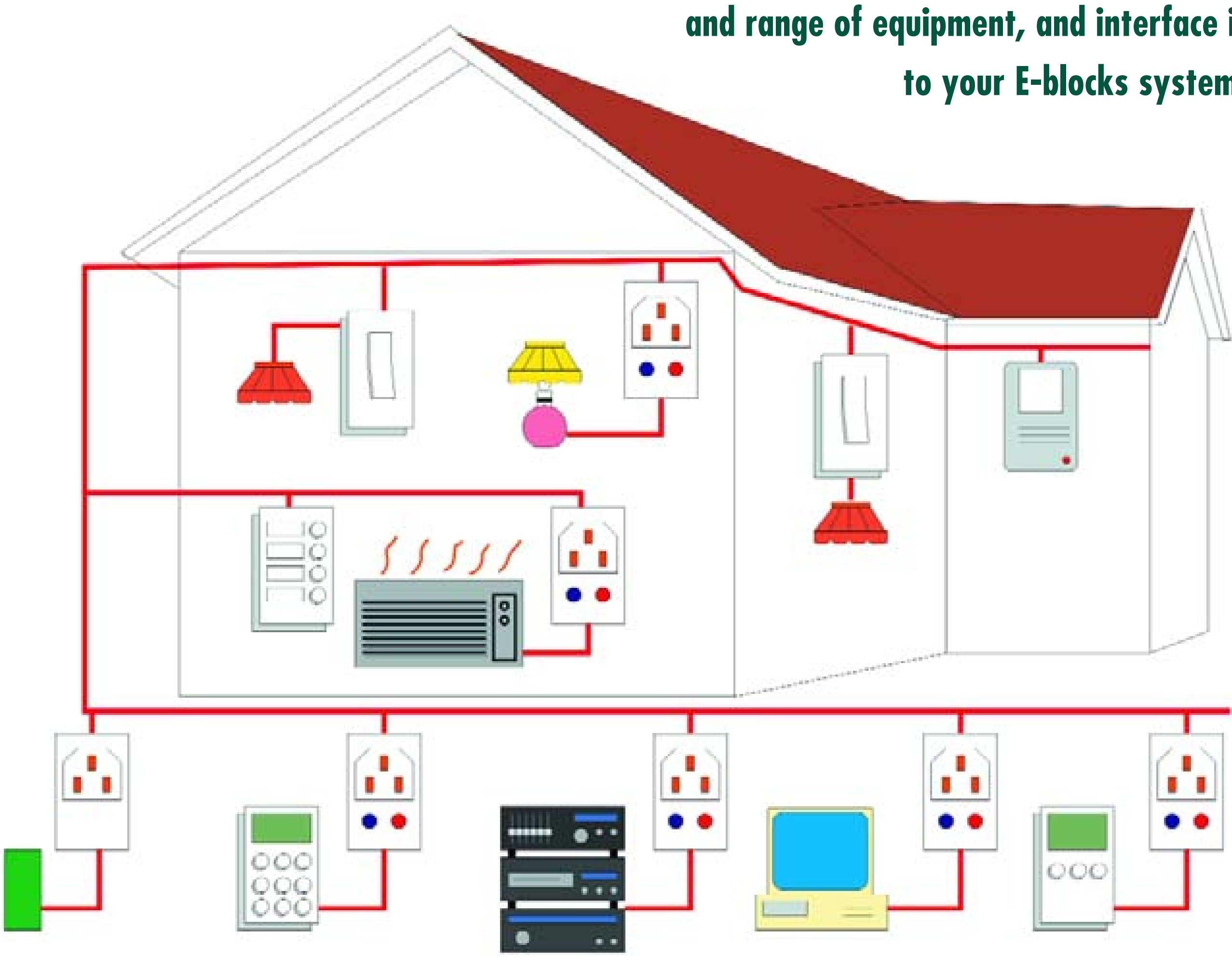
[2] winlirc.sourceforge.net/

[3] http://sprite.student.utwente.nl/~jeroen/projects/kaku-lirc/

E-blocks and

John Dobson

Home automation is a popular topic for many readers and in this article we describe how to take advantage of the popular X-10 Power Line Carrier standard, and range of equipment, and interface it to your E-blocks system.



X-10 is the brand name given to a range of equipment first manufactured in the 1970s by a small company in Scotland called Pico Technology. X-10 was designed to use the Power lines in a domestic house to convey signals that could control a wide range of domestic devices like lamps, heaters etc. Since then X-10 as a company has grown to include other communication mediums like the Internet and RF, but here we want to focus on the use of existing domestic power installations for communication — often referred to as Power Line Carrier control.

The diagram above shows you the basic top level concept: a wide range of electrical devices are controlled through the mains wiring using devices that are inserted between the actuating device (switch or controller) and the device under control (hi-fi, lamps, heaters, etc).

X-10 modules

The simplest way of introducing X-10 is to buy an off-the-shelf set of modules. You don't need to do any design

X-10 a modular approach to home automation

work here – you can simply buy controllers and actuators. For example in **Figure 1** you can see two X-10 appliances for the UK: an appliance module (on or off) and a lamp module (with dimming function). Similar devices are available for all Continental European countries with the appropriate mains plugs.
The range of devices here is large — you can buy X-10 thermometers, motor controllers, remote door chimers etc. you can also buy off the shelf a range of controllers from wall mounting light switches to multiple switch consoles, and units that are controlled from a PC. More importantly, the range of devices available is also cheap – a typical appliance socket for a lamp costs £ 18.

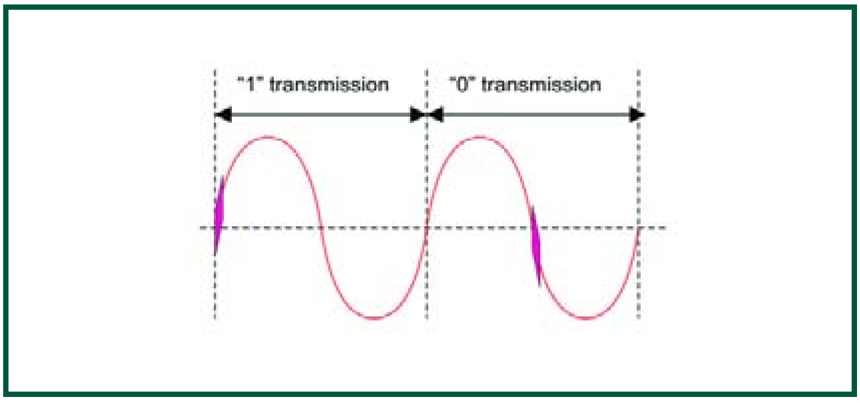
Figure 1. UK lamp and appliance modules.

The technical bit

So how does it work technically? The X-10 transceiver units modulate a low-level 120-kHz burst of carrier onto the household electrical wiring system just after the relatively quiet zero-crossing points of the 50-Hz (US: 60-Hz) waveform. The datastream is derived from the presence or absence of the 120-kHz waveform at the zero-crossing points. Here a binary '1' is represented by a 120-kHz burst at the zero-crossing point and a binary '0' is represented by the absence of a 120-kHz burst. **Figure 2** shows the representation of binary code 10010. Note that to make X-10 compatible with three-phase systems the 120-kHz burst should also be repeated at 120-degree intervals in the waveform corresponding to the post-zero crossing points of the other two cycles, but we will not consider that here.

Clearly there is potential for confusion here as the point at which you start sampling the message can determine the message itself. Because of this, all messages start with a synchronisation sequence of '1110' which is a pattern that is not repeated by any other parts of the data packet. This works out because all of the subsequent transmissions are sent in pairs in 'true complement' form where a whole cycle is used for each data bit. So for a data bit 1 you should send 10, and for a data bit 0 you should send 01.
Having defined how the data bits are sent we next need to look at the overall packet structure. Data bits are sent in two groups of 9 bits: in the first group of 9 bits, the first four are the house code (A to P) and the next five are the key number code. You can see this in **Figure 3a**. As the 9 bits of data are sent in compliment form the basic X-10 'frame' takes up 22 bits or 11 cycles of the mains waveform.
The second group of 9 bits again

Figure 2. Transmission of 10010.



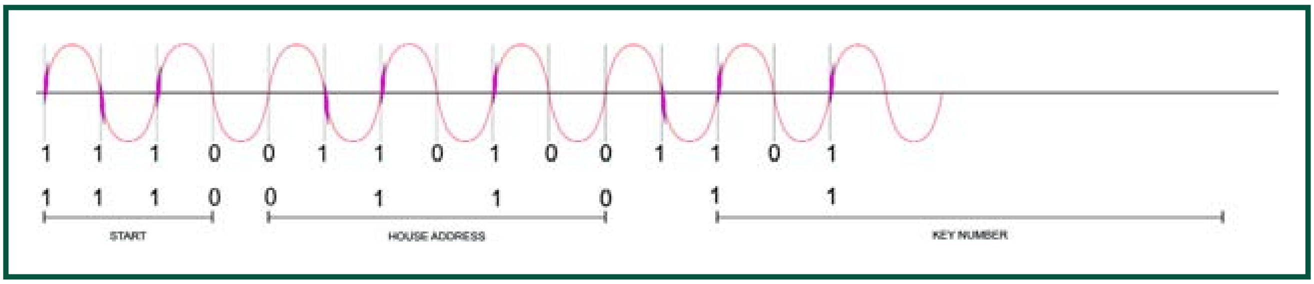


Figure 3a. X-10 data 'frame' showing the first 9 bits of data in a message.

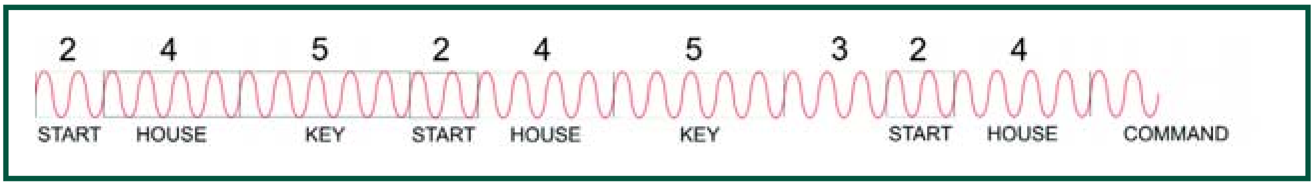


Figure 3b. A complete data packet of 47 cycles.

includes the house code, as well as a 5-bit command code which is used to instruct the target device. To make the system more immune to noise, each frame is sent twice, with a three cycle pause between each pair of frames. So that the whole packet — made up of four data frames — resembles that shown in **Figure 3b**.

Within the data packet, 5 bits are used as a Key Number or a Command. The Key Number is used to refer to the unit within the house (0 to 16). The Commands are used to give the unit an instruction. **Table 1** shows you how this works.

The house address can be set between A and P: this allows for the possibility of several houses using X-10 on the same phase of the power supply in your area. The key number is used for

Table 1. X-10 address/number/command overview.

House address					Key number						Command					
A	0	1	1	0	**1**	0	1	1	0	0	**All units Off**	0	0	0	0	1
B	1	1	1	0	**2**	1	1	1	0	0	**All Lights On**	0	0	0	1	1
C	0	0	1	0	**3**	0	0	1	0	0	**On**	0	0	1	0	1
D	1	0	1	0	**4**	1	0	1	0	0	**Off**	0	0	1	1	1
E	0	0	0	1	**5**	0	0	0	1	0	**Dim**	0	1	0	0	1
F	1	0	0	1	**6**	1	0	0	1	0	**Bright**	0	1	0	1	1
G	0	1	0	1	**7**	0	1	0	1	0	**All Lights Off**	0	1	1	0	1
H	1	1	0	1	**8**	1	1	0	1	0	**Extended code**	0	1	1	1	1
I	0	1	1	1	**9**	0	1	1	1	0	**Hail request**	1	0	0	0	1
J	1	1	1	1	**10**	1	1	1	1	0	**Hail Acknowledge**	1	0	0	1	1
K	0	0	1	1	**11**	0	0	1	1	0	**Preset Dim**	1	0	1	X	1
L	1	0	1	1	**12**	1	0	1	1	0	**Extended data (analogue)**	1	1	0	0	1
M	0	0	0	0	**13**	0	0	0	0	0	**Status = on**	1	1	0	1	1
N	1	0	0	0	**14**	1	0	0	0	0	**Status = off**	1	1	1	0	1
O	0	1	0	0	**15**	0	1	0	0	0	**Status request**	1	1	1	1	1
P	1	1	0	0	**16**	1	1	0	0	0						

addressing an individual unit on your mains network, (0 to 15) or for sending a command to a unit as in the table. Note that in Figure 1 you can see two dials for the actuator and lamp units: the red dial here is a 16-way rotary switch for the house address (A to P) and the blue dial is a 16 way rotary switch for the unit number (1 to 16).

Our solution

At this point we could start to look at the actual design of the X-10 transceivers, but there are safety implications here and the off the shelf units are not that expensive. Instead we will focus on how to get an X-10 communications system up and running as quickly as possible, and for this we will use a ready-made Power Line Controller interface — in the UK this is the XM10U shown in **Figure 4**. We are told that the European Continent equivalent is the XM10E and the US equivalent is called TW523.
The XM10U has a TTL serial interface which conveniently connects to the E-blocks X-10 board — shown in **Figure 5** — using a simple RJ11 phone style cable. The RJ11 socket is in the top of the unit in Figure 4. The cost of the XM10U is £ 25 from the **Simply Automate** website.
The E-blocks interface contains circuitry designed to protect your microcontroller from the spikes and surges of the XM10U. In **Figure 6** you can see the E-blocks setup we have used:

- a PICmicro 16F877A microcontroller;
- a sensor board on port A;
- an LCD board on port B;
- the X-10 unit on port C;
- a keypad on port D.

To get us started we are going to make a simple electronic light switch that reads the light value from the light sensor on the sensor board, and turns a remote light on when it gets dark.
To control the X-10 unit I happen to have obtained some C code for X-10 communication. It has three key routines:

```
X10_Initialize()
X10_SetAddress(char house_code,
      char unit_code)
X10_Send(char function_code)
```

The block of C code takes care of all of the tasks required by the lower layer of the X-10 communications protocol: this includes routines that wait for the mains zero-crossing point, sending individual start and stop codes, sending individual bits etc. However the three routines above will allow us full control of the X-10 protocol for sending commands. I don't have the code for receiving X-10 commands but we can deal with that later. The way we use X-10 is to initialize the unit for communication, set the house and unit address and then send a function code.

Figure 4. The XM10U Power Line Controller Interface from the Simply Automate website.

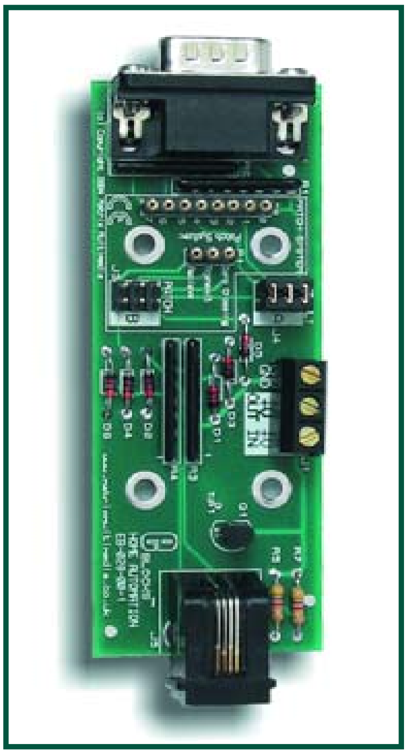
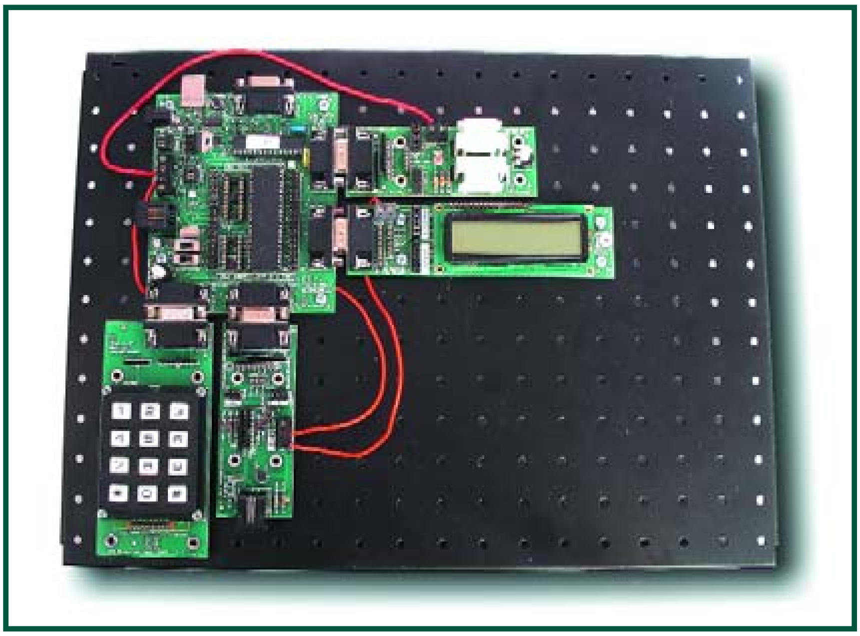


Figure 5. The E-blocks X-10 interface.

Turn on the lights

As an example of how to operate X-10 control we are going to make an electronic light switch using the small light

Figure 6. The E-blocks X-10 prototype system.



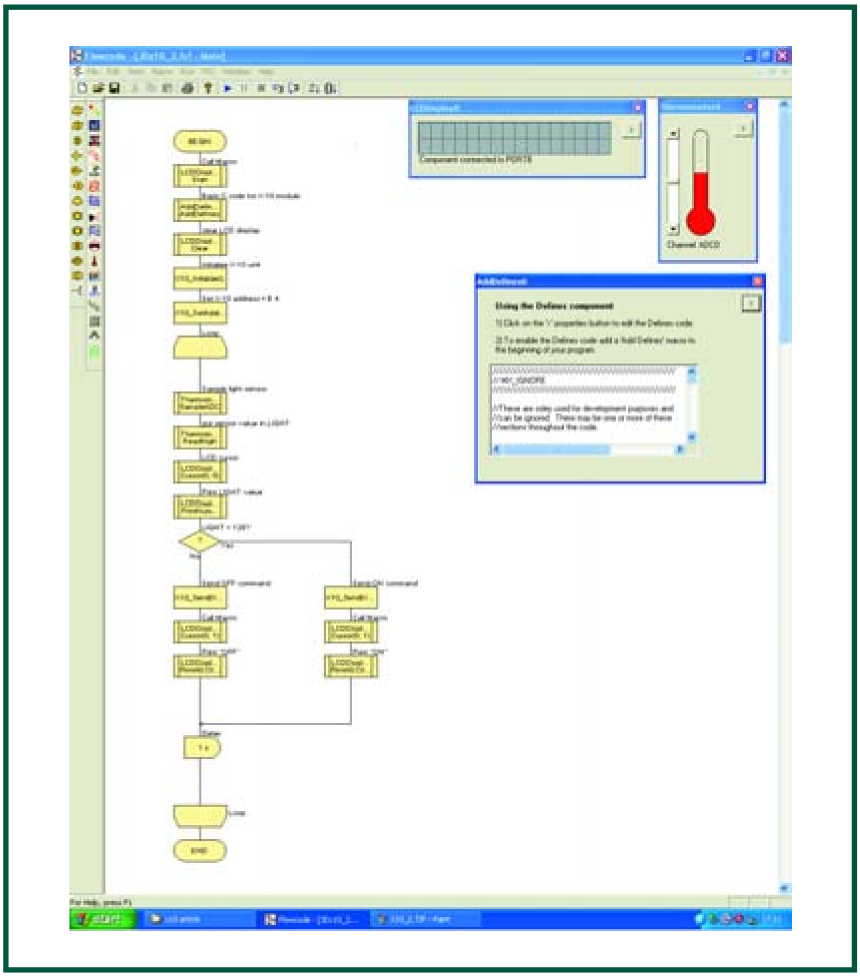


Figure 7. The entire X-10 electronic light switch program.

Earlier in this series

Electronic Building Blocks, November 2005.

E-blocks and Flowcode, December 2005.

E-blocks in Cyberspace, January 2006.

E-blocks – now you CAN, February 2006.

E-blocks Making Waves, March 2006.

E-blocks Making Waves at C, April 2006.

E-blocks for Prototyping Systems, May 2006.

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Resources

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sensor on the E-blocks sensor board. First, however, a little more about Flowcode and C.

As we saw in a previous article (May 2005) it is possible to embed C into the Flowchart using the C icon as Flowcode first makes C before compiling the C into object for the PICmicro. However, if you simply embed the C code into the flowchart then that C code is only available for running at that point in the flow chart. What we need to make our X-10 system work is a way of embedding a large block of C code which contains subroutines that can be called from many points in the flow chart. This will give us a library of flexible commands we can use. The way we do this is to use the Flowcode #DEFINES component.

#DEFINE is a C protocol for defining constants that can be referred to many times in a C program. This component also allows us to enter a block of C containing subroutines which is compiled at the top of the C code program. Implementing this is a two step process: first we add a #DEFINE component to the work space area and paste the C code we want to include into the component text window. Then we put a #DEFINES Macro into our flow chart so that the flow chart compiler includes the C code. The first icon in the flow chart in **Figure 7** does this for us. Here is an explanation of the whole flow chart.

The first icon is the #DEFINE macro described above. Next we have icons to clear the LCD display, initialise the X-10 unit, Set the X10 address to be B 4, then enter an endless loop. In the loop we sample the ADC channel 0 (which has the light sensor on), then take the most significant eight bits and put it into variable LIGHT, position the LCD display cursor, and print the value of the light sensor so we can see what the light reading is. Then we test for the light level: if more than a value of 128 is returned then the light level is low (note that the sensor is the bottom half of a potential divider chain and the impedance increases as light level falls, meaning that the voltage, and the value of the LIGHT variable, at the PIC ADC pin increases as light level falls). When the light level is low, an X10_ON message is sent to turn the light on, and print ‘ON’ on the LCD display. Conversely if we detect less than 128 then light level is high and we turn the light off. A one-second delay is included to make sure the X-10 message has time to send.

The entire program – including C code – is available for free downloading from the *Elektor Electronics* website. The name of the Flowcode program is **JDX10_2.fcf** and the file number is **065033-11.zip**. This starter program should be sufficient for those who want to make an X-10 controlled system at home. If there is sufficient demand then we will get a custom X-10 component designed for Flowcode – please give us your opinion on the Elektor Electronics Forum.

(065053-1)

Elektorscope (1976/1977)

This classic from Elektor's publishing history has survived in two ways, really. Firstly, the design history can still be told (well, globally) by a member of our current design staff and secondly, the actual prototypes could be found in our relics cabinet, having survived thirty years of storage and hauling around Europe.

One day in 1976, a slightly over-confident member of the Elektor design staff claimed that under his total supervision the team would be able to design a two-channel all-transistor oscilloscope from scratch in exactly one week. Although all other work was dropped and sub-tasks were assigned to various designers, at the end of the week just two things were in the clear: the power supply design and the strong suspicion that the rest of the circuit had been copied from a design found in a technical catalogue from a German supplier called RIM. After careful study of the two designs, one printed in the catalogue and the other carefully produced with pencil and paper, one of the younger designers discovered that the pencilled design had npn transistors for pnp types in the RIM schematic and the other way around, and that the supply voltages had been transposed. Further serious design flaws soon surfaced. The Editor/Publisher was informed and the project was given a complete redesign which took the usual period of a couple of months.
The final design was for a 2-channel transistor 'scope with a 3-dB bandwidth of 2 MHz. Part 1 of the article was published in the December 1976 issue of Elektor, discussing the power supplies (!), the blanking amplifier and the choice of CRT (cathode ray tube) that could be used in the project. Probably as a teaser, the front panel of the 'scope was already shown (subscriptions due for renewal in January…). The next two instalments, January and February 1977, were also pretty large which indicates the scale of the project although remarkably it was never mentioned on the magazine cover.
Looking closer at the design, the home constructor was able to select different types of CRT, albeit you had to use a tube without an acceleration voltage terminal. The choice of the CRT had important consequences as not only the high-voltage supply had to be adapted to suit, but also the oscilloscope enclosure and with it the ready-made front panel Elektor was selling at the time. Two front panels were available: one for 7-cm diameter CRTs and one for 13.5-cm types. The photograph shows finished instruments of either version, the smaller one had a DG7-210 CRT and the larger, a D13-620, both from Telefunken and compete with their mu-metal covers. By the way, the prototypes shown above have Perspex top covers allowing inquisitive enthusiasts to see the innards of the 'scope without the danger of touching anything.
Reportedly the Elektorscope boards, controls and electronics were carefully designed to fit in a commercially available case, and not the other way around as customary with many hobby projects. Unfortunately the case used was not specified. Also, a 'special transformer' was used in the power supply, with the optimistic announcement that it would become available from "various advertisers and kit suppliers in this magazine". Although I was unable to find adverts listing the transformer or the enclosure in subsequent editions, the March 1977 magazine had a follow-up article describing how the Elektorscope modules could be built into a rack-style Vero case. Due to size restrictions, this could only be done using the 7-cm CRT version. Although home construction of an oscilloscope was accepted practice in 1976, most instruments at the time (including my own) were valve-based and single-channel, not just because valves were easy to get, cheap and resilient but also because several excellent designs were available that could be assembled from parts salvaged from an old TV or radio. By contrast, the Elektorscope was innovative, semi-professional and lightweight — at the time!

(065046-1)

Retronics is a monthly column covering vintage electronics including legendary Elektor designs. Contributions, suggestions and requests are welcomed; please send an email to editor@elektor-electronics.co.uk, subject: Retronics EE.

Solder pistol as demagnetising tool

Luc Lemmens

Metal tools, in particular screwdrivers, may become magnetic. The powerful magnets in loudspeaker drive units fitted close to the tool storage rack may produce a few 'sticky' tool heads after some time. Not just screwdrivers, but all iron-based tools may be affected and even turn into permanent magnets.

True, the property may come in handy, for example, when fishing for small parts accidentally dropped in inaccessible locations in equipment. However, a magnetic screwdriver is also a nuisance in many cases, especially if you are working on delicate constructions and small bolts and nuts keep sticking to the screwdriver head.

The solution to the problem is to demagnetize the tool by inserting it into a strong, varying magnetic field. The magnetic property is removed when the magnetised tool is slowly passed through the field.

Demagnetisers with a specially designed coil to generate the required field are available commercially in several sizes. However, there's a fair chance you already have one in your workshop — the solder 'pistol'.

A solder pistol with its pair of steel 'wires' and a copper wire 'loop' doubles as a perfect demagnetising tool. The loop forms part of a transformer secondary winding and encloses a magnetic field when the pistol is switched on.

To use the solder pistol as an effective demagnetiser, the iron or steel tool to be treated has to be inserted into the copper wire loop. Pull the 'trigger' on the pistol and slowly withdraw the tool (or tool shaft) from the loop. Repeat the treatment if the tool is not sufficiently demagnetised.

If the loop on the solder pistol is too small for the tool, a larger loop may be made. Be sure to use copper wire with a cross-sectional area (c.s.a.) of at least 5 mm^2, as appreciable currents are involved.

(060064-1)

NOPs for faultfinding

Luc Lemmens

It's a reality that a newly built microprocessor board does not work spot-on, or a board gives up the ghost after many years of service. This usually marks the start of a cumbersome search for bad solder joints, broken or short-circuited PCB tracks, defective components or problems with failing software. Such faultfinding jobs can turn out to be very time consuming, particularly if the microcontroller has internal program memory and no external address- or data bus. Considerable extra 'fun' is thrown if the operation of the software is not known!

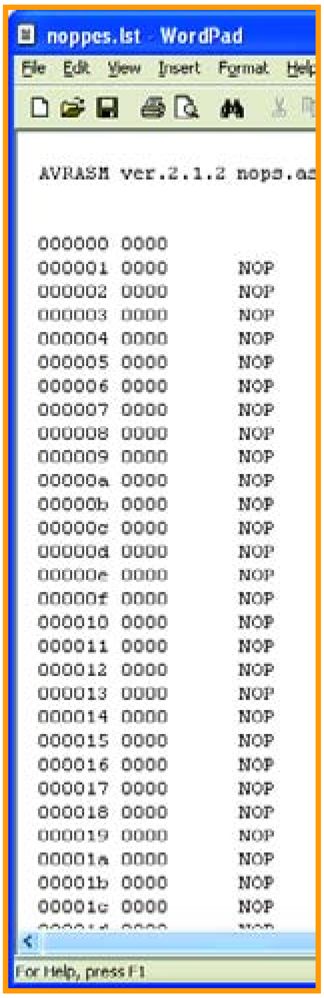
In many cases, however, it's the hardware that's playing up, instead of the software. If the microcontroller has an external data/address bus, at least the problems become manageable. Address bus faults are fairly easy to track down using an oscilloscope — you should only see 'neat' rectangular waves, as opposed to the data bus, where 'half levels' may appear, indicating the bus line is switched to tri-state (high impedance). In the picture, the lower trace shows an address line, the upper trace, a data line.

An address line 'doing nothing', often reveals a defective microcontroller, or does it indicate that the software does not employ a certain part of the address range? The same question is relevant to the selection lines of the 'chip enable' and 'output enable' variety, hardware-decoded out of the address bus and used for the communication with peripheral hardware devices. Often, we find combinatory logic devices (based on PALs, GALs and the like), which may not function correctly, while it is difficult to find out which output should be low to enable a certain address or address range.

Still, it is remarkably easy to debug address decoding devices by making the processor execute a program that actually covers the complete address range. In the vast majority of cases, that program is the simplest you can think of, because it should do… nothing! We simply fill the entire program memory with No Operation instructions (NOPs) which cause the micro to faithfully step through its entire address range. The lowest address line, A0, will then exhibit the fastest switching rate; A1 will be two times slower, A2 four times slower, and so on. Moreover, in most circuits the chip select lines and similar will go active, allowing you to check their operation using the oscilloscope. In this way, you can at least verify if the addressing on the board is functioning, that being an obvious requirement for a properly working microcontroller board

Please note that an external watchdog is used in some systems. A watchdog will reset the microcontroller if it is not triggered at regular intervals. The operation of the watchdog may frustrate the execution of the NOP program as the controller is reset before the full address range has been completed. In that case, break the connection between the watchdog and the reset input of the microcontroller and connect a standard Power On Reset network (refer to the microcontroller's datasheet). In some case, it may be easier to connect the watchdog's trigger input to a low address line like A0.

(060072-1)



Hexadoku

Puzzle with an electronic touch

This June 2006 issue marks the sixth Hexadoku puzzle. We're sure it will give you a few enjoyable hours to solve. So, no reason to get bored if the weather is not as it should be (dry & sunny). Send us your solution and win one of the fantastic prizes!

The instructions for the puzzle are straightforward. In the diagram composed of 16x16 boxes, enter numbers in such a way that **all** hexadecimal numbers 0 through F (that's 0-9 and A-F) occur once in every row, once in every column, and in every one of the 4x4 boxes (marked by the thicker black lines). A number of clues are given in the puzzle and these determine the start situation.

Your solution may win a prize and requires only the numbers in the grey boxes to be sent to us (see below). The puzzle is also available as a **free download** from our website (Magazine → 2006 → June).

(065042-1)

2		6		9	8		E		5	D			A		B
	F	3	B	7	D					9		6	8		
	A	D			3	4	1		0				C		E
0	5					C			F	3	8		D	4	
3	7					6			8	E	5	9		C	
			C				5	1	2			F			8
9	4					1	7	3	D		F		5		
1		B	5		4			6			9	7		2	
6		9	3	1	7		0	D		F		E			5
5	2	7	0	E		B		9		8					
B	8	1	A				C	2	7			4			
	D		E	A	5		3	C			6	8		9	
A	B	0		2			9					D	4		
4				5	B	A	6					C	0		
E	3	C						8			0		9	5	6
	6	5				3	D						E		F

Entering the competition

Please send the numbers in the grey boxes by email, fax or post to

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editor@elektor-electronics.co.uk
Subject: hexadoku 06-2006.

The closing date is **26 June 2006.**
Competition not open to employees of Segment b.v., its business partners and/or associated publishing houses.

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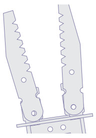
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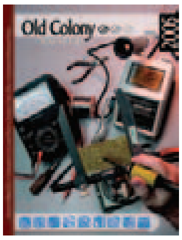

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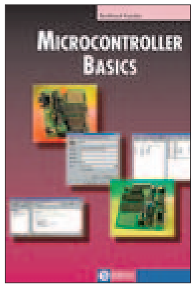

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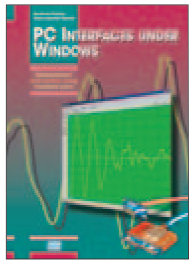

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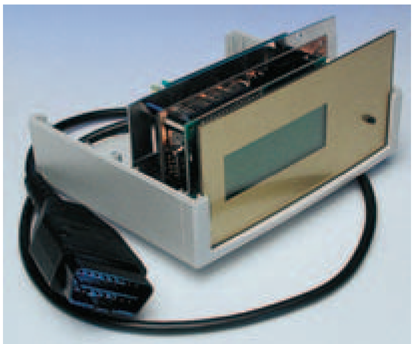

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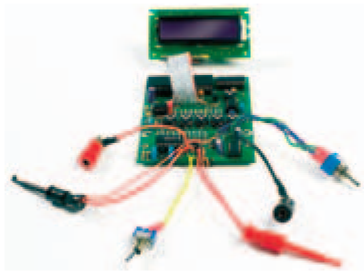

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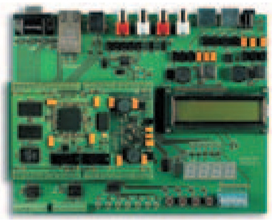

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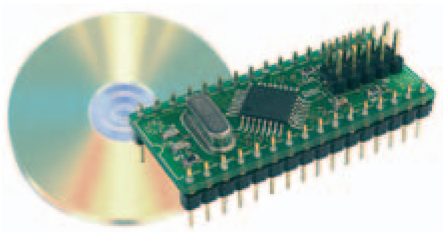

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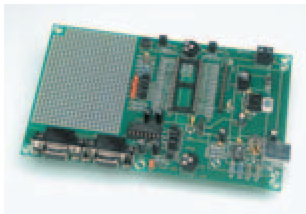

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February	Motors / Propulsion
March	Development / Microcontrollers
April	Power Supplies / Safety
May	Soldering / Etching
June	Test & Measurement
July/August	**Summer Circuits**
September	RFID / Medical Electronics
October	E-Simulation
November	Chipcards / Security
December	Electromechanical / Enclosures

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