CLOCKS & CLOCKING
OVERCLOCKING
TUNING

Profiler
build a versatile milling machine

EXTRA!
FREE CD-ROM
MPLAB IDE - MPLAB C30 - Proteus VSM

JANUARY 2007
£3.80
www.elektor-electronics.co.uk
**Magnetic Cartridge Pre-amp**

**KC-5433 £115.95 + post & packing**

This is used to amplify the 3-4mV signals from a phonograph cartridge to line level, so you can use your tape player with the CD or tuner inputs on your Hi-Fi amplifier. The design is suitable for 12” LPs, and also allows for RIAA equalisation of all the really old 78s. Please note that the input sensitivity of this design means it is only suitable for moving-magnet, non-moving-coil cartridges. Kit includes PCB with overlay and all electronic components. Requires 12VAC power.

**Theremin Synthesiser MKII**

**KC-5426 £43.50 + post & packing**

By moving your hand between the metal antennas, create unusual sound effects! The Theremin MKII improves on its predecessor by allowing adjustments to the tonal quality by providing a better waveform. With a multitude of controls, the instrument's musical potential is only limited by the skill and imagination of its player. Kit includes stand, PCB with overlay, machined case with silk-screen printed lid, loudspeakers, pitch antenna, all specified electronic components and clear English instructions. Requires 9-12VDC wall adapter (Maplin #UG018 £13.99).

**IR Remote Control Extender MKII**

**KC-5432 £72.50 + post & packing**

Operate your DVD player or digital decoder using its remote control from another room. It picks up the signal from the remote control and sends it via a 2-wire cable to an infra-red LED located close to the device. This improved model features fast data transfer, capable of transmitting Fozel digital remote control signals using the Pace 400 series decoders. Kit supplied with printed front panel, PCB with overlay and all electronic components. Requires 9VDC wall adapter (Maplin #G574W £10.99).

**Battery Zapper MKII**

**KC-5440 £91.00 + post & packing**

This kit attacks a common cause of failure in wet lead acid cell batteries: sulphation. The circuit produces short bursts of high level energy to remove the damaging sulphation effect. This new improved unit features a battery health checker with LED indicator, new circuit protection against badly sulfated batteries, test points for a DMM and connection for a battery charger. Kit includes case with screen printed lid, PCB with overlay, all electronic components and clear English instructions. Suitable for 6, 12 and 24V batteries. Powered by the battery itself.

**Galactic Voice Kit**

**KC-5431 £125.00 + post & packing**

Be the envy of everyone at the next Interplanetary Conference for Evil Beings with this galactic voice simulator kit. Effect and depth controls allow you to vary the effect to simulate everything from the metallically-challenged C-3PO, to the hysteral ranting of Davek Hail-Oct on exminating anything not nailed down. The kit includes PCB with overlay, enclosure, speaker, and all components. For those who really need to get out of the house a lot more. Take me to your leaders. Requires 9V battery.

**High Performance Electronic Projects for Cars Book**

BS-5080 £79.00 + post & packing

Australia's leading electronics magazine Silicon Chip, has developed a range of projects for performance cars. There are 16 projects in total, ranging from devices for remapping fuel curves, to nitrous controllers. The book includes all instructions, components lists, color pictures and circuit layouts. There are also chapters on engine management, advanced systems and DIY modifications. Over 150 pages! All the projects are available in kit form, exclusively to Jaycar. Check out our website for all the details.

**Hand Controller for Digital Adjusters**

**KC-5386 £25.95 + post & packing**

This hand controller is used for mapping/programming the independent electronic boost controller Kit (shown right). It features a two line LCD, and easy to use push buttons. It can be used to program the adjusters when removed, or left permanently connected to display the adjuster’s operation. It is designed as an interface and display, and is not required for general adjuster functions after they have been programmed. Kit supplied with silk-screened and machined case, PCB, LCD, and all electronic components.

**Independent Electronic Boost Controller**

**KC-5387 £22.75 + post & packing**

It can be used in cars fitted with factory electronic boost control using the factory control solenoid, or cars without electronic boost control using a solenoid from a wrecker etc. This is ideal for switching between say, a race/ street mode, or a performance/ wet weather mode. Boost curve selection is via a dashboard switch, and is all programmed using the handheld digital controller KC-5386 (shown left). Kit supplied with PCB, machined case, and all electronic components. Suitable for EFI and engine management systems only.
BitScope PC Oscilloscopes & Analyzers

DSO Test Instrument Software for BitScope Mixed Signal Oscilloscopes

BitScope DSO Software for Windows and Linux

BitScope DSO is fast and intuitive multi-channel test and measurement software for your PC or notebook. Whether it's a digital scope, spectrum analyzer, mixed signal scope, logic analyzer, waveform generator or data recorder, BitScope DSO supports them all.

Capture deep buffer one-shots or display waveforms live just like an analog scope. Comprehensive test instrument integration means you can view the same data in different ways simultaneously at the click of a button.

BitScope DSO may even be used stand-alone to share data with colleagues, students or customers. Waveforms may be exported as portable image files or live captures replayed on other PCs as if a BitScope was locally connected.

BitScope DSO supports all current BitScope models, auto-configures when it connects and can manage multiple BitScopes concurrently. No manual setup is normally required.

Data export is available for use with third party software tools and BitScope's networked data acquisition capabilities are fully supported.

www.bitscope.com
Teaming up

If you are not in the electronics industry or without a formal qualification in the field, it may be good to realize that electronics as a pastime would be non-existent without the wide diversity of manufacturers of equipment, tools, components and, recently, software to run on your PC, not forgetting a growing number of PCB-to-order service providers.

Although some readers have expressed a desire to see a version of Elektor Electronics without any advertising pages, short discussions on the phone or by email are usually sufficient to agree that their vision is unrealistic. For one thing, our advertisers make up for a good part of our income, the other main pillars being subscribers, newsstand sales and product sales. On the other hand, from a reader viewpoint, advertisers are the gateway to services and products (including components and tools) that are essential to enjoy electronics as a pastime, or pursue it at any level in education.

Sure, old hands with a fully loaded workshop may object to seeing basically the same advertisers for years on end. But then, when I was learning about electronics at a relatively young age, I believe I got as much information and fun out of browsing ads, comparing component prices and seeing the big names in industry, than from actually reading articles, trying to understand it all and building circuits in front of me.

I am happy to say that Elektor Electronics is attracting an increasing number of companies, big and small, advertiser or not, wishing to run projects with us. Without their input we would not have been able to publish hugely successful projects like the E-SIM DVD (October 2006; miscellaneous software suppliers), RFID’s (September 2006; Philips/ACG/Visi- roncard) and RBC Tom Thumb (February 2006; Renesas/Glynn) in the past year. With this January 2007 issue comes two massive contributions, one from advertisers Microchip and Labcenter in the form of a free CD-ROM coupled to a 16-bit microcontroller development kit, the other from Colinux offering a kit of parts to assemble a milling machine for use in the electronics or mechanical workshop. Both deals have taken us much effort to arrange exclusively for you — or should I say ‘for your pleasure’. More is in the pipeline.

Jan Bueting, Editor

30 ‘Profiler’ Milling Machine

If ever you dreamed of having your own milling machine in the workshop but found it just too expensive, we have the perfect solution for you.

Working in close collaboration with Colinux, we present Profiler, a construction kit that enables you to build a professional milling machine for a fraction of the cost of a ready-made model.

If ever there was a golden opportunity to move on to 16-bit microcomputing at a serious level, join Microchip, Labcenter and Elektor with their groundbreaking Explorer-16 project. As a kick off, you get a free CD-ROM this month, allowing you to install Microchip MPLAB IDE as a development platform, MPLAB C30 for C language compiling and Proteus VSM for some really powerful simulation right up to a complete PIC24F system.

20 Explorer-16 (1)
CONTENTS

know-how
28 The Quest for Accuracy

hands-on
14 'Profiler' Milling Machine
20 Explorer-16 (1)
42 Sputnik Time Machine
48 Berlin Clock Remake
54 Text at the Speed of Light
66 FPGA Course (8)
69 Design Tips
   Blinking Christmas decoration
   Test beeper for your stereo
70 Improving
   RFID Reader Sensitivity
72 Display Recycling

technology
34 Clocking, Texas Style
38 Turbo Tricks
58 Scoot me up, Scotty
60 Warp Speed on Demand

info & market
6 Colophon
8 Mailbox
10 News & New Products
81 Elektor SHOP
84 Sneak Preview

infotainment
76 Electromechanical
   switching technology
77 Hexadoku

FREE MICROCHIP/LABCENTER
CD-ROM on PAGE 21

The most advanced
atomic clocks are breath-
takingly accurate, many millions of times more so than
the best quartz-based clocks. How do they manage it?
Jens Nickel reports.

Fifty years after the launch the first
artificial satellite, it seems fitting
to build a clock in the shape of
the Sputnik-1 that combines a
nostalgic Nixie tube display with
a modern microcontroller and a
lightweight state of the high-vol-
age supply in a single design.

28 The Quest for Accuracy

42 Sputnik Time Machine
Easy-PC version 10 sets another milestone
Winning accolades the world over, Easy-PC for Windows V10 is another major milestone in the evolution of this extremely popular software tool. Try a demonstration copy of Easy-PC and prepare to be amazed at the power, versatility and remarkable value for money.

Fully integrated Schematics & PCB layout in a single application complete with forward and back annotation. Design and rules checks at all stages ensure integrity at all times. Professional manufacturing outputs allow you to finish the design process with ease.

Stop press... Stop press... Stop press... Stop press...
Easy-PC imports Eagle files as well as Tsien Boardmaker 2 files

call for a brochure, prices & CD on +44 (0)1684 773662
or e-mail sales@numberone.com
you can also download a demo from
www.numberone.com

Oak Lane, Bredon, Tewkesbury, Glos. GL20 7LR. United Kingdom

---

No Compromise Oscilloscope

Other oscilloscopes in this price range force you to compromise on one of the key specifications: sampling rate, memory depth or bandwidth.

The PicoScope 5000 series is a no compromise PC oscilloscope at a price every engineer can afford.

www.picotech.com 386
01480 396395

---

Pico
Technology

1GS/s sampling rate
250MHz bandwidth
128M sample buffer memory
125MS/s 12 bit AWG built in

PicoScope 5203
32M buffer £ 2199
PicoScope 5204
128M buffer £ 3299
Hexadoku November 2006 solution

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

Electronics for youngsters

Dear Jan — I have been subscribing to Elektor Electronics for a couple of years — and quite frankly I think you are missing a trick or two. Many of your projects are extremely clever and interesting, and in quite a few designs it anticipates the reader has acquired a PhD in Electronics or Communications Technology! The bulk of your projects are far too complex for the major-pupils will find inspiring and eagerly want to build, test and run. a) Each ‘junior’ project needs to be carefully packaged and include a comprehensive Parts List.
  b) Contain a list of Test Equipment.
  c) The availability of a PCB.
  d) If software is included in the project — the source coding lines need labelling in an ‘unambiguous’ manner.
Finally, a good starting point for a ‘junior’ project, are those constructed using the Parallax BASIC Stamp I and II chips. Quite complex circuits can be designed and built, and there is an element of programming involved.
From my experience of projects in past issues of your magazine! You and your contributors might understand the gobbledygook included in some of your software listing, but an eleven year old will struggle for a while, then give up and put the magazine in the shredder and the partially tested PCB in the bin! (I imagine quite a few adult Elektor readers have gone down this route!)
David Jack (UK)

Many thanks for your email, feedback of the level you supply is few and far between and therefore much appreciated. I agree that many of our projects are ambitious, certainly compared to those I get to see in other magazines. Having said that, I should attempt to adjust your view somewhat by pointing out the following articles that appeared in recent issues, which I believe should not deter 11-15 year-olds:
1. At least 10 to 20 items in each Summer Circuits edition published these past 31 years.
2. The Modding & Tweaking pages authored by student Jeroen Domburg.
3. Selected items from the ‘Design Tips’ pages in a number of recent issues.
4. Non-constructational articles like the ones on Cubesats, RFID, Electromag etc., which, although unlikely to be fully understood, do present a mind challenge to 11-15 year olds, as well as topical information on the role of electronics in today’s society.
5. Lots of free downloads with published articles; even if the associated project is not actually built (or even understood), source code listings etc. are great as educational material.

6. A number of ‘lesser’ programs on our free e-SIM DVD.
7. All projects in our free 24-page e-TRIX supplement supplied with the December 2006 issue. In fact a number of these circuits were supplied to us by your students!

Sadly, our ‘Mini Circuits’ articles were discontinued due to lack of interest and feedback particularly from the age group you mention, as well as their teachers. Also, from a commercial point of view, sales of PCBs specially designed for these projects were negligible. We will, however, consider publishing Mini Circuits again.

We are grateful for encouraging us to look after the coming generation in respect of publications on electronics and hope to serve them better in the future. On another positive note I should mention that an “Elektor Beginners Kit” is being developed and hopefully goes on sale later this year.

FTP for free downloads
What about having an FTP for the free software where we can download it easily? A well arranged FTP with every year issues in a separate folder will be a great help to grab the free software of the whole issue by simply drag and drop using any FTP client and it will reduce the bandwidth used to browse each article and download each attached free software separately.

Also, you can encode a link for the PCB (if exists) to direct immediately to the purchase page with the compressed files. It will save you lots of bandwidth and save us a lot of time browsing articles and downloading & arranging files. All the best!

MAZ
(reproduced from Forum)

From a publisher’s point of view, it is not desirable to revert to the system on the previous version of the website where clients could just grab a lot of free software
or PCB layout files from a single page, often without making the small effort to find out what the associated article was about. Unfortunately this system caused a lot of unnecessary queries sent to our customer services, design and editorial staff.

The current system is a little more complicated but superior in that customers at least have an idea what the magazine articles are about (through the short intro supplied) hence do not start downloading free software they will never require. Secondly, the system currently in use is a result of database-driven publishing which will be strengthened in the future to enable us to run the entire Elektor operation in ten languages with the resources and staff we have available. Everyone is welcome to download our free software and do whatever they like with it (but subject to copyrights) — all it takes is a little effort in navigating and reading "what's on the tin" as our mothers taught us.

---

**Vintage Elektor audio projects**

Dear Jan — I have pleasure in sending you some photographs of Elektor projects I built over the years. The first shows your Portable Mixer from 1986 (I think). I actually built three of these! The circuit boards and the chassis are 100% do it yourself products and all three units still work fine after all these years. I got a lot of fun from building and using them!

The second photo shows the 100-watt audio power amp from your April 1982 issue complemented with the DC and switch-on delay from January 1983. I built ten of these amplifiers and none of them ever failed in (rough) use. Unlike some of my friends, I should add, who on occasions asked me to replace BDX66 or BDX67 power transistors as a result of short-circuiting the output or connecting loudspeakers with an impedance well below 4 ohms. As with the mixer project, the PCBs and chassis are 'home-made'.

**Roger Demarsin (Belgium)**

Congratulations on your projects, Roger. It goes to show how our designs stand the test of time if built properly.

---

**Separated grounds**

Dear Editor — in the article "ECG using a Soundcard" [October 2006, Ed.] I noticed in the circuit diagram that the input and output have the same ground sign, while in actual fact electrical isolation exists between them. The design of the associated circuit board confirms that separate grounds are used. I was wondering how this should be indicated in a circuit diagram?

Or is the matter I'm trying to raise largely academic?

**W. Wade (UK)**

It is not — in fact, it is essential for electrical safety concerns and we are grateful to you for writing in on the subject. The two electrically isolated sub-circuits are shown with two different ground symbols, a small horizontal bar and a triangle. Unfortunately, the indicators for 'input' and 'output' give rise to confusion because they all include the same ground symbol (a small bar). In circuits drawn to our standards, the ground bar is included almost automatically with circuit inputs and outputs (open and solid arrow respectively), and that is where we went wrong in this specific case as the diagram now suggests that the input ground is the same as the output ground. With the output ground we should have printed a solid triangle (as used in the rest of the output circuitry) — this would have precluded any misconception.

---

**DiSEqC Monitor**

September 2006, ref: 040398-1

The value of C5 was originally 2.2nF according to the Euelsat specs and worked okay with Nokia sets. Later it was discovered that 220 pF was required for Dreambox sets — as it turned out, this value also worked with the Nokia 9500 set. Some experimentation with the capacitor value may be required for other brands.
Pico USB scopes get a speed boost

Pico Technology have opened up a new class of applications for their PicoScope 3000 Series USB instruments by hugely increasing their data transfer speed.

The new, fast streaming mode can transfer over six million samples per second, bypassing the oscilloscope hardware's memory buffer and transferring data direct to the PC. This allows programs to capture waveforms at high sampling rates over long periods of time, resulting in very large data sets limited only by the size of the PC's physical memory. Previously, the only way to sample at high speed was to use 'block mode', which resulted in lost data due to the dead time between blocks. The new streaming mode uses high efficiency USB 2.0 data transfers to capture data continuously without dead time.

Now it's possible to capture high resolution data in situations such as vehicle road tests and lengthy laboratory experiments. For example, when used with a PC with 1 GB of available physical RAM, a PicoScope oscilloscope can capture over 8 minutes of data sampled at 1 million samples per second. Using functions built in to the driver, the developer can easily display this data as a single waveform representing the entire 8 minutes, or zoom in one million times to show half a millisecond of data in great detail.

Pico has released the new driver with a fully documented API and an example C++ program aimed at experienced programmers, so that developers can start to use it immediately. Like most Pico software, it is free of charge, and is available to download from the web without registration. The PicoScope 3000 Series software can be downloaded from the Pico Technology website.

Pico Technology, 1480 396 395. www.pico.com

Surface-mount resistor with 20 watts power rating

Providing design engineers with a thermally efficient high current resistor in a surface mount package, TT electronics BI Technologies SMT Division has developed a non-inductive power resistor rated up to 20 W. Designated the SMHP Series, the resistor is housed in a small, thin TO-263 package suitable for high density PCB installation.

The TO-263 style package is claimed to offer extremely low thermal resistance. The surface mount power resistors are particularly suitable for high precision CRT colour video amplifiers, pulse generator load resistors, in-rush current protection, and bleeder resistors. The SMHP Series device is an extension of the company's MHP Series through-hole resistors. The MHP Series non-inductive high power resistors are available in five power ratings (20W to 140W) and three TO-style package types, including TO-126, TO-220 and TO-247. The SMHP Series resistors are rated for 20W power dissipation, with resistance ranges from 0.01 Ω to 220 Ω with values to ±1% available. TCAs range from 50ppm/°C to 250ppm/°C, with tolerances of ±5% and ±1%. Maximum operating voltage is 500 V and dielectric withstanding voltage is 2000 VDC. Thermal resistance is 3.3°C/W from the resistor's 'hot spot' to the package's metal flange and operating temperature range is -55°C to +155°C.

TT electronics BI Technologies, Eastfield Industrial Park, Glenrothes, Fife, Scotland KY7 4XN. Tel. (+44) 1 592-662200 e-mail sales@tttechnologies.co.uk, www.tttechnologies.com/power/index.htm.

Watch "ur" PCB®

PCB POOL® with over 18000 customers is said to be Europe's largest supplier of prototype printed circuit boards (PCBs). The PCB POOL® concept convinces two hundred new customers a month to use this service, not only due to the low cost 'cost sharing' principle, but also with first class customer service. For the past few years the possibility to track your order online has been amongst these services. Now, the innovative electronic company has spent the last 18 months developing a way to seriously increase the scope of that information. Watch "ur" PCB® is the result — with its help the customer doesn't just find out that an order has been processed, they can now actually watch the progress of their printed circuit board through each manufacturing stage. Customers can now log into their personal account and view high-resolution photographic images of their current order.

Whether the production phase is drilling, exposure, tin stripping, UV curing or hot air levelling (surface finish) — the customer can view the printed circuit board as a large picture. Watch "ur" PCB® is an easy and convenient way of monitoring the progress of your order. The images available are exact representations of what the customer will receive. If there is a layout problem or a data issue, then the customer can discover this long before he/she has the board delivered. The customer can respond much quicker and send PCB POOL® new files for an immediate restart of production. The customer can plan in advance to remedy any errors and prepare for re-design, thereby saving valuable time and money.

If the board is perfect, customers will know this long before the delivery, and can begin preparation for component assembly. Simply brilliant!

Using the Watch "ur" PCB production monitoring service, the customer can have the pictures of his boards sent to him/her as a Zip file. On request he/she can even be informed by E-mail whenever there is a new picture available to view. This means PCB POOL customers will miss nothing, and can archive all printed circuit board images for future reference.

Beta Layout Ltd (PCB-POOL), Freephone UK 0800 3898560, www.pcb-pool.com

INFO & MARKET NEWS & NEW PRODUCTS
Become a video game developer with the Propeller powered Hydra

If you have ever thought about becoming a video game developer, now is your chance. Parallax, Inc. a privately held company located in Rocklin, CA has partnered with Nureve Networks LLC and Andre LaMothe, best-selling game development author, to release a new Propeller powered gaming product, the HYDRA Game Console! With the HYDRA you can develop games, graphics and media applications.

For beginner to intermediate coders, you need only basic programming experience in any BASIC or C-like language. All of the hardware and software you need is included. Additionally, the HYDRA hardware is covered in detail with schematics, descriptions, dozens of games, demos, and tips allowing you to take full advantage of its resources, including its expansion port and 128K game card.

But it gets even better! The HYDRA kit also comes with Game Programming for the Propeller Powered HYDRA, Andre LaMothe's latest book. This comprehensive book covers everything you need to know about game programming for the Propeller in Spin and assembly language. All aspects of the Propeller chip are introduced, from its architecture to using the Propeller Tool for programming.

The Propeller chip was released by Parallax, Inc. in April of this year. The chip, designed at the transistor level, uses a new custom-silicon design for simultaneous multi-processing. The Propeller is a 32-bit architecture consisting of eight processors which run at 3.3V up to 80 MHz. The Propeller is programmed in both a high-level language, called Spin™, and low-level (assembly) language.

The HYDRA Game Console is available at www.parallax.com or by calling the Parallax Sales Department at (+1) 888-512-1024.

See twelve cylinders of secondary ignition on your oscilloscope

Pico Technology has released the new Mixmaster secondary ignition signal mixer for automotive diagnostics. The Mixmaster can produce a parade display of up to twelve cylinders using a single channel of an automotive oscilloscope.

In the world of automotive oscilloscopes, more cylinders usually means more money. Mixmaster saves you money by letting you use just one channel of your automotive oscilloscope to show an ignition parade of up to twelve cylinders. If you have a two-channel scope, then Mixmaster can also display two engine banks separately with up to six cylinders per bank. Mixmaster is battery-powered and conveniently portable, with a shockproof rubber case suitable for heavy-duty workshop use. It is supplied with a set of four secondary ignition leads, three BNC leads to connect to the oscilloscope, an engine-block ground lead, and an illustrated manual in English, French, Italian, German and Spanish. Additional features include a trigger output to synchronise the scope to a known cylinder, and an 'invert' switch to deal with negative-going wasted-spark signals.

Alan Tong, Technical Director of Pico Technology, explained, "Mixmaster will enable engineers and technicians to test V8 and even V12 engines using a standard two-channel or four-channel automotive oscilloscope. Owners of our Automotive Oscilloscope Kits will be able to work on a wider range of engines without having to buy an expensive multi-channel scope."

Mixmaster is available now, priced at £197. Extra packs of four secondary ignition leads are also available at £60.

Pico Technology
(+44) 01480 396 395
www.pictoch.com

PCBs in 24 hours from £30.00

Tel: 01635 40347
Newbury Electronics Ltd
Pencarly Road, Newbury, Berkshire RG14 5GD
www.newburyelectronics.co.uk
Split-core transducers for AC current measurement

LEM has introduced the AT series of AC current transducers, reducing the price point for products made to LEM's demanding quality standards. An innovative core material enables split-core current transformer technology to reach new levels of performance for this category of products.

The AT transducers combine an accurate current transformer and signal conditioning electronics in a very light and compact case to offer substantial savings in size. They measure only 44.5 x 67 x 36.5 mm with a 16-mm diameter sensing aperture for non-contact measurement and are, therefore, particularly suitable for installation in tight environments. Being split-core and either self-powered or loop-powered they are easy to install and put into operation, which means they can be retrofitted into existing installations without shutting down operation. This ease of mounting, coupled with the transducers' high reliability, will reduce installation and maintenance costs.

The transducers have been designed to measure 50/60Hz AC signals with RMS (average) computation. They provide an absolute accuracy better than 1.5 percent of the nominal current over a broad range of inputs. A choice of primary current measurement ranges from 5 A to 50 A are available, with a selection of industry standard output types (4-20 mA, 0.5 VDC or 0-10 VDC).

The AT integrated transducers will simplify the development of accurate, reliable and cost-effective solutions for real-time process automation, supervision and regulation. Principal applications will be in the field of industrial process control and condition monitoring of equipment such as HVAC, conveyors and pumps.

www.lem.com

ICs simplify HID ballast circuits and extend lamp life

International Rectifier introduced the IRS2453D family of integrated 600-V self-oscillating full-bridge driver ICs for HID ballast applications including general lighting, outdoor street lighting and projectors.

The new ICs utilize IR's proprietary high-voltage integrated circuit (HVIC) technology, integrating two high-side and two low-side gate drivers. This process allows improvements in device capabilities, tighter specifications, temperature stability and the integration of previously unavailable features.

The IRS2453D features a simple RC network to program the oscillator, eliminating the need to synchronize two half-bridge drivers. In contrast, solutions using two SO-8 driver ICs require a separate oscillator to drive each half-bridge, resulting in unsymmetrical voltages across the load due to mismatches of the on-time states caused by tolerances and temperature. In lighting applications, this can cause mercury migration shortening lamp life. The IRS2453D overcomes this problem by driving both half-bridge drivers with a single oscillator to guarantee accurate matching over the complete temperature and supply voltage range.

Greatly simplifying overall design, the IRS2453D integrates both a latched and non-latched shutdown input, and eliminates up to seven components. The latched shutdown allows for implementation of various protection features such as cycle-by-cycle overcurrent, open-load or short-circuit detection without additional components, while the non-latched shutdown allows for easy interface to a microcontroller for use in a wider variety of power management applications.

Available in 14-lead DIP and SO packages, the lead-free devices provide 50% duty cycle, fixed one-micro-second (typical) internal deadline and integrated bootstrap circuitry. While the new ICs are designed to drive the required low-frequency AC voltage in HID lamps, they can also be used as a general-purpose block for other high-frequency applications such as fluorescent ballasts and power supplies.

Other key specifications for the IRS2453D include 15.6 V Zener diode clamp on VCC and typical micropower startup current of 140 uA. Noise immunity is achieved by low di/dt peak of the gate drivers and with an undervoltage lockout hysteresis of greater than 1.5 V.

www.irf.com
C Compiler Applications for PIC & AVR Microcontrollers

- Complete ANSI C Compiler Development Environments for PIC and AVR
- Rapid Application Designer (RAD) front end - the fastest way to fully working code
- Drag & Drop interface into library routines and hardware drivers
- Link C functions into hardware events
- Hugely featured Simulator including Logic Analyser and big range of external devices

Our development systems are standalone and include RAD front end, compiler, assembler and simulator. All systems include elements/library functions for Timers, Ports, A/D, SPI, I2C, USART, Watchdog, Delays, USB, PWM, Capture, Compare, Oscillator functions, Voltage Ref, LCD modules, 7 Segment Displays, Graphic LCD, ANSI libraries and many more.

FED Support the complete development Lifecycle
- Learn - Free manuals including C tutorials for the PIC/AVR
- Design - RAD front end to WIZ-C
- Develop - Complete integrated development environment (IDE)
- Simulate - Fast simulator with huge range of device types
- Prototype - We supply a variety of prototyping boards
- Program - Forest have Serial, USB and In Circuit Programmers
- Debug - In Circuit Debugging operates with all our IDE's

Forest Electronics
www.fored.co.uk
sales@fored.co.uk
01590 - 681511

EzPCB, Easy Way To PCB
Features:
UL Proved High Quality
ISO 9000 Certified
Accept Orders From 3pcs to 1M Pcs.

Capabilities:
Up to 40 Layers
2.5mil Track/Space
0.1mm Hole Size
Blind And Buried Vias
RoHs, WEEE Compliant

Prices:
Only $50 For 5pcs 4" x 4" 2L
Only $188 For 3pcs 4" x 4" 4L
Only $288 For 3pcs 4" x 4" 6L
Free Solder Mask & Silkscreen
Very, Competitive Price For Bulk Orders

Http://www.ezpcb.com
sales@ezpcb.com
Profiler
Construction kit for a general-purpose milling machine

Harry Baggen

Have you always dreamed of having your own milling machine but found them just too expensive? If so, we have the perfect solution for you. Working in close collaboration with the Belgian manufacturer Colinbus, we have put together a construction kit for our readers that enables you to build a professional milling machine for a fraction of the cost of a ready-made model. This machine is suitable for a wide variety of jobs, ranging from making parts for models to milling circuit boards.

As an electronic hobbyist or professional, you have to work with more than just pure electronics, and you often have to deal with a lot of mechanical tasks. This includes jobs such as making printed circuit boards, routing wiring, and fashioning a suitable enclosure with a corresponding front panel. Some of these jobs require suitable tools if you want to achieve good results — at least if you want to do it all yourself.

Many hobbyists, as well as designers of prototypes and small development labs, would certainly be able to make good use of a small milling machine for this sort of work. Investing in such a machine may be affordable for commercial use, but the situation is a bit different for home use. A good, accurate milling machine can easily cost several thousand euros, and even then you only have a basic model without all the bells and whistles (such as vacuum swarf removal and a high-speed spindle motor).

We launched this project especially for all electronics hobbyists and professionals who regularly pursue their job and/or hobby at home. The idea for this construction project arose spontaneously during a conversation with Frank Jacobs of the Belgian company Colinbus, which specialises in milling machines. When you talk with someone who not only sells milling machines but also designs them from the ground up, the conversation quickly turns to the fact that most electronics types have splendid ideas about all the nice things they could do with such a machine, but the price is an obstacle in most cases. Frank Jacobs understood this immediately (he has been an avid reader of Elektor Electronics for many years), and he suggested offering a construction kit at a special price for a limited time, exclusively for readers of Elektor Electronics.
'Profiler' technical specifications

Dimensions 453 (w) x 583 (d) x 468 (h) mm
Max. working area 300 (X) x 400 (Y) x 100 (Z) mm
Interface Serial
Power 240 V, 50-60 Hz
X/Y/Z linear transport MultiStab guideways
X/Y/Z drive Stepper motors
Positioning speed 60 mm/s
Mechanical resolution 0.0075 mm
Software resolution 0.025 mm
Software Colinux User Interface
Conversion program for Gerber and Excellon files

Naturally, we must admit that the kit is not exactly inexpensive at £ 1099 or € 1599 plus shipping costs, but this still represents a savings of nearly £ 1400 relative to a comparable ready-assembled model. That's an attractive reward for a day or so of assembly work.

Of course, several small milling machines are also commercially available at a lower cost, but they are all quite small and have limited features. If you look at the photos in this article, you can see that we're talking about a completely different category here. Robust construction, high accuracy, and a generous working area of 30 x 40 cm — now that's something you can sink your teeth into! This machine is suitable for all sorts of jobs, such as dispensing, potting, camera inspection, boring holes in boxes, milling front panels, and even 3D modelling (using separate software). You can also mill circuit boards with this machine, although the manufacturer explicitly wishes to state that this model is not designed primarily for this purpose, since it requires even higher accuracy. However, based on our experience it yields excellent results for average PCBs, and the necessary software is included.

Assembly of the machine is quite straightforward, and the clearly written instructions practically exclude any problems. The accompanying circuit boards with the drive electronics are fully assembled and tested, so all you have to do is install and connect them.

Design

The 'Elektor Profiler', as we have christened the machine, is the smallest milling machine produced by Colinux. Its construction is largely the same as the commercial CBR-40 model (see www.colinux.com).

The machine is made from steel and aluminium parts. This combination of materials provides sufficient weight and stability to withstand the motion of the machine, while the accuracy of the guideways and the speed of travel are very high thanks to the use of aluminium extrusions.

The MultiStab system, which uses three rollers per edge travelling along precision steel rods pressed into aluminium extrusions, provides good mechanical guidance with minimum play. This design is used for all three axes. One roller of each set of three for each guideway assembly can be manually positioned to adjust the amount of play as necessary. Each of the three axes is driven by a spindle with a special zero-backlash nut.

The milling machine is controlled by a built-in processor board fitted with a Renesas H8/3003 and a driver board fitted with three ST L6208 ICs, which look after driving the three stepper motors. This approach makes the timing independent of the connected PC. The computer simply sends commands and coordinates to the processor board, which processes and executes the commands independently.

The processing power of the built-in microcontroller is not sufficient to drive all three stepper motors at the
same time (this trick is reserved for the larger and more expensive Colibus models), so it can only drive two at the same time. The machine can thus execute smooth motions in a two-dimensional plane. For 3D motions, it switches rapidly back and forth between two axes, which makes it appear that all three motors move simultaneously. This has little noticeable effect in practice, since the steps resulting from the interpolation are very small.

The control board in the milling machine has a serial interface, but a standard USB to RS232 adapter can be used without any problems to operate the machine via the USB port of the PC.

The spindle motor supplied with the milling machine is a fairly basic model from Ferm, which allows you to start using the machine right away. Naturally, you can also fit other types of motors, but we should remark here that a true professional-quality spindle motor can easily cost more than the entire construction kit.

**Construction kit**

What do you get for the price of £1099 or 1599? The photos in Figure 1 and Figure 2 show almost all the parts included in the kit. They include all the mechanical parts, screws and bolts, guideway rollers, spindles, bearings, stepper motors, cables and so on, plus the drive electronics on the two pre-assembled circuit boards. The previously mentioned Ferm spindle motor (and associated bracket) is also included in the kit. A MDF panel (also included in the kit) serves as the base plate.

The companion software for the milling machine consists of two programs: a user-friendly interface for configuring and operating the machine and a conversion program for PCB layouts (see below). The kit includes assembly instruc-
tions that provide a step-by-step description of how to put the machine together.
There's not much that can go wrong during assembly. The various parts fit together very accurately thanks to the combination of precision holes in the steel panels and the steel rods in the aluminium extrusions, so no further alignment is necessary. You have to provide the necessary wiring for the two circuit boards for the control and drive electronics, and the connectors and transformer must be soldered in place.
All the assembly steps are clearly described in the instructions. However, we would like to clarify a few details here.
Once the machine is partially assembled, the guideways must be adjusted. The accuracy of the entire milling machine depends entirely on this adjustment. The guideways for the bridge (on the sides) have of three rollers, of which one can be adjusted using an adjustment plate. It must be adjusted so there is very little play, but it should not be made too tight, since otherwise the rollers will jam. A similar construction is also located at the top of the bridge and in the motor column, but the latter part must be partially disassembled to access the rollers.
The drives use spindles with trapezoidal threads that run in special plastic nuts (see Figure 4). These nuts are fitted with transverse pins that provide the coupling to the bridge or the boring column. The X and Y spindles must also be carefully aligned to achieve the specified accuracy and linearity. Note that the special plastic nuts on these spindles must be lubricated using only the special grease included with the kit. Do not use normal grease!
The rest of the assembly process is adequately described by the instructions included with the kit.
Software

The user interface specially written for the Colinux milling machine provides the operator interface for the machine (Figure 6). This program is designed such that even inexperienced users can work with it easily.

The screen is composed of several windows. The effective working surface of the machine is shown in the right-hand window. After loading a file, you can use the mouse to place the object to be machined in the desired location on this surface. The machine will then start working at exactly this position. You can also specify the values of all the settings and preferences for the machine. In addition, you can operate all machine axes manually using this program. Everything you can think of can be configured here, such as reading memory points, relative zero points, and so on, with micrometre accuracy.

The user interface includes a PCB contouring program (Figure 7), which you can use to edit and merge the Gerber and Excellon files generated by commonly used PCB programs and then convert the coordinates in these files into contours used by the milling machine. You can manually specify the reference points to be used on the circuit board and then use them to ensure that the data in the Gerber and Excellon files are registered exactly with each other (the Gerber file contains the data for the PCB tracks, while the Excellon file contains the hole data). The file generated by the program can then be imported into the user interface program so you can see the PCB layout, which you can drag to a specific location on the working surface.

If you want to process 3D files (such as DXF files), you will need the separate RAMS3D program, which is not included in the construction kit due to the special price.

Finally, there's something for diehard DIYers: the entire command set for controlling the milling machine is freely available, so you can also write your own code.

1001 jobs

This robust, versatile milling machine opens up a world of opportunities for handy hobbyists and professionals who aren't afraid to roll up their sleeves. With it, making rectangular openings in a box is a piece of cake and a machining a slot in a front panel for a slider is no sooner said than done. What's more, this milling machine is a handy tool for things that have nothing to do with electronics. For instance, you can use it to make your own parts for a model airplane or toys for your kids (and donate your jigsaw to local charity!).

In short, there are more than enough things you can do with this machine. Once you've used it, you won't want to do without it.
Explorer-16

Jan Buiting & Luc Lemmens, in cooperation with Microchip UK & Labcenter Electronics

January is a time for fresh starts and good intentions. If ever there was a golden opportunity to move on to 16-bit microcomputing at a serious level, join Microchip, Labcenter and Elektor with their groundbreaking Explorer-16 project for which a fantastic hardware offer will be made next month. And there’s more in the pipeline if you like to run simulations on your PC. For now, no hardware is required. You have your free CD-ROM supplied with this issue so let’s get started with installing Microchip MPLAB and C30 and then Proteus VSM.

If we say that ‘Explorer-16’ is the next logical step from 8-bit micros, we should hasten to add that the project is also perfect for relative newcomers who will be aware of, but need not necessarily bother about, the rock-solid foundations for popular microcomputing laid by so many 8-bit micros (including PIC® MCUs) these past 15 years or so. There’s no objection to starting with 16-bit microcomputing straight away as the tools available for the job are powerful to say the least. That said, we should warn that ‘Explorer-16’ takes off at a fairly high level although all material to learn about programming your own 16-bit PIC micro is available as part of the project.

Regarding the choice of a PIC 16-bit microcontroller, Elektor Electronics being very much an independent magazine, we never went down a single road by using one and the same processor family for years on end. Through our articles we will continue to underline the wide diversity of micros available on the market today and respect every user for his or her preference of PIC, AVR, ARM, 8051 or MC9 over ‘the others’. In the case of Explorer-16, the PIC MCU road offered good options and tools for a series of instructive, reader-interactive articles linking to high quality hardware that can be obtained at a discounted price, and (mostly) free software.
Part 1: introduction to MPLAB®, C30 and Proteus VSM

No EXPLORER-16 CD-ROM found here?
Go to the EXPLORER-16 page at www.elektron.com
or phone Elektor Electronics on +44 208 2614509.
Outlook on the series

This series of articles comprises three main ingredients which we need to mention right at the start.

1. Software

The free CD-ROM you get with this January 2007 issue contains three major pieces of software that lock together into a platform designed to help you become familiar not just with Microchip’s PIC24F 16-bit microcontroller, but also with the general concept of microcontroller simulation. All three components are extremely user-friendly (if not downright ‘slick’) programs that run on a reasonably fast PC with MS Windows installed:

- MPLAB IDE — version 7.50 of this world famous platform for PIC MCU software development.
- MPLAB C30 — version 2.05 (student edition) of the ‘C’ higher programming language compiler for PIC microcontrollers, complete with an array of utilities.
- Proteus VSM v. 7.00 — a special edition of the Labcenter simulation software that’s so fast it can simulate a complete microcontroller board on your PC. Yes, an Explorer-16 board, too, as (for the first time) a PIC24F simulation plug-in is included free of charge to provide the link with the Explorer-16 board!

The software is valuable in itself that you can cheerfully use it without having any hardware available except of course your PC!

2. Hardware

With the publication of the February 2007 issue, Elektor Electronics, the third party in the triumvirate, will offer the Explorer-16 Development Board with a special add-on configuration and at an unbeatable price. A preview of the board is shown in the introductory photograph. Mind you, the development board is supplied exclusively by Elektor, i.e., it’s not available anywhere else in the configuration to be described in part 2.

3. Website support

File support for the project will be built on a dedicated “Explorer-16” page of our website at www.elektron.com. Experts at Labcenter, Microchip and Elektor will be contributing and providing help as required. With Part 1 of this series an Explorer-16 topic is available on the Elektor website. The forum is open for everyone to read but only registered users can post new topics and reply to existing ones. But then, registration is free.

Three (possibly four) consecutive instalments are planned. In these we’ll be running demos and doing a pretty advanced classroom exercise to explore the workings of Proteus VSM software.

PIC24F Architecture

You knew you had it coming — a functionally oriented block diagram of the PIC24F device (Figure 1) and the CPU Core block diagram (Figure 2). The good news is that this article series (and the Explorer-16 board) is based on the top-end processor in the family, the PIC24FJ128GA010 sporting 128 kB Flash... and a 100-pin case! Its “business card” is shown in the PIC24FJ128 Quick Specs inset. This beast has A/D, UART, SPI, I²C, RTCC, WDT ICE, ISP and POR, not forgetting advanced power-saving technology and a parallel-port master and slave functionality.
Software installation

The Explorer-16 CD-ROM you should have received with this issue presents a welcome screen (Figure 3) which should pop up after inserting the disc in your CD-ROM drive or DVD drive. If the welcome screen does not appear automatically, click on Start → Run... and then use Browse to point to the file index.htm on the CD-ROM or DVD drive. The software installation screen you should see after leaving the welcome screen is shown in Figure 4. No-frills installers are used for the software components of this project. We recommend installing all three components. It should be noted that the installer employs the program installed as the default web browser on your PC. It was successfully used with Internet Explorer build 6.0.2900.

PIC24FJ128 Quick Specs

CPU
- Modified Harvard architecture
- Up to 16 MIPS operation @ 32 MHz
- 8 MHz internal oscillator:
  - 4x PLL option
  - Multiple divide options
- 17-bit x 17-bit single-cycle hardware
- Fractional/Integer Multiplier
- 32-bit by 16-bit hardware divider
- 16 x 16-bit working register array
- C compiler optimized instruction set architecture:
  - 76 base instructions
  - Flexible addressing modes
- Linear program memory addressing up to 12 Mbytes
- Linear data memory addressing up to 64 kBytes
- Two address generation units for separate read and write addressing of data memory

Special microcontroller features
- Operating voltage range of 2.05 to 3.6V
- Flash program memory:
  - 1000 erase/write cycles, typical
  - Flash retention 20 years, typical
- Self-reprogrammable under software control
- Selectable power management modes:
  - Deep, idle and alternate clock modes
- Fail-safe clock monitor operation:
  - Detects clock failure and switches to on-chip, low-power RC oscillator
- On-chip LDO regulator
- JTAG boundary scan and programming support
- Power-on Reset (POR), Power-up Timer (PWRT) and Oscillator Start-up Timer (OST)
- Flexible Watchdog Timer (WDT) with on-chip, low-power RC oscillator for reliable operation
- In-Circuit Serial Programming™ (ICSP™) and In-Circuit Emulation (ICE) via 2 pins

Analogue features
- 10-bit, up to 16-channel analogue-to-digital Converter (A/D)
  - 500 kops conversion rate
  - Conversion available during sleep and idle
- Dual analogue comparators with programmable input/output configuration

Peripheral features
- Two 3-wire/4-wire SPI modules, supporting 4 Frame modes with 4-level FIFO buffer
- Two I^2C modules support multi-master/slave mode and 7-bit/10-bit addressing
- Two UART modules:
  - Supports RS-232, RS-485 and LIN 1.2
  - Supports IrDa with on-chip hardware encoder/decoder
  - Auto-wake-up on start bit
  - Auto-baud detect
  - 4-level FIFO buffer
- Parallel Master Slave Port (PMP/PSP):
  - Supports 8-bit or 16-bit data
  - Supports 16 address lines
- Hardware real-time clock/calendar (RTCC):
  - Provides clock, calendar and alarm functions
- Five 16-bit timers/counters with programmable prescaler
- Five 16-bit capture inputs
- Five 16-bit compare/PWM outputs
- High-current sink/source on select I/O pins:
  - 18 mA/18 mA
- Configurable open-drain output on digital I/O pins
- Up to 5 external interrupt sources
MPLAB IDE v. 7.50 follows a traditional Windows program install procedure. At some point you will see this message: the publisher could not be verified. Are you sure you want to run this software? Click Run to continue.

MPLAB C30 Compiler v 2.05 - Student Edition is a similar installation. The Release Notes document that's available at the end of the installation is particularly worthwhile to read (and print).

Proteus VSM 7.00 Demo is also easy to install simply by accepting the defaults suggested by the installer program. The Guided Tour of the MPLAB viewer you'll see near the end of the installation has some interesting information and shows the effort that Labcenter and Microchip have put into their cooperation for the Explorer-16 project.

MPLAB IDE

Paradoxically - considering its size and power - little needs to be said about this renowned PIC microcontroller development platform from Microchip. The reason is simple: MPLAB has been around for many years now and has matured into the de facto development platform for PIC MCUs. The program, or suite of utilities, really, is comprehensive, user-friendly and marked by excellent support not just by virtue of the Help file functions but also through Microchip's online forum and technical support.

MPLAB Integrated Development Environment (IDE) is a development platform for the Microchip Technology PIC MCU and dsPIC® microcontroller families.

MPLAB IDE includes the following components: MPASM™ Assembler; MPSIM™ software simulator; MPLINK™ linker; Source Level Debugger; On-line Help; Project and setup wizards; Project Manager; Visual Device Initializer; Programmer's Editor; drivers for various hardware tools. Special versions of a number of utilities like the assembler and linker, are supplied for the dsPIC30 devices.

With MPLAB IDE you can:

- write, build and debug source code;
- automatically locate errors in source files for editing;
- debug with breakpoints;
- single-step the program with software simulator, in-circuit debugger or in-circuit emulator;
- view variables in watch windows;
- program code with certain programmers;
- find quick answers to questions using the MPLAB IDE on-line help.

MPLAB looks rather dead when launched. To see some action on the screen follow File → Open Workspace and then navigate to the 'examples' folder. Various projects can be opened there. Although not very meaningful just yet, they allow the newcomer to explore a large number of functions without 'serious consequences'. Importantly, release notes for all utilities in MPLAB can be found at Start → All Programs → Microchip → MPLAB IDE v. 7.50 → Documentation. This screen also lists 'install and repair' utilities.

Even an introductory discussion of the features packed into MPLAB and the best way to use them for your PIC projects would easily fill an entire magazine hence beyond the scope of this article. Not to worry, the complete MPLAB User's Guide and various other pdf documents are accessible via the CD-ROM install screen under 'View Design Series Literature'. Plus, there's MPLAB Getting Started.

MPLAB C30

The free Explorer-16 CD-ROM contains the student edition of the Microchip C30 compiler, version 2.05. This is a fully functioning C compiler for the first 60 days after which a number of the cleverest optimisations are disabled. If you start using the C30 compiler now, you will have a full version of the product all the way till the third article instalment. The functions disabled after 60 days are described by Microchip as: 'procedural abstraction' and 'optimisation options -O2, -O3 and -Os'. Not too worrying, we'd say. Everything else works the same as the full version and
with the huge memory capacity on the PIC24F128 used, code size optimization is unlikely to become a problem. Of course, you are free to use C30 for any smaller 16-bit PIC MCU or dsPIC® DSC you may have available, just give it a try.

The student edition of C30 may be upgraded to a full edition by purchasing a licence key from Microchip. Good news: with the publication of the February 2007 issue, buyers of the Explorer-16 Development Board will be able to purchase the full version of C30 at a discounted price by returning a voucher enclosed in the box.

MPLAB C30 seems to be a lesser known ‘plug-in’ of the MPLAB environment so a short introduction is given here (realizing that the real work starts with coding your own C programs, compiling, debugging and finally transferring them to a PIC — but stop, do your simulation first!).

MPLAB C30 is a fully ANSI compliant compiler with standard libraries for all popular PICs, including the latest dsPIC® DSC devices. It is fully integrated with the MPLAB IDE for high level debugging at the source code level. This compiler comes complete with its own assembler, linker and librarian to write mixed-mode C and assembly programs and link the resulting object files into a single executable file.

The MPLAB C30 library includes functions for string manipulation, dynamic memory allocation, data conversion, timekeeping, and math functions (trigonometric, exponential and hyperbolic).

The ‘small code model’ offered by C30 takes advantage of a more efficient form of call instructions, while the ‘small data model’ supports the use of compact instructions for accessing data in SFR space.

Although C30 is embedded into the MPLAB environment, you will still be able to use it as a separate command line program. Use the ‘Open Workspace’ menu item in MPLAB and navigate to MPLAB C30 → Examples → MPLAB Link30. The example ‘Locate_access_EEPROM’ is shown in Figure 5 with the Program Memory and File Registers viewers open.

The complete C30 Users Guide is accessible via the menu on the CD-ROM, as discussed with MPLAB. Alternatively, navigate to the ‘Documentation’ menu on the CD-ROM.

Proteus VSM

The circuit simulation component of the Explorer-16 project is presented to you courtesy of our long-standing advertiser Labcenter Electronics. VSM (virtual systems modelling) is part of the Proteus Design Suite which also comprises:

- ISIS schematic capture;
- ProSPICE mixed mode simulation;
- ARES PCB design.

Specially for the Explorer-16 project, Labcenter are supplying a large number of sample designs featuring the PIC16, PIC12, PIC16, PIC18 and, of course, the PIC24F. You can run any software code you like on the samples but to experiment on your own hardware designs you will need to purchase the full Proteus VSM package. Alternatively, you can take advantage of a special offer exclusive to Elektor readers by visiting www.labcenter.co.uk/products/elektoroffer.htm.

To get a taste, if you start a copy of ISIS via Start → Labcenter → Proteus 7 Demonstration → ISIS 7 Demo, you are invited to view a number of examples. Some nice ones are found in the Tutorials folder.

Kick start to Proteus VSM within MPLAB

This short demonstration will show you how the basics of how to configure and run a Proteus VSM simulation under the control of the MPLAB IDE.

1. Download the file Demo1.zip from the Explorer-16 page you can reach via www.elektor.com. Save the unzipped Demo1 folder to the directory: c:\program files\microchip\mplab\c30\examples.

2. Launch the MPLAB IDE application, go to the File menu, select the Open Workspace command, navigate into the Demo1 directory and open the Demo1.mw workspace.

3. Go to the Debugger Menu in the MPLAB IDE, select the Select Tool command and then Proteus VSM. This configures MPLAB to use Proteus as the tool of choice for debugging.

4. You should now see that the Proteus VSM Viewer has opened inside MPLAB. Use the Open Icon on the viewer and select the Demo1 schematic from the resulting file selector.

5. Now select ‘Build All’ from the Debugger menu.

6. Now that we have the schematic and project we can start the simulation. Use the green button at the top of the MPLAB IDE to start the simulation.

7. At this point the simulation is paused at time 0. Start the Simulation by clicking on the Play button near the top right of the MPLAB IDE. This will execute the program code and the VSM Viewer will show you the effects of your program on the design.

8. Use the red button at the top of the MPLAB IDE to disconnect the VSM Viewer from MPLAB and stop the simulation. A more detailed demonstration of debugging follows later in the series.
MPLAB inset. This impressive demo requires an archive file called Demo1.zip to be downloaded from the Explorer-16 page of our website. You can also apply the same procedure to any of the pre-installed Virtual Evaluation Boards. More about VSM on [4].

Next month

We reckon the amount of software presented in this article will keep you busy for about a month. In the February 2007 issue we’ll discuss the Explorer-16 hardware (on special offer then) and show its first application which is related to speech reproduction. This will take us along C30 and MPLAB to see how the software is built. We’ll also delve into Proteus VSM to demonstrate that simulation is now a firmly established—if not essential—step in prototyping microcontroller circuits.

Web links


26
16-bit Microcontrollers

16-bit PIC24 MCUs and dsPIC® Digital Signal Controllers

Unified 16-bit Architecture
- PIC24F, low-cost entry level
- PIC24H, 40 MIPS high performance
- dsPIC30F/33F for seamless DSP integration

Low-Risk Design
- Easy migration from 8-bit MCUs
- Common core instruction set and architecture
- Peripheral and Pin compatible families
- One development tool platform for all products
- Free MPLAB® IDE Integrated Development Environment
- Other tools include C-compiler, programmer and In-Circuit Emulator

Visualise...16-bit Microcontrollers with 32-bit Performance and 8-bit Simplicity

Today’s embedded systems demand more. The 16-bit PIC® microcontroller families from Microchip give you the performance and flexibility you need with 8-bit simplicity. Pin and code compatibility lowers risk, and allows re-use of development tools, software and hardware designs. For the most demanding applications the dsPIC digital signal controller families seamlessly integrate high-performance DSP capabilities with the PIC microcontroller core.

Over 50 PIC24 Microcontrollers and dsPIC Digital Signal Controllers sampling today. For data sheets, samples and pricing go to www.microchip.com/16bit

microchip DIRECT
www.microchipdirect.com

microchip
www.microchip.com/16bit

Pb-free!
RoHS Compliant
The Quest for Accurate Time Measurement using Atomic Clocks

Jens Nickel

Of all nature's physical quantities it is time that we know how to measure best. The most advanced atomic clocks are breathtakingly accurate, many millions of times more so than the best quartz-based clocks. How do they manage it?

Figure 1. Sundials are the oldest clocks known to man. In this example a magnifying glass ignites a powder charge in the tiny cannon at midday. (Photograph: German Clock Museum, Fürthwangen (14))

Before we get down to business we should confess that we are going to dodge the question 'what is time?' in this article by using the rather unhelpful definition 'time is what a clock measures'. A clock lets us put a number on the duration of an event or on how long ago an event occurred. The precision of the measurement depends on how small the briefest basic interval is that the clock can resolve, and the repeatability of the measurement depends on the extent to which these basic time intervals can be kept constant. To test the repeatability of a measurement we need access to another, more accurate, clock.

The first 'clock' used by mankind was the rotation of the Earth. Over the centuries the precision of clocks based on this principle has continuously improved, from the earliest sundials (Figure 1) to modern astronomical

Figure 2. The accuracy of the best clocks has improved over the millennia by more than 12 orders of magnitude: a factor of one trillion.
accuracy

instruments. As recently as the last century the repeatability of this measurement was considered ‘perfect’ and the second was defined as one 86,400th of a mean solar day [1]. It was not possible to detect any changes to this period, as nothing of remotely comparable accuracy was available (Figure 2).

History of timekeeping

Waterclocks superseded sundials in antiquity; and in the Middle Ages glass-blowing technology improved to the point where they in turn could be replaced by sand-filled hourglasses. The first mechanical clocks date from the thirteenth century, driven first by weights and later by springs, the latter making for a more compact construction. In 1657 the Dutchman Christian Huygens developed the first functional pendulum clock, claimed to have an accuracy of around 10 s per day [2]. That may not sound very impressive, but his revolutionary design paved the way for orders of magnitude improvements in accuracy. External influences on the pendulum were identified and eliminated one by one, exactly as would later happen with electronic clocks. Among the sources of inaccuracy were temperature and feedback from the clock mechanism to the pendulum.

A driving force behind these developments was navigation: only with the help of a chronometer having good long-term stability could one determine one’s longitude when on the open sea. The first electrical clock (Figure 3) was also based on a pendulum. Developments ultimately culminated in a highly-accurate pendulum clock using pendulums suspended in a vacuum and a kind of master-slave arrangement [3], achieving a final ac-

SI Base units

Physical quantities such as resistance are measured in fixed units, in this case the Ohm. So that an Ohm represents the same resistance in every laboratory in the world its value must be defined. This is simple: a resistance of one Ohm appears across a component and a current of one Ampère flows, the resistance is one Ohm. The Ohm is therefore derived from other units, which, in turn, must of course be defined themselves. The Volt happens to be defined in terms of other units, but the Ampère is a ‘base unit’. The choice here is somewhat arbitrary: the laws of physics will not change if we define the Ampère via the Ohm rather than vice versa. However, international agreement has been reached on the use of seven base units.

These SI base units [8] must be defined somehow, and there are various options available. The classical, though rather awkward, approach, is to have a ‘standard’ somewhere in the world. At present this is still how the kilogram is defined: one kilogram is the mass of the ‘ur-kilogram’, made of a special alloy and kept at the International Bureau of Weights and Measures at Sèvres near Paris, under several glass envelopes. A more elegant way to define a unit is via a measurement rule. For example, since 1967 the second has been defined as 9 192 631 770 times the period of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the 133Cs atom.

Using a caesium atomic clock allows a precise standard for the second to be available anywhere in the world — even potentially in every house!

The Ampère is defined via an experimental procedure where a carefully-controlled voltage and resistance are used [9]. The reasons why the Ampère was nevertheless chosen as a base unit are historical.

Clocks at the German Federal Institute for Physical Technology (PTB)

The German Federal Institute for Physical Technology (PTB) in Braunschweig is the body responsible for providing a statutory time reference for the whole of Germany. Its approximate UK counterpart is the National Physical Laboratory (NPL). The PTB has ten atomic clocks at which two are caesium atomic fountain clocks (the photograph shows the room where the clocks are kept). With relative accuracies of between 5 and 10 x 10^-16 these devices are among the most accurate timepieces in the world. The PTB continues to develop the atomic fountain design, and so we can expect these figures to improve in future.

So-called optical atomic clocks are under development at the PTB. So far, the accuracy achieved has been comparable to that achievable using atomic fountain clocks, and several sources of error stand in the way of obtaining the theoretically possible accuracy of 10^-16. According to Robert Wyndas, who runs the time standards team, ‘we have to be careful that the chips do not distort with temperature and cause changes in propagation delays’.

These high-precision atomic clocks and modules such as frequency generators are developed in-house at the PTB. Individual components are usually bought in as ready-made devices, although they tend to be top-of-the-range products. The bill for a particularly low-noise quartz crystal might run to four or five figures’ says Wyndas.

The PTB runs a further three atomic clocks in Mainflingen near Frankfurt. These units, bought from commercial suppliers, determine the time that is broadcast using the DCF77 signal [10]. The signal can be received by radio-controlled clocks within a radius of approximately 2000 km of the transmitter, and is of course checked in Braunschweig. If the time should depart from the true value, the Mainflingen clocks are corrected using a telephone line.

Figure 3. The first electrical clocks used pendulums in conjunction with electromagnets. This example, by Alexander Bain, was made in 1845. Since there was no mains electricity at that time, the maker constructed his own ‘earth battery’ by burying two sheets of dissimilar metals in the ground. (Photograph: German Clock Museum, Pforzheim)
Figure 4. In 1950 Rohde and Schwarz brought their 'portable' quartz crystal clock to market. It weighed some 40 kg. (Photograph: Rohde and Schwarz [4])

Figure 5 and 6. Diagram and internals of a classical cesium atomic clock. The frequency of an adjustable quartz VCXO is set by the control loop shown. Cesium atoms, in gaseous form, move towards a magnet (the polarizer). Those atoms that are in one of the two hyperfine structure transition states (A) are deflected to a slightly different sector from those in state B, and only the former are allowed to enter the resonator. The atoms are illuminated with microwave radiation at a frequency which is a known multiple of the quartz crystal oscillator frequency. When resonance occurs many of the Cs atoms are excited from state A to state B. This can be detected by separating the atoms using the analyzer magnets at the end of the resonator, and measuring the intensity of the separated beams. (Photograph and graphic: FTB [5]).

accuracy of a few milliseconds per day. Only the very best quartz crystal clocks can beat this figure.

Quartz accuracy

The first quartz crystal based clock was developed in the 1920s, and the first reasonably portable device was produced in 1938 by instrument makers Rohde & Schwarz (see Figure 4). It used a silver of quartz crystal as its frequency reference, made to vibrate by applying an alternating voltage to it, using the piezoelectric effect [5]. At a certain frequency the crystal resonates, and this phenomenon can be detected. Dividers convert this frequency to the desired time interval.

In the 1930s a quartz crystal clock was used to determine that the speed of rotation of the Earth is not a constant. There is a general slowing down resulting from friction due to tides as well as unexpected variations thought to be due to movements of rock within the Earth. There are also seasonal variations with relative magnitudes of the order of $10^{-6}$ [1].

Inside the atom

Over the last century remarkable progress has been made in physics. Sophisticated theories now explain observations over which generations of scientists had scratched their heads in puzzlement. If light is shone through a gas, it is found that certain wavelengths are absorbed. It is also observed that the gas then re-emits light of a certain wavelength in response to this stimulus.

The atom (or more precisely, the electron shells of the atom) can only take on certain defined energy levels. Consider the following analogy: the flats in a tower block are each on a definite floor, not in between floors (except in the famous John Malkovich film). So if you throw a ball from the window of your flat, there are only certain velocities with which the ball can hit the ground. Depending on which floor the ball was thrown from, it might reach the ground travelling at 15, 30 or 55 km/h, but never at 40 km/h. Conversely, if you wish to throw the ball back from the ground so that it just reaches the window, you will have to launch it at one of the three admissible speeds. In the case of the atom, we have to provide light of a certain wavelength in order to move an electron from one energy level to another. Things are slightly more complicated in this case, since the 'floors' are not all of the same height; furthermore, there is the occasional mezzanine floor (and even mezzo-mezzanine floors!); see the text box 'Hyperfine structure'. The complete collection of observed and absorbed wavelengths (the 'spectrum') is thus rather complicated and varies from element to element, giving rise to a kind of element fingerprint.

The best part of all this is that the difference between energy levels is essentially independent of external influences. Whereas quartz crystals suffer from the effects of temperature and long-term drift, the energy levels of atoms have their origins in physical constants with essentially fixed values. This gave American physicists in the 1940s the following idea: in some atoms (for example in the alkali metal caesium) the energy levels are so close together that rather than light waves, microwave radiation is emitted, having a frequency of a few GHz. We can thus 'illuminate' a caesium atom with microwave radiation of a frequency close to this atomic resonance frequency, and
then it is a 'simple' matter of measuring our success at exciting the atoms and use this as part of a control loop to generate a highly accurate frequency.

Resonance
In practice the excitation frequency is produced using a voltage controlled crystal oscillator (VCXO) as a reference, with a frequency of perhaps around 5 MHz. A 1 Hz signal can be derived from this as in an ordinary quartz crystal clock. The reference frequency is controlled and regulated as described above. In the classical caesium atomic clock (see Figure 5 and Figure 6) a caesium sample is heated in a small evacuated oven to form a gas. A fine beam of caesium gas then escapes via a small opening and passes through a magnetic field. Atoms that are in hyperfine structure state A are deflected by a slightly different amount than those in state B. Only the A atoms are allowed to enter the resonator cavity.

The atomic resonance frequency is derived from the 5 MHz reference by frequency multiplication; the microwave radiation at the relevant frequency is coupled in using a cavity resonator through which the caesium atoms pass. When the resonant frequency is hit a large number of caesium atoms make the hyperfine structure transition from state A to state B. This can be detected by separating the caesium atoms using a further magnet at the end of the resonator and measuring the intensities of the separated beams. The caesium atoms are ionised using a heated wire and the resulting current can then be amplified by several orders of magnitude using a secondary electron multiplier. All that remains is a little control theory to vary the frequency of the VCXO to maximise the measured current.

Atomic standard
Even a simple caesium atomic clock can achieve a relative accuracy of 10^{-11}, corresponding to an error of one second in 3000 years. It is something of an understatement to call this 'high precision': if we could measure distances as accurately, we would know the distance to the moon to the nearest millimetre! In 1967 the definition of the second was changed to use the caesium 'atomic' standard (see the 'Base units' text box). The use of the 'atomic' tag can probably be traced back to the more media-savvy academics of the time, aware that the word 'atom' was naturally associated with the white heat of the scientific and technical revolution. In industrialised countries atomic clocks allowed standardising bodies to provide a statutory framework for timekeeping. However, even atomic clocks drift slowly relative to one another and so regular comparisons are made, even across national boundaries. An averaging process, involving some 50 institutions and 200 individual atomic clocks, is used to produce a world time standard called International Atomic Time. Because of the (relatively!) erratic rotation of the Earth extra seconds are sometimes added at the end of June or at the end of December. This ensures that astronomically-derived time never deviates far from Atomic Time [1], [7].

Ultra precision
The best classical caesium atomic clocks, such as those kept at the German Federal Institute for Physical Technology (PTB), achieve relative accuracies of up to 10^{-14}. When comparing clocks of such high accuracy even the smallest local variation in gravity must be taken into account, as Einstein's general theory of relativity tells us. These devices are therefore not the end of the story as far as accuracy is concerned.

Inaccuracies in the type of clock described above can be traced back to (among other things) the fact that the caesium atoms are moving rapidly through the resonator. In a so-called caesium fountain atomic clock the atoms are cooled (i.e., slowed down) using a laser and then gently
Commercial applications

The atomic clocks used at national physical laboratories are specially made and criteria such as price, size and current consumption are not particularly important. However, there are various manufacturers producing a range of atomic clocks: for example, Symmetricom Inc. [11] offers both caesium- and rubidium-based atomic clocks which are easy to use and compact. The photograph shows such a unit, which is only a little larger than a cigarette packet and which can be used as a drop-in replacement module for a quartz crystal oscillator.

Symmetricom's rubidium clocks start at under two thousand pounds and have a relative accuracy of around $10^{-9}$ to $10^{-10}$. Customers include telecommunications companies who use them in mobile telephony base stations. A caesium clock can be had for around twenty thousand pounds upwards while hydrogen maser clocks come in at a hundred thousand pounds. The latter exhibit a very high degree of short-term stability and good accuracy over periods of hours to days. This makes them ideal for use in navigation satellites, where the time as measured by the on-board atomic clocks can be adjusted from time to time from the ground stations. The satellites of the EU Galileo system will include hydrogen maser clocks. The first-generation American GPS satellites contain souped-up rubidium clocks while the more recent models each contain two caesium and two rubidium clocks [12].

This more accurately the satellites can keep time the more accurate the positioning system can be. The theory is explained in [13].

Nudged into the resonator cavity, like a fine water fountain they now turn back under gravity and are filtered and detected in a detection chamber. This kind of clock can achieve relative accuracies of $10^{-15}$ and better.

Within a few years so-called optical atomic clocks will become widespread, using light instead of microwave radiation. Relative accuracies of up to $10^{-18}$ are expected.

With clocks of such astonishing accuracy it will become possible to determine whether the energy levels, the differences between which are calculated from physical constants, really are constant. Any drift in these physical 'constants' will give scientists something to scratch their heads about once more!

Internet links

[1] www.npl.co.uk/time/
[8] www.npl.co.uk/reference/
Microcontroller Development Tools

**PICmicro Starter Pack now with ICD—still £99**
- High-quality development board with on-board USB programmer and built-in I/O devices.
- Supports 8, 14, 18, 20, 28, and 40-pin PICs in 10F, 12F, 16F and 18F families.
- Now features mikroICD in-circuit debugger.
- Supplied with PIC16F877A.

The new EasyPIC4 development board now supports even more PICs including 8, 14, 18, 20, 28, and 40-pin devices from the 10F, 12F, 10F and 18F families. With its on-board USB programmer, mikroICD in-circuit debugger and useful I/O devices, the EasyPIC4 must be the best-value development board on the market. Our Starter Pack includes the EasyPIC4 board, USB cable, 16x2 LCD, 128x64 GLCD, DS18B20 temperature sensor and a starter’s guide with example programs in assembly language, BASIC, and Pascal.

**PICmicro BASIC, C and Pascal Compilers—from £59.50**
- Easy to use with user-friendly IDE.
- Features simulator and mikroICD in-circuit debugger.
- Plentiful ready-written routines and example programs.
- 30% discount for customers purchasing EasyPIC4/BIGPIC4 development boards.

MikroElektronika’s popular mikroBASIC, mikroC and mikroPascal compilers now include the mikroICD in-circuit debugger for use with the EasyPIC4 and BIGPIC4 development boards—programs can now be executed on a target PIC with variable values, special function registers, memory and EEPROM viewed on the PC screen. Great value at £59 each for mikroBASIC/mikroPascal £145 for mikroC, or when bought with an EasyPIC4/BIGPIC4 only £59.50 each for mikroBASIC/mikroPascal, and £101.50 for mikroC.

We also stock development tools for 8051, ARM, AVR, dsPIC, PICmicro, PSOC and other devices—please see our website for details.

Educational Products

**PICmicro Microcontroller Training System—£99**
- Teaches both assembly language programming and interfacing.
- Based on the popular PIC16F877A.
- Includes USB programmer.
- Features built-in I/O devices and solderless breadboard.
- Supplied with tutorial and program examples.

The PICmicro Microcontroller Training System is an ideal platform for students and hobbyists alike to learn about PIC microcontrollers. The experiment board features a range of built-in I/O devices and a solderless breadboard on which experiments may be conducted. Circuits are connected using the provided jumper wires. A USB programmer is also supplied and connects to the experiment board to program the PIC. Also included are a mains power adapter, 16x2 character LCD, connecting leads and a tutorial with example programs.

**Digital Logic Training System—£99**
- Ideal for learning about and experimenting with digital logic devices.
- Built-in logic and pulse switches, LEDs, 7-segment displays, piezo speaker, pulse generator, logic probe and solderless breadboard.
- Supplied with useful range of ICs, jumper wire and mains adapter.

The Digital Logic Training System makes learning about digital logic and experimenting with discrete logic ICs easy. The experiment board features a range of built-in I/O devices and a solderless breadboard on which experiments may be conducted. Circuits are connected using the provided jumper wires and the system includes features such as a power supply, pulse generator and logic probe. Also included is a mains power adapter, selection of ICs and a tutorial with example circuits.

We also stock other trainers, circuit labs and solderless breadboards—please see our website for details.

Robots and Accessories

**Robo-BOX 3.0 Robot Kit—£99**
- Complete robot kit including controller, programming software and all mechanical parts.
- Build different robot configurations from one kit, including wheel-based and track-based.
- Program intelligence to follow light, detect collisions and trace lines.

Learn about, experiment and have fun with robotics with Robo-BOX 3.0—an incredibly easy-to-build yet adaptable and expandable robot. Various wheel-based and track-based robots can be built from the standard kit including light-following, collision-detecting and line-tracing models. Programming is carried out in graphical Logo. A range of low-cost options allow for easy expansion and the development of more sophisticated robots. We also stock similar robot kits based on PICmicro, 8051 and 68HC11 microcontrollers.

**PoScope USB Oscilloscope/Logic Analyser—only £99**
- Low-cost PC-based instrument featuring oscilloscope, spectrum analyser, logic analyser, pattern generator, and chart recorder.
- Decodes serial buses including UART, SPI, I2C and 1-wire.
- Supplied with logic analyser test lead set, two oscilloscope probes, USB cable and software.

PoScope has to be one of the best-value pieces of test equipment available and features a dual channel oscilloscope (100Hz to 200kHz sample rate), 16 channel logic analyser (1kHz to 6MHz sample rate), and 8-channel pattern generator (1kHz to 1MHz). What makes the PoScope really useful to those working with microcontrollers is its ability to decode serial communications including RS-232, I2C, SPI, I2C and 1-wire. Priced at only £99, the PoScope comes with a USB cable, logic analyser test lead set, two oscilloscope probes and software.

Tel: 0845 226 9451  Fax: 0845 226 9452  Email: sales@paltronix.com

All prices exclude UK delivery (£5 standard/£10 next-day) and VAT. Major credit and debit cards accepted. Secure online ordering.
Clocking, Texas-style
A 300 MHz spread-spectrum clock generator from TI

The CDCE706 and CDCE906 from Texas Instruments are interesting new clock generators which include three independent PLL modules. They also feature a spread-spectrum output to help minimise EMC problems. But what are these devices like in practice?

It is often the case that a fixed-frequency clock generator is needed, but crystals of a suitable frequency are not available. The problem can be solved using a PLL device which can be used with a standard crystal to generate almost any desired frequency. The CDCE706 and CDCE906 ICs from Texas Instruments even allow the generation of frequencies above 100 MHz, which can be difficult to achieve using conventional crystal oscillators. The CDCE906 can produce a clock output with a frequency of up to 167 MHz, while the CDCE706 can operate at up to 300 MHz. The devices are in other respects compatible. They contain three entirely independent PLL modules and can be configured using an IC interface. Up to six different output frequencies can be obtained using dividers driven from the PLL outputs or from the input clock frequency. Figure 1 shows the pinout of the device and Figure 2 the functional block diagram. Using the output switch matrix [see Figure 3] the six outputs of the IC, Y0 to Y5, can be connected at will to the outputs of six programmable dividers. In turn, the inputs to the dividers can be connected at will to the PLL outputs or to the input crystal frequency. In a typical application the device is used with an external crystal (Figure 4); alternatively, an external clock signal can be fed to the device. The decoupling of the 3.3 V supply is critical: there are four pairs of adjacent VCC and GND pins on the TSSOP20 package. Decoupling capacitors,
ideally SMDs with a value of 100 nF, should be mounted as close as possible to each pair of supply pins. This will help ensure that the internal PLLs do not affect the operation of one another.

**Programming**

At [2] Texas Instruments provides an overview of the products, tools and documentation available relating to the CDCE706. The 'TI Pro Clock' program that can be found there is a comprehensive tool for configuring the device. The program can drive the PC bus directly via the printer port. Using the tool it is possible to reprogram the clock generator freely, since it writes the configuration settings directly into the device registers. There is also an option to transfer the settings to an EEPROM area in the device: settings are automatically transferred from this area into registers on power-up, so that the device can be arranged to operate using preset values without the need for permanent connection to a PC.

The program and its use are comprehensively described in application note scuo17.pdf; the note also describes the evaluation board which is available.

**Figure 5** shows a modified interface between printer port and PC bus. In theory the PC bus can be driven directly from a printer port, as described, for example, in [3]. It turns out, however, that the SCL signal in particular is susceptible to interference and an extra buffer is a worthwhile addition. We have, however, used the same printer port pins as in the TI design.

The 74HC125 quad buffer has tristate outputs which go into the high-impedance state when the OE input is high. This is necessary in the case of the SDA signal, since data can be travelling in either direction. D0 is therefore used to control the 1OE input (pin 1), while its buffer’s input is tied to ground. When D0 is low SDA is also pulled low; when D0 is high the buffer goes into the high-impedance state and the 10 kΩ pull-up resistor pulls the signal high. Now the PC slave device can pull the SDA line low, for example when it needs to generate an ACK signal. The instantaneous state of the SDA signal can be read using a further buffer driving the PE input on the printer port. Printer ports normally operate using 5 V signal levels rather than the 3.3 V used by the clock generator, and two resistors, in the D0 and D1 lines, serve to adapt the voltage levels. The protection diodes inside the 74HC125 clamp the maximum input voltage to slightly above 3.3 V.

The 'TI Pro Clock' program can be used in conjunction with this interface. Not only does the program assist with calculating the required settings for the clock generator device, it also includes a 'storage oscilloscope' to analyse the signals on the PC bus (see **Figure 6**), which is helpful when trying to track down communications errors. The display is also very handy when developing one's own software, for example to run in a microcontroller.

**In practice**

When the program is started up it displays the default configuration stored in the device during manufacture (**Figure 7**). It is assumed that you will be using an input frequency of 27 MHz, and this frequency is also present on all six outputs. The signal, however, is not simply being passed straight through: it is being processed by PLL 1. The input frequency is multiplied by 8 (i.e., the PLL operates at 216 MHz) and then divided by 8 again us-

---

**Figure 3**
Simplified block diagram of the CDCE706 and CDCE906.

**Figure 4**
Block diagram of the dividers and output switch.

**Figure 5**
Typical application circuit with external crystal.
crystal is used instead, the outputs will all be oscillating at 16 MHz. We thus have a simple test that the power supply and crystal oscillator circuit are operating correctly. We can now go on to program the device to generate almost any desired frequency. In theory it is a simple matter of calculating:

\[ f = \frac{f_r}{M \times N / P} \]

but often a little experimentation can be helpful to find suitable settings. The PLL frequency should lie within one of two bands, either from 80 MHz to 200 MHz or from 180 MHz to 300 MHz. The software should be used to set the VCO \( f_{\text{max}} \) value to 200 MHz or 300 MHz accordingly.

In practice it is found that in 200 MHz mode the PLL oscillator can operate at well below 80 MHz, although at some detriment to the performance of the device. In particular, phase noise increases. The general rule here is that if possible the highest available comparison frequency for the PLL should be chosen. This means that the \( M \) divider ratio should be set as low as possible. For example, suppose we wish to generate an output frequency of 17 MHz from an input frequency of 16 MHz. We first set \( M = 16 \), giving a comparison frequency of 1 MHz. We then set \( N = 170 \), giving a PLL frequency of 170 MHz, which is finally divided by \( P = 10 \) down to 17 MHz.

**Assistance**

When more obscure frequencies are wanted, say 10.245 MHz for example, a little more thought is called for to find the best settings. Help is provided in the form of the ‘Programming Assistant’ (Figure 8): you can select the desired output and frequency and the assistant calculates the best settings. In this case the program suggests 16 MHz / 160 * 2049 = 204.9 MHz and 204.9 MHz / 20 = 10.245 MHz. This would now make a suitable oscillator for a dual-conversion superheterodyne receiver with a first IF at 10.7 MHz and a second IF at 455 kHz. PLL 2 and PLL 3 can be switched off in the interests of producing an output signal with low noise and weak sidebands.

**Spread-spectrum clocking**

In these days of strict EMC regulation, it can often happen that a piece of equipment produces radio interference at its clock frequency (or a harmonic of it) and hence fails emissions testing. The best defence against this is good screening and decoupling of all signals that leave the enclosure. A backup technique is to use spread-spectrum clocking. The spectrum of a signal can be ‘spread out’ using a kind of frequency modulation; a receiver will then not see a sharp spectral peak but rather a noisy signal with lower peak power occupying a wider region of the spectrum. PLL 2 can be configured for frequency modulation around the specified centre frequency with a deviation of up to 0.4 %, or down from the specified frequency with a deviation of up to 3 %: see Figure 9. Centre modulation is a good choice for generating a microcontroller clock since the average frequency will be exactly the specified value.

**RF characteristics**

Although the frequencies of the VCOs in the internal PLLs are determined by simple RC circuits, it is nevertheless
possible to use them to construct a clock generator with a low-noise output on a par with that achievable using a crystal oscillator. It is therefore possible to consider using this integrated clock generator in advanced RF applications, for example in a triple-conversion superheterodyne receiver with an adjustable first oscillator and two fixed-frequency IF stages. In this case any failure to decouple the PLL modules adequately from one another can reduce performance. If two PLLs are set to operate at closely-spaced frequencies, even a small amount of coupling can have a significant effect: as you can imagine, the two PLL control loops will interfere with one another, resulting in an output signal that is not clean.

In critical applications (for example in a DRM receiver) it could be a good idea to use just one of the PLLs. However, it will still be necessary to ensure that the device's supply is clean by providing good decoupling at the Vcc pins with very short connections to the bypass capacitors. A ground plane should also be used. Texas Instruments recommends using a four-layer printed circuit board with both Vcc and ground planes.

We took a simpler approach for testing, simply connecting a SOT167 ceramic capacitor directly across each pair of power pins. Setting two PLLs to two reasonably-separated frequencies we were able to obtain two clean output signals simultaneously. With all three PLLs operating at the same time it is harder to avoid a certain amount of phase noise on the outputs.

Turbo Tricks
Notebook and microcontroller overclocking

Dr. Thomas Scherer

It's not well known but it's quite a simple job to boost the clock rate of almost all Centrino® notebooks with Intel i915 chipsets and Pentium M CPUs. We take a look at what's required for this simple mod.

The Centrino family of processors have been a great commercial success for Intel. From the beginning of 2005 up to the present day the 915 chipset with its low power consumption and good processing power have made slim portable computers more affordable. The progression of the Pentium M processors from the first generation 'Banias' which contained a 1 MB L2 cache through to the 'Dothan' processor fabricated with the more recent 90 nm technology and offering a 2 MB L2 cache, DDR2 memory support and an FSB clock increased from 400 to 533 MHz. The last two features are supported by the 915 series chipset family but not by the previous 855 series. More recently we have seen the introduction of dual-core processors supported by the 945 chipset but the 915 still has much to offer including low-cost and the ability to be overclocked extremely easily.

Wind up the clock

Many of you probably take the view that overclocking is the domain of geeks with too much time on their hands, they start off with a perfectly reliable notebook and end up with something that is really only good for toasting sandwiches. In reality the risks involved with this modification are quite small, no soldering is necessary and most people with an average level of technical competence would be able to identify the correct processor socket pins and fit the necessary wire jumper. The entire process should not take longer than 15 minutes and best of all the modification is reversible!

The most recent processors from Intel have a built-in (fixed) multiplier which derives the processor clock from the FSB (Front Side Bus) clock rate. These processors can therefore only be overclocked by increasing the FSB clock. The disadvantage of this modification is that it also increases the clock rate to the DDR RAM and the chipset cannot reliably handle the increased clock rate. Reports indicate that systems with this type of overclocking tend to become unstable when the acceleration approaches around 20%. In contrast the Pentium M processors have much more in reserve.

In an effort to prevent owners from tampering with the clock speeds many notebook manufacturers define the FSB clock rate from values contained in the machines BIOS. It is usually uneconomical to attempt overclocking on these machines.

Only connect

Partly in response to competition from their rival AMD, Intel released (along with the existing Celeron processor) a low-cost variant of their Pentium M "Dothan" processor with a reduced FSB speed of 400 MHz and half the normal L2 cache space (1 MB instead of 2 MB). This chip marked the beginning of the entry-level Pentium based
Controllers

The technique of overclocking is not necessarily confined to the PC and Laptop world; microcontrollers are also likely candidates for this type of treatment including those contained in many Elektor Electronics projects.

The microcontrollers contained in commercial equipment are best left alone because the software source files are generally not available for modification and increasing the clock speed will cut short timing loops and may cause the device to malfunction or run erratically. Our experience with off-the-shelf microcontrollers indicate that most will run quite happily (at room temperature) with a clock rate of up to 50% higher than the maximum frequency quoted in the data sheet. Despite these findings it is time for a reality check; any competent engineer would of course be asking for trouble if their latest production design relied on overclocking or stressing any component beyond its guaranteed operational envelope.

In most cases a controller can be tested by simply replacing the existing crystal with another of a higher frequency. When the circuit operates correctly it will be necessary to make changes to the firmware, taking into account the new clock speed. Routines using timing loops or timers and serial interface drivers will require modification. In some cases if the original firmware is retained a 30% increase in processor clock speed is likely to give a 30% increase in baud rate. Any timing constants in the communication routines will therefore require adaptation.

Eventually the clock increase will impact on the I/O, SCI and other serial channels. Communications with peripheral equipment will not be possible until the firmware is modified.

Unlike PCs and notebooks when a microcontroller is overclocked it produces a proportional increase in current consumption and heat dissipation in the device. And if you push the clock too far it is no surprise to find that, the controller will simply refuse to work.

Notebooks which would supersede the Celeron based machines. Intel uses a voltage level on a processor socket pin to indicate to the chipset whether the bus clock rate is either 400 or 533 MHz. The slower processor variants numbered 715, 725, 735 etc leave this processor pin B16 open-circuit while the faster types 720, 730, 740 etc connect the pin to ground (see Figure 1). What happens if we fix this pin to ground anyway using a wire jumper?

Well not much! At least nothing bad, according to reports on the Internet (try Googling with ‘pinmod’ and ‘735’ or ‘725’) it seems that the majority of ‘pin modders’ who have tried this modification on their notebooks have been successful.

The modification has no effect on the faster processors (numbers ending in zero) using a 533 MHz FSB because they already have the pin grounded. For example the mod gave no speed increase on a 1.6 GHz Pentium M 730 notebook while a 1.6 GHz ‘economy’ notebook using a 725 chip reported a 33% increase with the processor clock now at an unbelievable 2.13 GHz! Almost as fast as a more expensive 770 based machine. Reports from overclockers on the Internet indicate that the vast majority of overclocked 735 machines are completely stable.

Making a jumper
Figures 2 to 6 show the modifications carried out to the author’s notebook which is fitted with a 725 processor. Those of you who have machines from less well known manufacturers may find that the most difficult part of this mod is finding the information on how to open the notebook. Once open it should be possible to locate the processor within a few minutes. Figure 2 shows the inside of the machine with the keyboard and processor heatsink removed. The chip in the upper centre half of the picture is the processor. A turn of the large retaining screw is enough to release the processor from the socket. One thing we noticed with this particular machine was that the protective foil over the contact area (Figure 3) had not been removed from the heatsink when the machine was first assembled! The wire jumper is made from a single
The bottlenecks

The maximum clock frequency is limited by a number of factors. The most basic switching element in all microcontrollers and processors is the transistor; it makes up all the gates and logic functions inside the chip. Each transistor has a finite switching time which we cannot do much to improve once the chip has been fabricated. Each function block in the processor is designed to be able to complete its operation in the time between two clock pulses. When the clock frequency is increased beyond its design maximum it becomes more likely that the logic element has insufficient time (due to the fixed propagation delay in the transistors) to complete its function and the output value will be sampled before it has time to stabilise. The resulting incorrect value will cause the software to malfunction and eventually crash. For the sake of reliability and to ensure correct operation over the entire operating range and between production batches the manufacturer’s data sheet quotes a conservative figure for the maximum clock rate.

Temperature is also a limiting factor, each time a CMOS transistor changes state it dissipates energy. As the clock speed increases the transistor energy dissipation increases which raises the chip temperature and may lead to failure if it exceeds its rated maximum operating temperature.

An additional limitation of the transistor structure and interconnects is parasitic capacitance which must be charged and discharged when the transistor switches. With faster switching speeds the energy dissipation increases correspondingly along with the chip temperature.

The final bottleneck is the propagation speed of electrical signals along signal paths. Propagation speed can vary typically between 180 × 106 m/s and light speed (300 × 106 m/s) depending on the medium used. At first glance this would not seem to be too much of a problem but if we consider a modern CPU with a clock frequency of 3 GHz, a propagation speed of 180 × 106 m/s will dictate that a single clock period is just 6 cm long. At these elevated speeds it becomes more important to consider signal path length to ensure that data on the internal bus system is transferred when it has reached a stable state.

Figure 3.
The heat sink still fitted with a protective film.

Supply Tweaking

The bottlenecks outlined above are a function of the chip design and the materials so there is little that can be done to circumvent them. Researchers and chip designers are however continually working to improve the technology. One avenue of research involves the use of ‘faster’ materials (e.g. ‘strained silicon’) to reduce signal delay while another area concentrates on optimising the transistor geometry to reduce switching times. The most obvious method of improving switching speed is to make the structure as small as possible, this reduces the interconnect path length, the switching energy and parasitic capacitances.

All of these techniques are inherent to the basic chip architecture and the process technology, the ‘overclocker’ again has no chance of making any improvements here. The most usual type of ‘tweaking’ used in conjunction with overclocking is to slightly raise the supply voltage to the chip (checking that the device does not become too hot). The basis for this technique is that a transistor with a higher control signal will switch more quickly. Overclocked DRAM modules respond well to increased supply voltage operation as do processors.

In cases where excess dissipation in the chip is limiting the overclocking frequency it is possible to reduce the supply voltage slightly and still squeeze an extra few megahertz out of chip. A lower supply voltage reduces the energy consumed by the device, lowering power dissipation and reducing chip temperature. It also helps diminish transistor leakage losses which can form a not insignificant part of the total power consumed by modern processors.

Modern microcontrollers have not yet achieved gigahertz clock capability so the phenomenon plays less of a role in overclocking these devices. An overclocked microcontroller which is unstable may however benefit from an increase in the supply voltage by a few percent or alternatively with the above explanation in mind, a reduction of the supply voltage.
Once the modifications have been completed and the machine reassembled, a software tool such as CPU-Z can be used to measure the processor characteristics (see Figure 7). The test reports that the CPU type remains the same but the bus and CPU clock frequency have a new value.

To err is human...

Even though the modification suggested here should be relatively easy to perform there is undoubtedly room for error, if you are in the habit of making a sow's ear out of a silk purse then it's probably wise to keep the notebook well and truly buttoned up. Any intrepid reader planning to go ahead with the modification should at least equip themselves with a decent set of cross-headed screwdrivers (hopefully of better quality than ones you sometimes get in Christmas crackers) and some tweezers.

Reports from Internet-based forums indicate that the Celeron M 350 to 380 and Pentium M 715 to 735 are good candidates for overclocking. A 735 series can be clocked as low as 2.26 GHz while 745 types can be persuaded to run at 2.4 GHz but not always reliably. Incidentally is it quite rare to find 400 MHz DDR2 RAM (specified as PC3200) fitted to notebooks, it is far more common to find the faster PC4200 memory which is suitable for use with a 533 MHz clock. Overclockers should ensure that their RAM can handle the speed increase. All is not lost if the processor in your machine does not have a 3 as its last digit; it has been known for owners of 730 or 740 series notebooks to sell them and buy a lower spec 725 or 735 series replacement which they then proceed to overclock. The result is a faster notebook and with any luck a small profit.

A useful free program for the intrepid pin modder is 'Notebook Hardware Control'. The program allows control of the notebook hardware components including system power management. The voltage supply to most processors is typically 1.3 V or above but it is often the case that they run reliably under full load with a supply of 1.2 V or less. The freeware program Prime95 is the overclockers' program of choice to test the stability of modified machines. The program loads the processor at 100% and the machine is assumed to be "prime stable" if it runs the test for 24 hours without any errors. This is particularly good at detecting any instability caused by a modification to the processor supply voltage.

Finally it should be noted that tinkering with the insides of a Notebook is a good way of invalidating the guarantee, ideally the machine will not be under warranty and you must be prepared to accept full responsibility for any damage that may be caused by following any of the suggestions contained in this article.

Web links

Pinmod advice for Fujitsu-Siemens Notebooks:
www.amilo-forum.com

The 'Dothan' CPU datasheet is available from:
download.intel.com/design/mobile/datasheets/30218908.pdf

The 'Notebook Hardware Control' program is available from:
www.pbuses-167.com/nhc/nhc.htm

Stability testing can be performed with Prime95:
www.mersenne.org/freesoft.htm
Sputnik Time Machine

Nostalgia and microcontroller technology merged in a single design

Dieter Laues

Sputnik 1, the first artificial satellite, was launched in 1957. It captured the attention of the entire world with the eerie beeps it transmitted, which could be received by radio amateurs everywhere in the world. Fifty years after this historic event, it seems fitting to build a clock in the shape of the Sputnik satellite that combines a nostalgic Nixie tube display with a modern microcontroller.

Technology has changed a lot in recent decades. Launching a satellite that simply transmitted a beep signal was a major achievement in 1957, but now we routinely put satellites into orbit that can transmit hundreds of television channels. This design uses a combination of modern and old-fashioned technology. The shape of the Sputnik and the Nixie tubes are elements of old-fashioned technology, while the low-loss switching regulators for the supply voltages and the microcontroller-based control logic are examples of modern technology.

Nixie tubes

Nixie tubes were introduced commercially in 1954 to display numbers in electronic equipment. A Nixie tube is a cold-cathode valve, which means it does not have a heated filament. The valve thus remains quite cool during operation. The valve is also not evacuated, but instead filled with a gas mixture consisting primarily of neon. If a sufficiently high voltage is applied to the electrodes, the gas molecules around the cathode become ionized and emit light ranging in colour from reddish-orange to purplish. The valve contains a separate cathode in the form of a numeral for each digit to be displayed.

‘Nixie’ is a trademark name given to these valves by the Burroughs Corporation, which incidentally didn’t actually develop them but instead purchased the company that developed them, Haydu Brothers Laboratories.

Schematic diagram

The clock is controlled by a small microcontroller — an Atmel 89C2051, which has 2 KB of flash memory. The digit cathodes of the Nixie tubes are driven by type 74141 driver ICs. Although these ICs may appear to be standard TTL devices, they are specially designed to handle the high voltage level of Nixie tubes. Like the Nixie tubes, they are readily available through ‘regular’ commercial channels. We thus strongly advise readers who want to build this clock to first see whether they can find these parts before they invest in the rest of the hardware. The first digit of the display,
which shows tens of hours, is driven by two discrete transistors instead of a driver IC—since only the numerals '1' and '2' are necessary.

The power supply section consists of two independent switching regulators, each of which is built around an MC34063 general-purpose PWM regulator IC. IC5 operates as a step-down converter and provides +5 V for the low-voltage portion of the circuit. IC6 operates as a step-up converter and provides the high voltage for the Nixie tubes. FET T1 is included in the circuit because the MC34063 is not rated for operation above 40 V. One of the advantages of not using conventional voltage regulators is that the circuit is not choosy about the raw input voltage, so an AC mains adapter with an output voltage in the range of 14–25 V can be used. In addition, this power supply arrangement generates relatively little heat. This is important because the circuit is fitted in a closed housing and would otherwise become quite warm.

**Software**

The software is written in assembly language. This yields a very compact program that implements a 24-hour clock, the user interface, display brightness control, and smooth display transitions in just 568 bytes of code. The clock operates on the usual principle of dividing down the interrupt rate of the timer interrupts. The information to be displayed in hours and minutes is output in BCD format via I/O ports to the Nixie drivers. The tens of hours digit forms an exception here. As only the '1' and '2' have to be driven here, only two output lines are necessary. There is only one user control, consisting of a pushbutton that can be used to set the time, adjust the brightness, and display the software version number. Refer to the inset for the details of the operator interface.

The brightness of the Nixie tubes is controlled by varying the duty cycle of the drive signals instead of varying the anode current. Every time the minutes display changes, the clock makes a smooth transition from the one number to the next. This is also implemented using the variable duty cycle. The duty cycle of the old number decreases gradually while the duty cy-
Use sockets for all of the ICs. Then turn the board over and solder the Nixie tubes on the copper side of the board. It is a good idea to trim the leads of the Nixie tubes stepwise and then insert them in the holes in pairs starting with the longest ones, since it is rather difficult to get all the leads into the holes if they all have the same length. Align each Nixie tube exactly perpendicular to be board before soldering the leads.

**Initial checkout**

Start by fitting only the voltage regulator ICs (IC5 and IC6) in the sockets, and check the polarity of C8 before plugging in the AC mains adapter. Then use a meter to check the supply voltages. The voltage for the low-voltage portion must be +5 V, and the voltage on C8 (for the Nixie tubes) must be approximately +180 V. If everything’s OK, you can unplug the AC adapter. Be sure to give C8 enough time to discharge before proceeding further. (Caution: high voltage!) After this, you can fit the remaining ICs. After being powered up or after a voltage dropout, the display shows a blinking value of '000'. The default brightness value is set to '7'. The time is shown in the European 24-hour format. A zero in the first digit is not displayed, so this digit remains dark every morning until 10 o’clock.

**Mechanical construction**

We know that electronics hobbyists often find it difficult to do a nice job of fitting a circuit in a rectangular enclosure, so how can we expect them to manage with a spherical enclosure? The answer is that it takes a certain amount of skill and patience.

Transparent plastic balls are available in hobby shops. For this project, we used one with a diameter of 10 cm, consisting of two hemispheres. In one of these hemispheres, we drilled holes for the three legs (along the upper rim), the control pushbutton (lower middle), and power supply connector (diagonally to the rear). You must drill carefully. The best results can be obtained using a drill press, but if necessary you can manage with a battery-powered drill. Drill the holes from the inside with the material supported on a firm surface, since otherwise the plastic can crack. The legs are made from aluminum rods, which you can buy in a DIY shop by the metre. Cut three lengths of 15 cm and bend one end of each rod in a vice (depth of bend approximately 2 cm) to give them the right shape. The angle of the bend should be approximately 90 degrees. The sharper the bend, the closer the legs will be together in the assembled clock. The legs must all have the same shape (as close as you can manage), since otherwise the finished clock will stand crooked. After bending the ends of the legs to the right angle, cut a 4-mm thread on the short end of each leg.

Cut a round cover plate for the circuit board from a sheet of plastic. Make a hole for the fastening screw in the middle and four larger holes for the display. Before assembling the clock, paint the bottom hemisphere and (if you wish) the cover plate. Spray-paint consists available in DIY model shops are quite suitable for this. After painting the ball black, you can use silver paint to give it a 'starry sky' effect by pressing the spray button very lightly. You can also use an airbrush to create attractive effects. Here you can give your creativity free rein, but make sure the paint

---

**Operating instructions**

**Setting the time**

1) Press and hold the button until the hours display starts blinking. After this, the time will be advanced by 1 hour each time you press the button briefly.

2) Press and hold the button until the minutes display starts blinking. After this, the time will be advanced by 1 minute each time you press the button briefly.

3) Press and hold the button until the display returns to non-blinking mode. The seconds are set to 0 at this time.

**Setting the brightness**

Press the button briefly. The current brightness setting will be displayed. The brightness setting is increased by 1 each time the button is pressed briefly, from 01 (minimum) to 09 (maximum). The clock returns to the time display mode if the button is not pressed for several seconds.

**Displaying the version number**

With the AC mains adapter unplugged, press and hold the button while plugging in the adapter. The version number of the software will then be displayed (such as '1.07'). After releasing the button, you can set the time as described above.
use compatible with the plastic of the ball otherwise you may end up with an unattractive, spotty surface. You can also use a transparent cover coat to protect the paint against scratching. Another option is to paint the inner surface of the ball. Although the colours may not be as bright with this option, the paint coating is absolutely scratch-resistant.

After the painting is finished, you can assemble the clock. Thread an M4 nut onto each of the three legs and then fit the ends of the legs through the holes in the ball. Secure each of them with a second M4 nut on the inside. Before tightening the inner nut, fit a length of copper wire with a loop formed on one end. Later on, you can solder the circuit board to these three wires to secure it in the enclosure.

Next, fit the power supply socket and the pushbutton and connect them to the circuit board with flexible wire leads. Finally, align the circuit board so it is level and solder it in place on the three copper wires, and then fit the cover board.

After checking to ensure that everything works properly, you can fit the top half of the ball.

**COMPONENTS LIST**

**Resistors**

- R1, R2, R3, R4 = 15kΩ
- R5 = 100kΩ
- R6 = 750kΩ
- R7 = 5kΩ
- R8 = 1.5kΩ
- R10 = 68kΩ
- R11 = 22kΩ
- R12 = 1Ω
- R13, R14, R15 = 10kΩ

**Capacitors**

- C1 = 1000μF 25V
- C2 = 470μF
- C3 = 100μF
- C4 = 470μF 16V
- C5 = 470μF
- C6 = 100μF
- C7 = 100μF
- C8 = 4.7μF 400V
- C9 = 100μF
- C10, C11 = 33μF
- C12 = 1μF

**Inductors**

- L1, L2 = 330μH

**Semiconductors**

- D1, D2, D3, D4 = 1N4003
- D5 = 1N5819
- D6 = BYV26C
- T1 = IRF820
- T2, T3 = MPS462
- IC1 = 89C2051, programmed, order code 050018-41
- IC2, IC3, IC4 = 74141
- IC5, IC6 = MC34063

**Miscellaneous**

- Q1 = 12.000MHz quartz crystal
- AN1, AN2, AN3, AN4 = ZM1332
- IC sockets: 2 off DIL 8-pin; 3 off DIL 16-pin; 1 off DIL 20-pin
- PCB, ref. 050018-1 from ThePCBShop
- Source and hex code files, free download #050018-11.zip from project page at www.elektor-electronics.co.uk
- Drilling templates, free download #050018-W.zip, from project page at www.elektor-electronics.co.uk

Web links

Mike's Gallery — a collection of several types of Nixie clocks

www.electricstuff.co.uk/nixiegallery.html

A recording of the original Sputnik beeps

www.muenster.de/~damberg/Sputnik.htm
E-blocks Starter Kits now with a 30% discount!

E-blocks AV-R-Kit
- C for AVR microcontrollers single user: £118.00
- E-blocks AVR multiprogrammer: £77.65
- E-blocks LED board: £14.65
- E-blocks LCD board: £19.90
- E-blocks Switch board: £14.65
Total value: £244.25
Special Offer: £171.80

E-blocks Easy Internet Kit
- Flowcode Professional: £118.00
- E-blocks LED board: £14.65
- E-blocks LCD board: £19.30
- E-blocks USB Multiprogrammer: £77.90
- E-blocks Switch board: £14.65
- E-blocks Internet board: £71.95
- PIC16F877: £10.50
- Ethernet 'crossover' cable: £5.30
Total value: £311.65
Special Offer: £232.50

E-blocks Easy ARM Kit
- C for ARM microcontrollers single user: £118.00
- E-blocks ARM programmer: £89.20
- E-blocks LED board: £14.65
- E-blocks LCD board: £19.30
- E-blocks Switch board: £14.65
Total value: £266.60
Special Offer: £171.80

E-blocks Easy CAN Kit
- Flowcode Professional: £118.00
- E-blocks LED board: £14.65
- E-blocks Switch board: £14.55
- 2 x E-blocks LCD board: £39.60
- 2 x E-blocks USB Multiprogrammer: £154.60
- 2 x E-blocks CAN board: £67.00
- 2 x PIC16F877: £21.00
Total value: £426.60
Special Offer: £299.00
Ho! Ho! Ho! Christmas 2006 is on it’s way!
BUT DON’T PANIC!
We have some fantastic gift ideas for young (and old) enquiring minds

Electronic Project Labs
An electronics course in a box! All assume no previous knowledge and require NO solder. See website for full details.

- Robot Sensor - £19.95
  Order Code EPLR20KT
- Digital Recording Laboratory - £29.95
  Order Code EPLDRKT
- AM-FM Radio Kit - £6.95
  Order Code EKAFKT
- Short Wave Kit - £6.95
  Order Code ERKSKKT
- Crystal Radio Kit - £6.95
  Order Code ERKCKKT
- 30 in ONE - £15.95
  Order Code EPL030KT
- 130 in ONE - £37.95
  Order Code EPL130KT
- 500 in ONE - £149.95
  Order Code EPL500KT

Solderless Electronic Project Kits

- Electronic Bell - £8.95
  Order Code EAKEBKT
- Electronic Motor - £8.95
  Order Code EAKEMKT
- Generator - £8.95
  Order Code EAKEGKT
- Hand Held Metal Detector - £9.95
  Order Code ELMDX7KT
- Metal Detector - £9.95
  Order Code ELMMDKT

Mechanical Motorised Wooden Kits
Future engineers can learn about the operation of transmissions steered through gears or pulleys. Easy to build, no glue or soldering required.

- Stegomech - £12.95
  Order Code C21-602KT
- Tyrannomech - £12.95
  Order Code C21-601KT
- Automech - £12.95
  Order Code C21-605KT
- Coptermech - £12.95
  Order Code C21-604KT
- Musical LED Jingle Bells - £17.95
  Order Code 1176KT
- Trainmech - £12.95
  Order Code C21-606KT
- Robomech - £12.95
  Order Code C21-603KT
- Flashing LED Christmas Tree - £6.95
  Order Code 4080KT

See our website for even more great gift ideas!

www.QuasarElectronics.com

Secure Online Ordering Facilities • Full Product Listing, Descriptions & Photos • Kit Documentation & Software Downloads
Berlin Clock Remake
Using the SPI bus

Prof. Dr. Bernd vom Berg and Dipl.-Ing. Peter Groppe
(Georg Agricola University of Applied Sciences, Germany)

In the world of unusual timepieces one example stands out: the Berlin clock, which has been showing the time since 1975 using an ever-changing pattern of lights. Our version imitates the original using an LED display controlled over an SPI bus.

The original Berlin clock [1] was designed by local engineer and inventor Dieter Binninger as a mathematics teaching aid and was installed in 1975 in an upmarket shopping area in the city. The construction, seven metres high, shows the time using a number of lamps, mostly arranged in groups of four. At the time new mathematics teaching methods were being introduced, giving rise to heated discussions; perhaps not coincidentally the clock rapidly became famous.

By the end of the 1970s a desktop version had become available, using a Texas Instruments TMS1000 4-bit processor (the first mass-produced microcontroller); models are still for sale with almost identical external appearance [2]. A quick trawl of the Internet for 'Berlin clock' turns up not only photographs and information, but also a number of PC-based programs to emulate the clock [3].

We published a variation on the Berlin clock in the Summer Circuits issue of 1998 [4], using a DCF-77 module and a PIC16C54. In a future issue we will also describe another variation: a binary clock.

That example, designed by Professor Beutelsbacher for the 'Mathematikum', an interactive mathematics exhibition centre in Giessen, German...
Figure 1 shows. The time is shown using a series of rows of lights where each lamp is assigned a 'weight'. From the top row to the bottom row each lamp represents one second, 5 hours, 1 hour, 5 minutes and 1 minute. In the version described in this article we use 24 LEDs rather than lamps, but still arranged according to the original layout (Figure 2). At the top centre is a green LED which flashes at 1 Hz. The second row consists of red LEDs and the third row yellow LEDs. So that it is easier to read the quarter hours from the LEDs in the third row, every third one is red rather than yellow.

Components

There are two main parts to the design: the example clock software, written in C for an 8051 microcontroller, and the clock display. Figure 3 shows the block diagram of the system.

Almost any microcontroller system could be used, as long as it has three or four spare digital I/O port pins and either a real-time clock circuit or a radio timecode receiver. Alternatively, a real-time clock could be implemented purely in software.

The authors used a board that they developed themselves, featuring an Atmel AT89C51CC03 microcontroller from the popular 8051 family. The board also sports a 72421 real-time clock IC, although it would also be possible to receive and process DCF-77 signals.

The software reads the time from the real-time clock and generates the necessary control signals on the SPI bus, which connects to the clock display board.

The display board carries an SPI-compatible LED driver IC type MAX7219. Driving this device over a standard SPI bus gives the advantage that almost any microcontroller system can be used as the master, whether based on 8051, 80C, ATMega or PIC. The only point to bear in mind is that it must be possible to create the LOAD, CLK and DIN control signals of the SPI bus using the hardware, or that the selected microcontroller must already provide an on-chip SPI bus interface. In the latter case the communications software required is extremely straightforward.

MAX7219

This device is capable of driving up to 64 individual 20 mA LEDs using a multiplexing scheme. The most important

Sign of the times

However, it is not so difficult to interpret the display of the Berlin clock, as
features of the MAX7219 are listed in Table 1, and a more thorough description of the device can be found in its datasheet [5]. We will give a brief overview here.

The basic functions of the driver IC are controlled using six registers. The LEDs are arranged in eight groups of eight LEDs each; these can either be considered as eight seven-segment displays (plus decimal points) or as 64 individual LEDs to be driven in any desired pattern. This allows for flexibility in the arrangement of the display, and the use of different-sized LEDs (although they must all be 20 mA types).

**SPI bus**

As we can see in Figure 3 communication between microcontroller and MAX7219 using the SPI bus requires just two power supply connections and three digital I/O port pins, namely:

- **LOAD**: enable/transfer signal for communicated data;
- **DIN**: serial data transfer;
- **CLK**: clock signal for data transfer.

It is very easy to control the MAX7219 from the microcontroller in software using these three signals. The basic SPI signal timing diagram is shown in Figure 4. Transferring data to the device proceeds in four phases:

1. **Quiescent.** The LOAD and CLK control signals start in their quiescent states, LOAD being high and CLK low.

2. **Initiation of data transfer.** Before the data (in the form of two-byte, or 16-bit, packets) are sent to the MAX7219 the LOAD signal is taken low.

3. **Data transfer.** The microcontroller presents the first bit on the DIN data signal. The bit is written to the MAX7219 by setting the CLK signal high; on the rising edge of CLK the data bit is clocked into a shift register. The CLK signal is then taken low again. This procedure is repeated a further 15 times so that all the relevant data bits are clocked serially into the shift register. The maximum clock frequency is 10 MHz.

4. **Termination of data transfer.** Immediately after the 16 data bits have been transferred the LOAD signal must be set high again. The rising edge of the LOAD signal tells the MAX7219 that the data transfer is complete and that the data bits in the receive shift register can be processed. This last step is very important: if LOAD is not returned high the data bits will remain in the shift register and not be processed.

In our application the SPI bus is driven using three spare ordinary port bits of the microcontroller using the so-called ‘bit-banging’ technique:

- LOAD is connected to port pin P3.5,
- DIN to P3.3 and
- CLK to P3.4.

These port pins are available on practically every 8051-family device and so the SPI driver software can be used on most of these microcontrollers without modification. If the pins happen to be used for some other function, it is a simple matter to change the code to use other pins.

For correct operation of the MAX7219 each message must consist of two bytes (16 bits) sent consecutively on the SPI bus. The first byte contains the address of an internal control or data register in the device and the second byte contains the data to be written to it.

Full source listings and object code for the C program written for the AT89C51CC03 are available for free download from the Elektor Electronics website.
Circuit diagram and printed circuit board

Thanks to the use of the SPI bus and the MAX7219 the circuit diagram (Figure 5) and the display printed circuit board could hardly be more simple. Besides the MAX7219 and the 24 LEDs there is also a DC piezo buzzer on the board, which allows an alarm function to be added to the clock.

A simple way to connect the display to the microcontroller master system and power supply is to use a 6-pin mini-DIN connector: this conveniently allows the use of ready-made PS/2 mouse extension cables.

The printed circuit board layouts are too large to reproduce in this article hence are available for free download from the Elektor Electronics website, www.elektron-electronics.co.uk. Note that the display board is populated on both sides, the LEDs being soldered to one side and the other components to the reverse. This has the advantage that the display can be fitted behind an attractive front panel, making the device an eye-catching and functional addition to any living room, office or desk. All you need to do now is prepare yourself to explain to every visitor how to work out what time it is!

Finally, the author can supply unpopular circuit boards and aluminium front panels (www.palmtec.de).

[1] Information on the original Berlin clock:
http://www.surveyor.in-berlin.de/berlin/uhr/indexe.html

[2] Berlin clocks for sale:
http://www.berlin-uhr.com/ (in German)

[3] A Berlin clock for your PC:
http://www.tucows.com/preview/167639
http://widgets.opera.com/widget/4256
http://www.widgetgallery.com/view.php?widget=35808 (also available for Mac)

[4] Martin Raschke:
Berlin Clock, Elektor Electronics, July/August 1998, p. 87

[5] MAX7219 datasheet:
http://www.maxim-ic.com/quick_view2.cfm/qv_pk/1339
KCS TraceME
GPS/GPRS/SMS Module

Why buy TraceME products?

1. monitor your fleet with GPS/GPRS/SMS
2. monitor your staff in any country
3. send messages to/from your people
4. monitor your machines wireless via internet
5. update machines worldwide with your PC
6. sufficient I/O for sensors etc.
7. iButton auto start safety device
8. guard properties via mini camera
9. unlimited applications possible
10. Dutch design
11. Dutch production and support
12. Satisfied customers:

- IMTECH
- DUTCH POLICE FORCE
- PORTUGUESE FIRE DEPARTMENT
- AGGREKO GENERATORS
- SKYNET MOBILE
- UK GOVERNMENT
- MOTOROLA DUBAI
- AFRICAN OIL COMPANIES
- GERMAN ROADSERVICE
- and many others worldwide

TraceME mini SPY camera watches over your belongings and transmits pictures via GPRS. Watch them via your web browser.

Communicate in your car with the office or with another vehicle via a.o. SMS with the TraceME LCD module. Secure your vehicle with the help of an iButton start.

(c) KCS BV, Kuipershaven 22, NL-3311AL Dordrecht. Fax: +31 20-5248130 www.TraceME.eu kcs@kcs.tv
Very low price

Track & Trace all your people, machines, cars etc.

A TraceME solar version can be supplied for situations where no fixed power source is available.

TraceME application areas

Medical:
Monitoring transport of organs, stem cells, blood, etc. Amambulances and other transports.

Measurement & Control engineering:
Wireless distance control of generators, all equipment with an SPI or RS232-interface. Climate control.

Services & Logistics:
Tracing transports:
Busses, cars, lorries, taxis, fire engines, river craft, trailers (also on solar energy)

Cold-storage engineering:
Detection of temperatures during cold-storage transport and alarm signals when deviations occur.

M2M (machine to machine)
Pilot/control your machines/pumps etc. via the internet without the help of mechanics.

Security/safety:
Buildings with or without miniature cameras and/or sensors via wireless transmission.

Police:
Various police services have already been equipped with TraceME modules + cameras in various countries.
Text at the Speed of Elektor

A secondary school project was the starting point for this ingenious creation, which uses just eight blue LEDs to produce a scrolling text display with 360-degree all-round visibility. A more economical way of building a giant display device would be hard to imagine...

Steffen Sorge

The idea for constructing this display arose at a brainstorming session on our project for the school-leaving examination, what we call an 'Abi-Denkmal' (literally 'exam memorial' in Germany). This advanced level final exam involves an assignment to create something entirely original, a task in fact that at the author's school was traditionally undertaken by the electronics students. The original stimulus arose from bedside alarm clocks that function along similar lines. However, these inexpensive products from the Far East indicated only the time, not any text.

The first prototype was created in just one day using the following parts: eight LEDs from the junk box, a switch for synchronising the start of the message display, an AT90S2313, a PP3 (6F22/R222) 9-volt battery and a few other scrap components were mounted on a small wooden batten. The whole affair was then attached to the drive shaft of a small DC motor and set in motion. After a little programming effort were we rewarded with a display reading out the word 'Hallo'. However, this initial prototype (just like in 'Modding & Tweaking' projects — Ed.) had a number of shortcomings: The LEDs were not bright enough, the life expectancy of the switch was alarmingly short (little wonder: it operated with each revolution of the motor).

Having a rotating battery was not the cleverest idea...

Problems exist to be solved. The first task was to source some ultra-bright blue LEDs with an intensity of 3500 mCd. Next problem solved was the switch: we obtained a Hall effect switch from an old printer. The battery was replaced by a proper mains power supply and a slip ring. And finally the AT90S2313 made way for an ATmega8.

A controller for eight LEDs

As the circuit diagram (Figure 1) indicates, the functional circuitry comprises just a microcontroller (IC1), which drives the eight LEDs and is linked to the Hall sensor (IC3). As regards external components, the controller requires only a 16 MHz crystal (X1) with
two resonating capacitors (C4 and C5). Voltage regulator is the trustworthy old 7805 (IC2).

As the microcontroller cannot source enough current for pulsing the hefty LEDs, a follower stage comprising transistors T1 to T8 is provided. The eight rotating LEDs 'write' an image built up from eight lines of light (not from left to right of course but in continuous 360-degree rotation) and for this reason the microcontroller needs to be synchronised with what in TV or computer displays we would call a frame pulse, a signal indicating the start of a new image. This task is handled by the Hall switch (IC3), which alters its output level when it detects a magnetic field (in the vicinity of a magnet in other words). Its normal state produces a 'high' output that goes 'low' on approaching a magnet. This change of level sets in motion the process of building up the image, which the software in the microcontroller looks after.

**Software**

The ATmega8 is an AVR controller by Atmel, belonging to the family of RISC controllers (with reduced control set). The program for the rolling text is not written in Assembler, however, but in the well-known BASCOM AVR-BASIC language. This software, along with extremely very detailed annotations, can be downloaded freely from the Elektor Electronics website (data file 050014-11.zip). The program produces small image elements representing text fragments relating to character strings stored in the controller. These text fragments are...
The software produces the following characters: capital letters from A to Z (including the accented letters Â, Ô and Ú), a null or space symbol, question mark, exclamation mark, full stop, comma and hyphen.

A subroutine is programmed for each character, making it straightforward to substitute or alter these symbols. A subroutine consists simply of multiple write commands to Port D, which controls the LEDs. Each write command is followed by a brief pause created by a Wait loop.

Each Write command creates one column of the relevant character, which is composed of several of these columns each having eight pixels vertically. This makes it easy to design a character on squared paper and transpose the columns from left to right into Bytes. If you visualise the Wait loop (subroutine 'Wa') in the source code, it is easy to work out how a character will actually be selected (variable 'Strz'). At the end of the third text segment the display reverts to the first segment of text and begins again.

If you significantly vary parameters such as rotational speed and diameter of the rotating LEDs, then a few alterations need to be made to the program: Using a different radius (rotor arm length) the number of characters visible in the 'display' (diverging from 30) must be adjusted (at two locations in the program).

Alteration to the number of revolutions per minute requires adjustment of the pixel length (subroutine 'Wa').

The text readout speed (the rate at which the text scrolls) can be varied. The number of text segments can be increased (this requires a controller with greater memory storage, however).

Circuit construction

The circuitry is relatively easy to construct by following the circuit diagram. As the DIL version of the ATmega8 is used (ATmega8-16PU), there are no surface-mounted devices or other problematic issues to contend with. Resistors R9 to R16 must be selected according to the nominal current of the LEDs used. They can be calculated simply as series resistors for 5 V. The sample set-up used a value of 56 Ω.

To assist construction you can download the author’s circuit board layout and component plan together with the component list from the Elektor Elco-
tronics website (January 2007 items). You do, however, need to note that the designations used on the component plan may either vary from those shown in the circuit diagram (Figure 1) or else may not be shown at all. However, the circuit board does correspond with the diagram electrically and can always be cross-checked in case of doubt.

A rectangular format was selected for the circuit board, matching the dimensions of the rotor arm, with a separate smaller board provided at the end of the arm for the LEDs mounted one above the other (see photos). To make the 5-mm LEDs align with the hole spacing of normal 2.54-mm-spaced perf-board, the LED bodies need to be flattened a little with a file on two opposite sides (don’t overload this). The LED board is connected to the other board using a length of 9-conductor flat ribbon cable. The anodes of the LEDs are connected with one another and to +5 V, whilst the cathodes are wired to the series resistors provided (R9 to R16). D2 (linked to R1) is the uppermost LED on the board and D9 (linked to R8) is the bottom LED. If the LED array is wired the wrong way round (D9 on top, D2 below), the text will appear upside down!

**Programming**

The free download 060014-11.zip contains .bas, .hex and .bin files. The .bas file holds the source code in ‘Bascom’ format. The .hex or .bin data can be flashed direct into the ATMega8 and is then ready to run. The data supplied will produce scrolling text of the demonstration message programmed by the author.

If you would like to program your own text you will need Bascom. For this open the file Schrift.bas and change the contents of the array INSTRING. All that remains to do is press F7 to compile the new source code.

After connecting the operating voltage (9 to 12 V) the controller can be programmed. To do this you link the programming connections (K1 on the circuit diagram) via a suitable programmer (PonyProg for example) with the PC and flash the file Schrift.bin or Schrift.hex into the chip (set fusebits externally to 16 MHz).

If you would like to try compiling with the free BASCOM-AVR DEMO 1.11.3 software you will need to restrict the length of your text and avoid filling the INSTRING array with three texts, since the demonstration version will not compile more than 4 kB of code.

**Mechanical matters**

For the ‘rotor’ an arm made of sheet aluminium about 50 cm long was used. At the centre of the arm you need to fix a small bush that needs to be connected with good electrical conductivity to the drive shaft of the motor. The return wire is screwed or otherwise clamped to the casing of the motor. A slip ring of clean printed circuit board material (not the sort that are pre-coated with photosensitive lacquer) is fixed to the upper surface of the motor and wired up to the positive (plus) side of the voltage source. Above the slip ring a small carbon brush is fixed on the rotor arm in an insulated mounting to avoid contact with the aluminium sheet. Finally a magnet is fixed to the motor casing in such a position that the Hall sensor mounted on the rotor arm passes through its magnetic field at each revolution and is thus activated.

The circuit board is now fixed to the rotor arm (ideally without putting it out of balance). Power supply arrangements involve wiring the return (ground) connection on the circuit board to the bush on the drive shaft and the positive connection to the carbon brush. If the arm remains unbalanced this can be corrected by using compensating weights.

The power source (a 9 to 12 V plug-in power supply) can now be connected up to the slip ring (positive connection) and the motor casing (ground return). The current drawn by the circuit is set mainly by the total draw of the LEDs, to which you must add that of the motor if the same power supply is used for both.

As soon as the power is connected and the arm rotates scrolling text should be visible on the ‘display’—just like in the photo at the beginning of the article...

**PS**

The author was successful not just with this special assignment but also with his final exams, and is now studying Electronics and Information Technology at the West Coast Technical College in Keilde, Germany.
The Vinculum family of USB Host Controller not only handles the USB Host interface and data transfer functions, but owing to the inbuilt processor core and embedded Flash memory, Vinculum encapsulates the USB device classes as well. When interfacing to mass storage devices such as USB Flash drive, digital camera, or PDA, Vinculum also transparently handles the FAT File structure communicating via UART, SPI or parallel FIFO interfaces via a simple to implement command set. Vinculum provides a new cost effective solution for providing USB Host capability into products that previously did not have the hardware resources available.

**Future Technology Devices International Limited**
373 Scotland Street, Glasgow, G5 8QB, United Kingdom
Tel: +44 (0) 141 429 2777  Fax: +44 (0) 141 429 2788  Email: vinculum.sales@ftdichip.com
Vinculum Evaluation Modules & Application Areas

The **VDIP1** module is an MCU to USB Host Controller development module for the VNC1L device and is ideal for rapid prototyping and development of VNC1L designs.

- Jumper selectable UART, SPI or FIFO MCU interfaces
- USB "A" type socket to interface with USB peripherals
- 2nd USB Interface available via module pins if required
- Single 5V supply input
- Auxiliary 3.3V/200mA power output to power external logic
- Traffic Indicator LEDs

**VDRIVE1** is possibly the easiest solution for adding a USB Flash Drive interface to existing products. Only four signal lines plus 5V/GND are required to be connected.

- One USB "A" socket to connect to USB Flash Drive
- Link Selectable UART or SPI interface
- Only 4 signals to connect excluding PWR/GND
- Single 5V supply required
- Easy to implement command set

**VMUSIC1** is a product that not only lets you add USB Flash Drive interfacing to your product but allows you to play back MP3 and other popular digital music formats direct from a USB Flash Drive.

- One USB "A" socket to connect to USB Flash Drive
- Stereo 3.5mm headphone jack socket and audio line-out connector for audio playback.
- Link Selectable UART or SPI interface
- Only 4 signals to connect excluding PWR/GND
- Single 5V supply required
- Easy to implement command set

VINCULUM: IMAGINE WHAT YOU COULD DESIGN WITH IT...

http://www.vinculum.com
Scoot me up, Scooter

Christian Tomanik

Engine tuning for scooters (and mopeds) has always been popular. In the past this could only be done mechanically and required a certain level of know-how. In the present electronics age there are other ways of boosting the engine power of scooters.

The number of ways in which scooters can be tuned is still relatively small compared to those for cars. There are some very innovative concepts, however. But what is practical and what do you need to do? To answer that we first take a look at the basics of tuning.

Tuning

There are two types of tuning: increasing the engine power, or limiting it. Let’s start with a look at the latter.

There are many different ways of mechanically limiting the engine power, such as limiting the amount of fuel mixture fed to the engine or reducing the size of the exhaust port. But there are also electronic solutions. Many modern scooters come with electronic rev limiters. With contemporary scooters you often find they have a combination of mechanical and electronic limiters.

One way in which to limit the revs is to interrupt the ignition. Once a certain speed (and hence a certain number of revs) has been reached, the ignition is interrupted for one or more cycles of the engine. This stops the scooter from speeding up any more.

This type of limiting can be implemented with a specially designed CDI unit (see inset). But there are also other control circuits that take care of the limiting. These are fitted between the normal CDI unit and the ignition coil.

If you want to remove the limiting you’ll either need to remove the control circuit or change the CDI unit. It may of course also be possible to adapt the CDI unit or control circuit via dedicated hardware and/or software.

Where a control circuit is used, it is of course very easy to bypass it. A simple switch can be used to make the scooter work with or without the limiter. However, bypassing the limiter like this is of course illegal. Apart from the electronic limiter there is often a mechanical limiter as well, in the form of a disc that stops the Varioomatic (see inset) from going into its top 'gear'. This disc should also be removed when the rev limiter is bypassed, otherwise the engine may be damaged at high revs.

These days there are better limiters available, which continuously adjust the ignition rather than interrupt it for a longer period. These reduce the production of harmful gasses and oil residues in the exhaust.

How to get started

First of all, we have to make clear that all tuning activities that change (increase) the power and maximum speed have to be approved and noted by the relevant authorities. Otherwise the scooter will be uninsured and can’t be used on public roads.

In practice there is hardly any difference between the electronic tuning of scooters and chip tuning of cars. In both cases we make use of the inherent tolerances designed into the engine by the manufacturer, in order to improve the engine performance and increase its power. As an example, the ignition table is modified, with the assumption that you’ll only use the proper fuel and top-grade oil.
Scooter tuning without getting your hands dirty

There aren't really that many parameters that can be adjusted for scooters, and certainly not as many as for cars. The most important, and often the only ones, are the previously mentioned ignition table, a few control parameters and the maximum number of revs. Electronic tuning with the aim to increase the power is therefore mainly used in scooters when mechanical changes are made at the same time. The CDI can then be adapted for these changes, to obtain the best performance from the engine.

**GameBoy**

As you will have gathered from several past *Elektor Electronics* projects, the Nintendo GameBoy console is not limited for use as a games computer. It is also perfectly suitable for many other applications. Taking this one step further, the German firm AlphaTechnik [2] has designed a dedicated hardware/software add-on for this games computer. The result is the SpeedController, a complete tuning and diagnostic instrument for scooter workshops. It can be used to adjust both the maximum speed as well as the power (either increasing or decreasing them). Limiting the maximum speed doesn't automatically mean that there has to be a reduction in power. If you take a look at the graph for the power output of a Peugeot Ludix city scooter ([Figure 1](#)) you'll see that a (legal) speed limit of 25 km/h doesn't stop you increasing the number of HPs. The increase in power is possible because the manufacturers have designed large tolerances into the engine. A big advantage of this type of tuning is that everyday riding in traffic becomes a lot easier and the fuel consumption becomes better. After all, the throttle no longer has to be turned all the way just to get the scooter moving.

With the use of the SpeedController it is also possible to remove the speed restriction completely. This is done using a PIN number, but this can only be used one time. This means that once the restriction has been removed it is no longer possible to enable it again at a later date. This stops people from temporarily putting back the speed limiter for the MOT or police patrol or removing it again afterwards. This is the result of a strict EU directive, which came into being to reduce the tampering with the limiting systems, or even make it impossible to make changes.

**Summary**

These days there are several tuning methods for scooters that are relatively easy to install and which can either increase or limit the power. You should keep in mind that bypassing, or tampering with, the limiters is illegal. In some countries it is permissible to increase the power within reason (up to about 4.5 kW or 6 HP). One advantage of this is that the fuel consumption improves, which leads to fewer harmful exhaust gas emissions. You'll also find that the riding experience is more fun, which (if we're honest) is what it's all about.

---

**Web links:**


See also:

www.pmtuning.co.uk

---

**CDI**

CDI stands for Capacitor Discharge Ignition. The CDI unit calculates the optimal ignition timing for the current revs. To obtain the maximum power the ignition should take place when the piston is just before the top of its stroke. Because the piston moves faster with increasing revs and the gas mixture always requires the same amount of time to fully burn, the ignition has to fire earlier with increasing revs.

---

**Variomatic**

The Variomatic is a stepless fully automatic transmission developed in the early 1960s by the Dutch car manufacturer DAF. It works as follows: the drive belt sits between two conical drums. With increasing revs the distance between the two drums changes due to centrifugal weights, which results in a stepless change in the transmission ratio (refer to [3] for more details).

One side effect of this type of transmission is that vehicles with this 'gear box' can travel just as fast backwards as they can forwards, which is funny to see and much used in amateur car races.

Nowadays this type of transmission is used mainly in scooters, quads, snowmobiles and pillar drills. A further development of this is the so-called CVT system, which is used by Audi under the name Multitronic in several of its cars.
It is well-known that a modern car is filled to the brim with electronics. In 1990 there were only a couple of ECUs per vehicle. That number has now increased to 10 or 50 or even more ECUs per car. In addition to the engine controller and ABS controller we now also see dashboard, network, air conditioning-controllers etc. emerge. Furthermore, the computing power is ever increasing as well (see Figure 1).

The necessity of more computing power is driven mostly by the increased emission requirements and diagnostic abilities. Direct injection engines in particular, require a lot of computing power because of their multiphase fuel injection. An example of the tasks and processes that a modern ECU deals with are outlined in Figure 2. Some of the ICs that we are likely to find in an ECU are:

- a voltage regulator and processor watchdog;
- a driver IC with SPI diagnostic interface / SPI or PWM input;
- a CAN-bus interface IC;
- 2 MHz 8-bit microcontroller with 8 kilobyte flash memory on board;
- and a 40-MHz, 32-bit microcontroller with 2 MB flash memory on board.

### ECU reprogramming

To improve the performance of the engine you can interfere electronically with the engine controller. Professionals with a lot of expertise can change the parameters and
Service on Demand
optimisation in the electronic garage

J2534 standard

The J2534 standard came about to enable garages that are not part of a brand franchise to carry out programming operations on ECUs without having to invest in expensive, proprietary equipment.

It is easily possible that a software update is required to ensure that a car conforms again to the emission requirements. This standard makes that easier. Unfortunately, not all manufacturers participate in this (yet).

The J2534 standard is sometimes also called the pass-thru standard. To be able to program an ECU, software from the manufacturer is required, as well as hardware that complies with the J2534 standard. The number of manufacturers that support the J2534 standard grows every year. To buy the programming software a visit to the manufacturer website often suffices, Honda for example: http://techno.honda.com/rijanis/RIJAA001_tools2.aspx?home=Y

Figure 2. The Hardware Engine Controls. This keeps an eye on an ever increasing number of sensors.

Legislation

The car manufacturer is legally required to take various precautionary measures so that unauthorised programming of the various controllers is not possible. This is mostly to prevent an increase in exhaust emissions. However, if there is a change in the aspiration of the engine, perhaps because of a change in exhaust system, it is often desirable to change the ECU calibration so that the emission requirements are again complied with.

It may not be formally permitted to change the program, but it is actually desirable to return the air/fuel ratio back to the correct value.

It is, for example, well-known that a Subaru Impreza is adjusted quite rich (here is where the manufacturer slightly overshot the concept of 'safe engine adjustment' or perhaps the shareholders of the oil sheiks) and a little bit of 'electronic meddling' can result in not only more engine power, but also - at partial load - lower fuel consumption and therefore a lower emission of CO2. Whatever changes are made to a car engine, in the UK, MOT approval will determine whether or not a vehicle is allowed to go on the road.
tables that are stored in the ECU. These changes make it necessary to recalibrate the controller. A change in the exhaust and/or intake system changes the aspiration of the engine to such an extent that it will no longer comply with the emission standards that are legally defined. The factory settings (calibration) are, after all, based on a standard intake and exhaust system. Now that more air is sucked into the engine — at least that is the intention if more performance is required — more fuel needs to be injected as well. The amount of fuel supplied is typically looked up from a table by the ECU based on the following main parameters (see Figure 3):

- engine load;
- engine speed;
- engine temperature.

Along the Y-axis we find the engine speed and along the X-axis the engine load. The engine temperature is looked up from another table. As an example we take 6000 rpm (revolutions per minute) and 3.96 grams of air per cylinder. We can then see that the AFR-value is 10.01. In this case therefore, 1 part fuel to every 10 parts of air. If, for example, we enter the value 9.0 in the table, then the effective injection time will increase to get more fuel into the cylinder. Obviously the correct values have to be entered to prevent expensive engine damage and maintain conformance to emission requirements.

Programming via OBD

A lot is involved in order to program new table values into the ECU. In the past it was a case of desoldering the (E)PROM and replacing it with a version with the new code. These days all ECUs are provided with flash memory, which may or may not be a separate chip. Access to the ECU memory is always possible via OBD. This requires that the ECU is first placed into a special security mode. To put the ECU in security mode you need to ask for a 'seed'. This needs to be answered by the programmer with the correct 'key'. There are often multiple levels of security. For some cars a ready-made solution is available in the form of a handheld programmer.

Hard and software

The hardware provides for proper communication between the software and the ECU while programming. Consequently, the hardware has to have the right kind of interface, such as ISO, CAN, etc. and support non-standard baud rates such as 10,400 or 15,625 baud (bits/s). In some cases a programming voltage is also required. But in most cases standard OBD-hardware will suffice. If the car manufacturer supports the J2534 standard, then it is enough to buy a J2534 hardware interface. See [1], for example. Software is often available from the manufacturer of the car. See also the inset J2534-standard. Programming software often makes use of the service modes, as described in the SAE J2190 standard Enhanced E/E Diagnostic Test Modes, see [2].

The most common J2190 service modes for re-programming are:

- $10 start diagnostic service
- $20 stop diagnostic service
- $27 ask for security access (seed, key)
$34 ask for upload to controller
$35 ask for download from controller
$36 data transmission to/from controller
$37 ask transmission exit
$3D write to memory

Although the service modes are described in the SEA J2190 standard Enhanced E/E Diagnostic Test Modes, the parameter identifiers (PIDs) are manufacturer specific. The manufacturer determines the programming order and security access according to their requirements. In this way the security key could be 32 bits long, but it just as well be 128 bits long.

**Reverse engineering**

When the manufacturer is not prepared to supply the necessary information and also does not make available any programming software, then the only option that remains is reverse engineering of the controller software. Fortunately there are ever more manufacturers who are prepared to supply programming software to allow their ECUs to be updated.

To discover the correct programming order and to obtain security access the processor code will have to be unravelled. This requires a processor dependent disassembler and interface. Because it is necessary to work at the level of assembly language, this tends to be quite a time-consuming process. Depending on the way the programming operation is implemented by the manufacturer, it may also be necessary to write a kernel and/or flash programming routines just to be able to program the flash at all. This is therefore not a job for the novice.

**Car versus computer?**

The present-day tuning of cars looks more like hacking than it looks like working in a garage. Because of the far-reaching integration of electronics in the car of today, an increasing number of adjustments can only be carried out electronically. To make things safe and to comply with various legal requirements, the manufacturers lock up the software as much as is possible. Subsequently, several tuning companies such as Fastchip are busy ‘decoding’ the software in order to be able to make ‘adjustments’ themselves. This sounds a little like what happens in the pc software arena: hackers who circumvent the protection mechanisms to enable them to make a backup of their beloved Xbox game...

---

**Glossary**

**AFR** Air Fuel Ratio, ratio between fuel and air.

**CAN-bus** Controller Area Network; asynchronous, serial bus system developed for the use in cars.

**ECU** Electronic Control Unit; the ‘board computer’, which controls all the electronics.

**MIPS** Million Instructions Per Second; Number of instructions that a controller can process per unit of time (for example, adding two numbers is one instruction).

**PWM** Pulse Width Modulation; a standard for signal transmission in which the duty cycle of a rectangular wave contains the information of the signal.

**OBD** On-Board Diagnostic; electronic diagnostic system for vehicles.

**SPI** Serial Peripheral Interface; standard for a serial interface for a digital signal network.

The holy cow will not disappear from our driveway any time soon while the electronics becomes over more sophisticated. In all likelihood, it will play an increasing role in the garage of the future. That’s quite a promise!

**Web links:**

[1] www.passthruкс.com

---

The days that a mechanic got dirty hands when tuning an engine are gone...
FPGA Course (8)

Part 8: Playing with the USB port

Paul Goossens and Andreas Voggeneder

In this installment of the course, we’re going to put together our own USB microcontroller. In terms of technical features, it can certainly hold its own against commercial USB controllers such as the Cypress IC.

The specifications of our home-grown USB controller embedded into an FPGA are certainly nothing to be ashamed of:

- 8052 processor running at 48 MHz
- with single clock cycle per byte fetch
- full-speed USB controller with five endpoints
- 8 KB of ROM
- 4 KB of RAM

We built the USB controller by extending the familiar 8052 core with a USB controller core, which is also freely available from OpenCores (www.opencores.com). This is not the place to delve into the details of how the USB core works or its internal structure. What matters here is how it is linked to the 8052 core and how to use it in practice.

The USB core is the USBHostSlave core from OpenCores (www.opencores.org/projects.cgi/web/usbhostslave/overview). It was designed by Steve Fielding, and it has the following properties:

- register-configurable low-speed / high-speed mode (1.5 Mbps or 12 Mbps)
- 4 freely available endpoints, each with a 64-byte FIFO
- support for control, bulk, interrupt, and isochronous transfers
- host mode
- 8-bit Wishbone bus interface

The USBHostSlave core is coupled to the 8052 microcontroller via the Wishbone bus. As a result, the registers of the USB core appear in the XRAM memory area (in other words, they are addressed as external SRAM), where the USB core occupies 256 addresses. Figure 1 shows the block diagram of the overall system, while Figure 2 depicts the memory organisation.

Registers

The USB core has a set of four registers for each endpoint:

- EP[0-4]_Control
- EP[0-4]_Status
- EP[0-4]_Transtype_Status
- EP[0-4]_NAK_Transtype_Status

The Endpoint_Control registers can be used to control or drive endpoints for purposes such as sending data, setting or clearing stall states, or setting the operating mode of an endpoint (isochronous or bulk). The Endpoint_Status registers provide information about the current status of the endpoints – for instance, whether data has been received or an error has occurred.

The Endpoint_Transtype_Status register contains information about the last successful transfer between the PC and the USB core, such as whether a setup package was sent or the transfer was made in DMA mode. The Endpoint_NAK_Transtype_Status register displays any errors that may have occurred during the data transfer.

Besides these four primary control registers, each endpoint has an Rx FIFO buffer and a Tx FIFO buffer, each with a depth of 64 bytes. These two FIFOs can be controlled using an additional set of six registers for each endpoint.
Mixed Language

Besides VHDL, there are several other ways to design a digital circuit. One of them is to use a graphic drawing package. We describe this option in earlier instalments of this course.

Other entry methods include Verilog, AHDl, SystemC, and so on. Fortunately, the Quartus compiler can also handle some of these languages. Using two or more different languages is called 'mixed-language design'.

The USB core used in this installation was designed in Verilog. Some of the other components were designed in VHDL. Our design can thus be regarded as a mixed-language design (part Verilog and part VHDL).

The main advantage of this is that you are not limited to using only VHDL cores or only Verilog cores. You can use them in combination in your designs without any problems. However, you do need to know the Verilog equivalents of some VHDL terms, such as STD_LOGIC signals.

The link between the VHDL part and the Verilog part is located in the USB.vhd file. This file is what is called a 'wrapper', and its purpose is to export Verilog signals as VHDL signals.

Hardware

The pull-up resistance that defines the connect condition can be controlled by the microcontroller via port line P3.7. P3.7 is high after a reset. MOSFET T6 (which connects the pull-up resistor to D+) is cut off under this condition, so the PC does not see any connected device. When the software has initialised the USB core and is ready to communicate with the PC, it pulls P3.7 low. This causes the D+ to be connected to +3.3 V via the 1.5-kΩ resistor. As a result, the PC sees that a full-speed device (12 Mbps) is connected and initiates communication with the FPGA board.

The USBHostSlave core needs a 48-MHz clock. This is stipulated by the USB specification. A clock signal at this frequency is derived from the 50-MHz clock signal by a PLL in the FPGA. The USB core and the T8052 core are both driven by the 48-MHz clock signal. As the T8052 core can execute all instructions in 1 to 4 clock cycles (except the divide instruction, which takes 12 clock cycles), this provides a considerable amount of computing power (at least for an 8051).

The USB core in the FPGA handles all the tasks necessary for USB communication with the PC. All that remains to be provided is the USB physical interface (USB Phy). Its job is to provide the electrical interface (level adjustment). This task is also handled by the FPGA.

[Diagram of USBHostSlave core in the T8052 system.

Figure 2. T8052 memory organisation.]
The USB core also supports host mode, which means it can act as a PC for functions such as enumerating and driving a USB mouse or other type of USB device. However, host mode cannot be used with the FPGA prototyping board because it lacks the necessary hardware (external to the FPGA). Here the USB core can only be used in slave mode with low-speed (1.5 Mbps) or full-speed (12 Mbps) data transfer.

Sample application

Our demo application here (ex22) involves connecting an HID keyboard. It identifies itself to the PC as a keyboard, which causes the PC to use the Human Interface Device (HID) protocol defined in the USB standard. The main purpose of the HID protocol is controlling input devices such as keyboards, mice, and joysticks. The principal advantage of this protocol is that all major operating systems (Window, Linux and MacOS) incorporate drivers for it, so they do not have to be written for individual devices.

Endpoints 0 and 1 are used for communication with the PC. Endpoint 0 is a control endpoint, which must be present in every USB device. It is used for basic communication with the PC (enumeration). Enumeration is a process that takes place immediately after a USB device is connected to a host (PC). Each new device is recognised by the 1.5kΩ resistor connected to the D+ or D- line in every USB device. If the resistor is connected to the D+ line, the device is a full-speed device (12 Mbps); otherwise it is a low-speed device (1.5 Mbps). The FPGA prototyping board has a switchable resistor for each of these lines, so you can configure it as desired as a full-speed or low-speed device. The PC detects the type of device during enumeration and assigns a slave address to the device. The appropriate driver is then loaded based on the Device Descriptor data sent by the device. After this has been completed, an application can communicate with the device. In this case, the driver is the HID driver provided by the operating system. Other endpoints are not enabled until after the driver has been loaded. In the case of the HID keyboard, this is endpoint 1, which acts as an interrupt endpoint (IN = device to PC) and is used for transmitting keystrokes.

Join the FPGA Course with the Elektor FPGA Package!

The basis of this course is an FPGA Module powered by an Altera Cyclone FPGA chip, installed on an FPGA Prototyping Board equipped with a wealth of I/O and two displays (see the March 2006 issue).

Both boards are available ready-populated and tested. Together they form a solid basis for you to try out the examples presented as part of the course and so build personal expertise and know-how in the field of FPGAs.

Further information may be found on the shop/kits & modules pages at www.elektron-electronics.co.uk.

Bonus application

Our second sample application (ex23) is a PS/2 to USB adapter. You can use this adapter to connect a keyboard with a PS/2 connector to a USB port of a PC. The PC will see the keyboard as a USB keyboard. The FPGA causes the keystrokes of the PS/2 keyboard to be transferred via the USB interface just as though they originated from a real USB keyboard.

Naturally, this example uses the PS/2 interface as well as the USB interface. This means the associated firmware is more extensive, but if you read the PS/2 instalment you should be able to understand how this application works. As usual, the software for the examples described in this instalment is available on the Elektor Electronics website under item number 060025-8-11 (go to Magazine → January 2007 → FPGA Course Part 8).

Andreas Voggeneder

Andreas Voggeneder studied Hardware/Software Systems Engineering (HSSE) at the University of Applied Sciences in Hagenberg, Austria (http://www.in-hagenberg.at/), where he presently still gives occasional lectures.

As an enthusiastic electronics specialist, he devotes part of his time to designing digital circuits with the help of VHDL and Verilog. He is also a moderator at OpenCores (http://www.opencores.com/), a forum dedicated to the freely available TSI 8051 processor core used in several instalments of this course.
Blinking Christmas decoration

Dieter Folger

Have you already set up a Christmas tree in your house and decorated it with traditional lights? Build a couple of these blinking Christmas decorations to enhance the Christmas mood. The coloured LEDs blink in a seemingly random sequence and rate and create a festive appearance.

The circuit for the blinking Christmas decoration has a very simple design. It is based on a type 4060 digital counter (IC1). This IC has a built-in oscillator with a frequency set by the combination of resistor R1 and capacitor C1. The oscillator frequency is approximately 5 kHz with the component values shown here. The oscillator signal is divided by various factors by the internal digital circuitry of the IC. The division factors are designated by 'CT' in the IC drawing symbol. For instance, the signal on the CT3 output (pin 7) is a square wave with a frequency equal to 5 kHz divided by 2^3, which mean (5 kHz ÷ 8) = 625 Hz. The oscillator signal is divided by 2^4 (16) on the CT4 output, by 2^5 (32) on the CT5 output, and so on. The signals on each of the outputs thus change at different rates. Eleven LEDs are connected in three groups between six of the counter outputs, with the result that the group of LEDs flash in an apparently random pattern.

To assemble the circuit, first solder the IC socket (mind the polarity), the two resistors, the capacitor, and the battery clip to the triangular circuit board. Then fit the eleven LEDs. Pay attention to the polarity of the leads: the short lead is the cathode lead. After a final inspection, you can connect a 9-V battery to your Christmas blinker. It should produce a festive blinking pattern!

Test beeper for your stereo

Ton Giesberts

The test beeper generates a sinusoidal signal with a frequency of 1,000 Hz, a common test frequency for audio amplifiers. It consists of a classical Wien-Bridge oscillator (also known as a Wien- Robinson oscillator). The network that determines the frequency consists here of a series connection of a resistor and capacitor (R1/C1) and a parallel connection (R2/C2), where the values of the resistors and capacitors are equal to each other. This network behaves, at the oscillator frequency (1 kHz in this case), as two pure resistors. The opamp (IC1) ensures that the attenuation of the network (3 times) is compensated for. In principle a gain of 3 times should have been sufficient to sustain the oscillation, but that is in theory. Because of tolerances in the values, the amplification needs to be (automatically) adjusted.

Instead of an intelligent amplifier controller we chose for a somewhat simpler solution. With P1, R3 and R4 you can adjust the gain to the point that oscillation takes place. The range of P1 is 10% is large enough to cover the tolerance range. To sustain the oscillation, a gain of slightly more than 3 times is required, which would, however, cause the amplifier to clip (the 'round-trip' signal becomes increasingly larger, after all). To prevent this from happening, a resistor in series with two anti-parallel diodes (D1 and D2) are connected in parallel with the feedback (P1 and R3). If the voltage increases to the point that the threshold voltage of the diode is exceeded, then these will slowly start to conduct. The consequence of this is that the total resistance of the feedback is reduced and with that also the amplitude of the signal. So D1 and D2 provide a stabilising function. The distortion of this simple oscillator, after adjustment of P1 and an output voltage of 100 mV (P2 to maximum) is around 0.1%. You can adjust the amplitude of the output signal with P2 as required for the application. The circuit is powered from a 9-V battery. Because of the low current consumption of only 2 mA, the circuit will provide many hours of service.
Improving RFID Reader

ten picofarads are worth five centimetres

Jan Buiting

The devil's in the details, in this case, the dielectric constant of our printed circuit board material. Don't be put off! In this month's LabTalk we show how half an hour of measuring, thinking aloud and tweaking one capacitor value was rewarded by a five-fold increase in detection distance for the Elektor RFID Reader.

Having been in RF electronics for about 30 years I must have developed a special awareness for stray (that is, invisible) capacitance and inductance lurking in all kinds of circuits. Recently, when I saw my colleagues in the Elektor lab struggling to get RFID cards decoded using the September 2006 Elektor RFID Reader unit, I could not help noticing that the card distance at which the number decoding started to work, was very small indeed at just 1 cm or so. That's disappointing compared to the Mifare Light specifications which claim a far more practical distance of 5 to 7 cm.

Comparative measurements
A few facts were quickly established.

1. samples of the Elektor RFID Reader worked fine as far as the number decoding is concerned;
2. typical card distance for decoding was 1 cm but exceptions of 0.5 cm and 2 cm were observed;
3. a reader board from a Philips Mifare development system easily achieved 5 cm using the same RFID cards.

From these we can list some starting points for the investigation:

1. no problems in the digital circuitry on the Elektor RFID Reader board;
2. the RFID cards are not suspect;
3. a problem may exist in the antenna and 13.56-MHz RF sections of the Elektor RFID reader.

Trial and error

Surmising a problem with the resonance frequency of the on-board wire loop antenna, I initially got out a grid dip meter. Although a good dip was produced by the on-board antenna, the measurement was inaccurate in that the resonance frequency appeared to be dependent on the degree of coupling. So I hooked up an adjustable RF signal generator and an oscilloscope as illustrated in Figure 1. The 13.56MHz test signal of 1 Vpp or so was fed inductively into the RFID Reader via a coupling antenna made from 20 turns of wire shaped to give a diameter of about 5 cm. A distance of about 5 cm was set up, the RFID Reader was switched on, and the oscilloscope connected to the 'hot' end of R6 (simply because the RFIN pin of the MFRC522 chip is hard to get in touch with...). Once synchronised, the 'scope screen told me I had made a silly mistake in forgetting that the MFRC522 is not just receiving a signal at 13.56 MHz, but also generating one! As a result, the signal from the RF generator was swamped by the carrier supplied by the TX section of the MFRC chip. Now, disabling the transmitter part of the MFRC is tricky so I decided to remove the supply voltage altogether, making the measurement passive in essence. Super results this time — the inductively coupled signal from the RF generator showed up at R6 and I was able to make the coupling very light by increasing the vertical distance between the board and the coupling loop to about 5 cms. Then, the moment of truth: cheerfully turning the frequency control on the vintage HP8640B RF signal generator, the signal on the 'scope peaked at a setting of about 12.4 MHz. That's more than 1 MHz off the mark, confirming my suspicion. The resonance itself was nicely pronounced suggesting a reasonable Q factor of the balanced, parallel LC circuit formed by the loop antenna, the 'tuning' capacitors and the components for impedance matching to the MFRC chip.

Up with the resonance frequency

Delving into the interesting part of the RFID Reader schematics (reproduced here in Figure 2), the solution was looked obvi-
Sensitivity

ous — I thought! From your textbooks you'll no doubt remember that making a parallel L-C circuit resonate at a higher frequency requires lowering the inductance (L) and/or the capacitance (C). I did not want to mess with the etched loop antenna on the board so capacitor positions C25-C28 were given a 'serious review', whilst noticing that asterisked parts C26 and C28 are not fitted. Unfortunately, in this case of a too low resonance frequency, less capacitance was needed, not more, so the 'padding' positions C26 and C28 were useless. Apparently, the antenna circuit had been designed, prototyped and tested using PC board material different from that actually used for volume production of the RFID Reader by the assembly company. In scholarly terms: the real εᵣ value, or 'dielectric constant' was insufficiently observed.

A quick test with two 33-pF SMD Cs for C25 and C27 gave resonance at about 14.8 MHz, but the next attempt with 47 pF caps was almost spot-on. In the end, it turned out that 56 pF was the value that gave resonance as close as possible to the target frequency of 13.56 MHz.

The SMD C drawer

Mr. Murphy states that

10 IF 56 pF = required
20 THEN 27/33/47/68 pF = available in large quantities in the drawer.

So, 27-pF caps were fitted in positions C25/C27 and two more piggy-backed on top of these to give a theoretical 54 pF. Good resonance was obtained once again, and hey presto the distance at which our RFID cards were reliably read was suddenly a good 5 cm, well within the MiFare Light specifications. Mission completed.

Do it yourself

Figure 3 shows a close-up of the PCB area in which you need to work if your RFID Reader is rather insensitive (card recognition range <2 cm) and you wish to replicate the modification. Be sure to refer to the PCB component layout printed in the original article [1] to positively identify the two 68-pF SMD capacitors C25 and C27 you need to replace. RFID Readers supplied through the Elektor SHOP now come with 56-pF SMD capacitors fitted instead of 68 pF.

Finally, it appears that the antenna on the RFID Reader board is subject to slight detuning if batteries are fitted behind it. In practice, the metal surface formed by the battery pack will cause a slightly reduced sensitivity — simply compare with the card distance obtained with the batteries removed and powering the RFID Reader from USB. If necessary, do the capacitor tweak- ing trick as outlined in this article to get the best possible card detection range.

Reference

Display Recycling

An el-cheapo LCD controller

Jeroen Domburg & Thijis Beckers

LCDs are in. Just about everything these days has a display somewhere. That’s nice, since the displays can always be used for something else. Of course, it’s a bit difficult if the LCD doesn’t have a built-in controller. The controller chips are either much too small for DIY work (SMDs with way too many leads) or simply unavailable. But with a bit of ingenuity, it’s always possible to devise a solution.

If you work with LCDs and microcontrollers a lot, you certainly know the feeling: you see a nifty LCD in something like a photocopier or game computer that you’d like to use in your own project. You go looking for the pin layout so you can hook it up to your own PC or microcontroller, but it turns out that the interface consists of an Hsync line, a Vsync line, and four or eight data lines. That means the LCD is naked (no controller).

To get something on the display in this situation, you have to send the entire image at least 50 times a second. That’s not such a disaster for industrial applications, since LCD controllers are inexpensive and reasonably available from distributors, but it can be a real problem for electronics hobbyists. The controller ICs are usually only available in tiny SMD packages — if they’re available at all. Fortunately, you can use modern technology to build your own rudimentary LCD controller using parts that are easier to come by.

**How it works**

Here the idea is to operate the display in serial mode. You need several things for this: a video memory to store the image, a means to send the image to the LCD several dozen times per second (including driving Hsync, Vsync, and the other signal lines), and some way to update the data in the video memory. Discrete logic is normally used for the latter two functions, but as regular readers of this topic know, a lot of problems can be solved using an AVR. In this project, we managed to ‘compact’ a whole lot of electronics that would normally be implemented in discrete logic into software running in an ATtiny2313.

The Tiny2313 is nice device, but the downside is that it has only 13 I/O pins. This is nowhere near enough if you want to use SRAM for the video memory. It takes a 16-kB RAM chip just to feed a display with 320 x 240 pixels, which means 14 lines for the address data alone, and then you still need data lines, memory control lines, and control lines for the LCD. This would make a larger AVR necessary, but that’s not what you want.

Fortunately, there’s another way to tackle this problem by using another type of RAM that is used much less often by the average hobbyist: DRAM. The drawback of this sort of RAM is that it must be refreshed continually. In addition, it can’t be connected to a standard address bus. In this application, neither of these drawbacks presents a problem. If the DRAM is used as a video memory, it will be read out (and thus refreshed) every 200 ms, and you aren’t using a standard address bus here anyhow. (See the inset ‘How DRAM works’ for a general explanation of DRAM operation.)

**Intelligent use**

With a DRAM, you have to drive a total of eight address lines plus a set data lines (four lines in this arrangement). The two address bytes are latched on the falling edges of RAS and CAS. This should mean that the address lines can have any desired value when WE or OE goes low. It’s thus possible to use the address lines for data, which means you can omit the data lines. This reduces the total number of multiplexed lines to eight (plus four control lines). That’s not bad if you consider that you’re driving 64 kB with just 12 lines!

Naturally, the idea is to link all this to an LCD. A type that can be used with this sort of circuit has at most eight data lines, plus a line that marks the start of a frame (FIM), a line that marks the start of a line (L), a line for the sampling clock (KSCL), and possibly some other stuff, such as a display-enable line or a line that has to be toggled after each frame. With a bit of luck, there will only be three control lines, and even then it’s possible to combine one of the signals with one of the RAM lines. This means you need only 14 lines in total. If you use the last available line as a serial port to write data to the RAM, you use all the available parts of the ATtiny.

**Bad luck**

We needed only 14 lines and two quite common ICs for the first prototype of the display controller and the first display. That’s not bad for something that normally requires dedicated hardware. Unfortunately, things aren’t always so easy.
how careful you are, a single wrong connection can be the kiss of death for your hardware, and displays are no exception to the rule. To make a long story short: our first display landed in the rubbish bin along with a set of vapourised line drivers. The replacement display turned out to need an extra line. Naturally, this could be solved by using a large microcontroller, but this would probably mean that the firmware would have to be revised from the ground up. We thus had to come up with a different solution. We augmented the already highly multifunctional address/data lines for the RAM with a latch to provide eight more outputs. This brought the total number of ICs in final version of the circuit to three, which is still a respectable low number.

**Hardware**

We’ve already more or less revealed the overall architecture, so the schematic diagram in Figure 1 shouldn’t contain any surprises. Input buffer R1/R2/T1 converts the RS232 signal to a TTL level, and it can be omitted if the circuit is connected directly to another microcontroller. IC1 drives the rest of the chips and transfers the data on

---

**About the author**

Jeroen Domburg is a student at the Saxion Technical University in Enschede, the Netherlands. Jeroen is an enthusiastic hobbyist, with interests in microcontrollers, electronics and computers.

In this column he displays his personal handiwork, modifications and other interesting circuits, which do not necessarily have to be useful. In most cases they are not likely to win a beauty contest and safety is generally taken with a grain of salt. But that doesn’t concern the author at all. As long as the circuit does what it was intended for then all is well. You have been warned!
the serial interface port to the video memory. IC2 is a latch. In principle, a 74HC373 could be used just as well here if the different pin layout makes things easier. Finally, IC3 is the DRAM – in this case a HY514400, which was salvaged from an EDO RAM module from an old PC. In principle, any RAM with a capacity of at least 64 k words and a 4-bit data bus could be used here.

The interface lines of the LCD used here are labelled LP, FLM, FR and XSCL, but other labels such as HSYNC, VSYNC, and M or CP1, CP2 and S are often used. Find the data sheet of the LCD you want to use and see which signals it uses. Also check to see how they have to be connected.

Software

The software in the microcontroller uses a couple of tricks to make everything go a bit smoother. The program spends most of its time feeding data to the LCD. The line number to be sent out is set in the RAM by the falling edge of RAS. The actual line content is address using only CAS edges. This saves a lot of extra decision loops, which makes it possible to maintain a high frame rate. This means it’s not possible to interrupt the transfer of a line to the LCD to write a byte from the serial port to the DRAM, so data received on the serial port is first stored in a buffer in the AVR. When the AVR is finished sending bits to the display, the bits in the buffer are then written to the RAM in a single go. This minimises the visible effect on display refreshing.

The schematic diagram also includes an extension: two address lines of the RAM (A8 and A9) are connected to the latch. This makes it possible to select a ‘page’ in memory. If the address bits on these lines are changed, the display receives data from a completely different memory area. You may be wondering what this is good for. Well, if the firmware is configured so that it always displays two frames from page 0 and then a frame from page 1, you can generate grey tones. If a pixel is set in both pages, it will have an average ‘on’ time of 100% in the display. If it is only set in page 0, its average ‘on’ time will be only 66%, and the ‘on’ time drops to 33% if it is only set in page 1. Thanks to the high frame rate, your eye will hardly notice that the pixels are being switched on or off constantly, with the result that it sees a nice grey tone. The only disadvantage is that twice as much data has to be transferred to the controller. For the 160 x 160 display used here, the transfer takes almost a full second.

As a test, we also incorporated modes with three and four pages, which give pixel depths of 3 and 4 bits per pixel (bpp). This produces surprisingly good results. At 4 bpp with dithering enabled, the steps between the grey levels are hardly visible and each image is displayed like a black and white photo.

There are also disadvantages to this technique – in particular, the frame rate is reduced by 50% for each extra page. As a result, the lightest and darkest tones appear to flicker a lot more. For this reason, the number of bits per pixel is configurable in the final version of the software, so you can decide for each application or even for each
transferred image what balance you want to have between the number of grey tones and the frame rate and transfer time.

The serial interface to the PC is quite simple. Use a terminal emulator program such as HyperTerminal for Windows or vtterm for Linux. Set the communication parameters to 115,200 baud, 8 bits, no parity, and 1 stop bit. The data is transferred in binary form one line at a time.

The first byte is a synchronisation byte with the value OxAS, which is followed by a byte that specifies the page where the line is to be stored. This is followed in turn by a byte with the Y coordinate of the line of pixels to be transferred, and then by the pixel data. You can configure the number of bits per pixel by inserting an extra set of bits after the synchronisation byte.

The first byte has a value of OxFE, and the next one states the number of bits per pixel in binary notation. If you’re a bit uncertain about all this, have a look at the sample code at [1] and [2]. The firmware can also be downloaded from these sources.

**Web links**

[1] sprite.student.utwente.nl/~jeroen/projects/lcdc-avr


---

**How DRAM works**

DRAM has several control lines (RAS, CAS, OE and WE) in addition to the address lines. And of course, it also has a set of data lines. The address lines of DRAM chips are multiplexed, so a chip with 64 k words has only eight address lines. The address is set by first placing the first eight bits of the address on the lines and pulling RAS low, and then placing the second eight bits on the lines and pulling CAS low. The data can then be read by pulling OE low. To write data, you place the data on the data lines and then pull WE low.
Electromechanical switching technology

Luc Lemmens

What do you do with a large pile of electromechanical counters from the scrap parts bin? Exactly the same as with other display devices from the past: you turn them into a clock, just like the Nixie-tube clock elsewhere in this issue. Such components from the old parts box are eminently suitable for all kinds of designer timepieces, the combination of old and new technology has a certain appeal. The picture of the clock that we are describing here immediately reveals the origin of the counters, that is, an old electromechanical pinball machine. The clock is built into the so-called backglass. The five large relays underneath the counters are the control logic for the number wheels, the PCB at bottom left provides the clock ticks and is with its CMOS-technology an anachronism. But with EM-technology a pulse generator is indispensable. In the case of a clock you need a pulse every minute (start of a new event) followed by a few quick ones after that to get all the number wheels in the correct position (processing the event). In an EM-pinball machine the 'start' is caused by a target that has been hit by the ball, which then starts a score-motor which in turn generates the required pulses and depending on the state of various relays - ensures the correct processing of the points scored and then finally stops again.

(Electro-)mechanical calculators and computers have long included tubes, transistors and even ICs, it would take until about the mid seventies before the gaming machine industry finally embraced the microcontroller. After all, relay technology was reasonably robust and over many years had proved itself as a control system for pinball machines and other gaming machines. In the spirit of 'never change a winning team', this technology was held onto for many years. But in the end the power and flexibility of digital electronics was recognised, and the new possibilities that it offered, in particular the increase in processing speed. That is because the combination of relays and score-motor is very slow: every counter required a certain amount of time to change one step, every relay in the circuit caused a delay and the speed of the score-motor could not be increased with impunity.

A glance at the second picture shows how this was a very complex assembly of relays, switching contacts, so-called stepper units, motors and of course the wiring. The 'programming' of a pinball machine was fixed entirely in hardware and it must have been an immense liberation for the designers when the reprogramming of a design became a matter of just plugging in a couple of new EPROMs. For the players the disappearance of all the rattling and ticking was something to get used to, but time moves fast: the first electronic pinball machines are now already part of nostalgia!
Hexadoku
Puzzle with an electronic touch

Hexadoku has proved very successful so we cheerfully continue producing and publishing the puzzle instalments in the new year. Some of you may need a day to solve Hexadoku, others less than half an hour (they say).

No matter as long as you're having fun.

The instructions for this puzzle are straightforward. In the diagram composed of 16 x 16 boxes, enter numbers such that all hexadecimal numbers 0 through F (that's 0-9 and A-F) occur once only in each row, once in each column and in each 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. All correct entries received for each month's puzzle go into a draw for a main prize and three lesser prizes. All you need to do is send us the numbers in the grey boxes.

The puzzle is also available as a free download from our website (Magazine → 2007 → January).

Prize winners

The solution of the November 2006 Hexadoku is: 1AC70.

The E-blocks Starter Kit Professional goes to:
Paul Keers (Heworth).

Solve Hexadoku and win!
Correct solutions received enter a prize draw for an E-blocks Starter Kit Professional worth £248.55.

An Elektor SHOP voucher worth £35.00 goes to:
Greg Eaton (Victoria, Canada);
Franz Klein (Bishops Cleeve, UK);
Guy Savage (West Walton, UK).

Congratulations everybody!
ATC SEMITEC LTD
www.atcsemitec.co.uk
Thermal and current-sensitive components for temperature control and circuit protection;
• NTC Thermistors
• Current Diodes
• Thermistors
• Re-settable Fuses
• Temperature Sensors
Call today for free samples and pricing
Tel: 1606 871680 Fax: 1606 872938

CONFORD ELECTRONICS
http://www.confordelec.co.uk
Lightweight portable battery/mains audio units offering the highest technical performance.
Microphone, Phantom Power and Headphone Amplifiers. Balanced/unbalanced signal lines
with extensive FFI protection.

FUTURE TECHNOLOGY DEVICES
http://www.ftdichip.com
FTDI designs and sells USB-UART and USB-FIFO interface i.c.'s. Complete with PC drivers,
designed to simplify the task of designing or upgrading peripherals to USB

AVIT RESEARCH
www.avitresearch.co.uk
USB has never been so simple... with our USB to Microcontroller Interface cable. Appears
just like a serial port to both PC and Microcontroller, for easy and flexible connection to
your projects, or replacement of existing RS232 interfaces. See our webpage for more
details. Only £23.99 Inc vat.

DANBURY ELECTRONICS
http://www.DanburyElectronics.co.uk
Transformer manufacturer since 1983. Visit our
new site! Also link directly to Mike Holmes's Valve-/Tube DIY amplifier site, featuring our standard Audio
Transformers (Mains, Output, Chokes, PP, SE, etc).

FUTURLEC
http://www.futurlec.com
Save up to 60% on
• Electronic Components
• Microcontrollers, PIC, ATMEL
• Development Boards, Programmers
Huge range of products available on line for immediate delivery, at very competitive prices.

BAEC
http://baec.tripod.com
“The British Amateur Electronics
Club Archive Website. Archiving
extracts from 140+ Newsletters from 1966-
2002. Currently have interesting and useful
selected articles from 12 Newsletters. Also a
section about built electronics projects with
schematics and photos. Plus useful info.,
downloads and links. NO ADVERTISE!”

HEROS TECHNOLOGY LTD
www.heroesotechnology.co.uk
Introducing Modular Concept for microcontrollers. Suitable for Developers, Pre-production,
Educational and Hobby applications.
• WinPIC2006 USB full speed programmer.
• CPU microcontroller modules.
• Peripheral modules for all microcontrollers.

EASYSYNC
http://www.easysync.co.uk
EasySync Ltd sells a wide range of single and multi-
port USB to RS232/RS422 and RS485 converters at competitive prices.

BETA LAYOUT
www.pcb-pool.com
Beta layout Ltd Award-
winning site in both
English and German
offers prototype
PCBs at a fraction of the cost of the usual
manufacturer's prices.

ELNEC
www.el nec.com
• device programmer manufacturer
• selling through contracted distributors all over the world
• universal and dedicated device programmers
• excellent support and after sale support
• free SW updates
• reliable HW
• once a months new SW release
• three years warranty for most programmers

FIRST TECHNOLOGY TRANSFER LTD.
http://www.ftt.co.uk/PICProTmg.html
Microchip Professional C
and Assembly Programming Courses. The future is embedded.
Microchip Consultant / Training Partner developed courses:
• Distance learning / instructor led
• Assembly / C-Programming of PIC16, PIC18, PIC24, dsPIC microcontrollers
• Foundation / Intermediate

JLB ELECTRONICS
www.jlbelectronics.com
Suppliers of electrical / electronic parts and consumables. Including:
• Cable ties / bases
• Tools / hardware
• Bootlace ferrules
• Connectors
• Solvent sprays & cleaners
• PVC Tape
• Heat Sink compound

COMPULOGIC LTD
www.compulodic.com
Internet Remote Control Starter Kit £139.99
Create a simple web based remote control interface for many applications
• Miniature Web Server Module
• Analogue/Digital Module
• PSU
• Manuals, software, example HTML code

KMK TECHNOLOGIES Ltd.
http://www.kmk.com.hk
Low Cost DIY Robotic Kits and Computer Control Boards.
LONDON ELECTRONICS COLLEGE
http://www.lec.org.uk
Vocational training and education for national qualifications in Electronics Engineering and Information Technology (BTEC First National, Higher National NVQs, GCSEs and Advanced Qualifications). Also Technical Management and Languages.

MODular ElecTRONics
www.modetron.com
- Plug and Program
- FREE application s/w
- Hobbyist ease-of-use
- Professional finish with enclosure and LEXAM fascilplate
- We will design and brand your custom application
- Growing range of PSU's, i/o modules, displays and microcontrollers

MGP ELECTRONICS
http://www.mgpelectronics.co.uk
Leaders in Device Programming Solutions.
- Online shop
- Low Cost Adapters for all Programmers
- Single Site and Gang Programmers
- Support for virtually any Programmable Device

NEW WAVE CONCEPTS
http://www.new-wave-concepts.com
Software for Hobbyists:
- Livewire - circuit simulation software, only £34.99
- PCB Wizard - PCB design software, only £34.99
- Circuit Wizard - circuit, PCB and breadboard design software, only £59.99
Available from all Maplin Electronics stores and www.maplin.co.uk

PCB WORLD
http://www.pcworld.org.uk
World-class site: Your magazine project or prototype PCB from the artwork of your choice for less. Call Lee on 07946 846159 for details. Prompt service.

SOURCEBOOST TECHNOLOGIES
http://www.sourceboost.com
Next generation C compiler and development products at highly affordable prices:
- C, C++, and Basic compilers for PIC12, PIC16, PIC18
- Modern IDE, with PIC simulator, source level debugger and virtual devices.
- RTOS for PICmicro.
- PIC based controller and Development boards.
- Download and try for Free from http://www.sourceboost.com

SYTRONIC TECHNOLOGY LTD
http://www.m2telemetry.com
Supplier of wireless modules and accessories for remote monitoring M2M applications.
- GSM/GPRS TCP/IP modules
- Embedded GSM/GPRS modem
- Development Kits
- GPS modules
- GSM/GPS antennas
- Adapter cables
Online ordering facilities. Tel: 01728 685802

ULTRALEDS
http://www.ultraleds.co.uk
tel: 0871 7110413
Large range of low cost Ultra bright leds and LED related lighting products. Major credit cards taken online with same day dispatch.

SHOWCASE YOUR COMPANY HERE

I wish to promote my company, please book my space:
- Text insertion only for £220 + VAT
- Text and photo for £330 + VAT

NAME: 
JOB TITLE: 
ORGANISATION: 
ADDRESS: 
TEL: 
EMAIL: 
WEB ADDRESS: 
30-WORD DESCRIPTION:

SOURCEBOOST TECHNOLOGIES
http://www.sourceboost.com
Next generation C compiler and development products at highly affordable prices:
- C, C++, and Basic compilers for PIC12, PIC16, PIC18
- Modern IDE, with PIC simulator, source level debugger and virtual devices.
- RTOS for PICmicro.
- PIC based controller and Development boards.
- Download and try for Free from http://www.sourceboost.com

SYTRONIC TECHNOLOGY LTD
http://www.m2telemetry.com
Supplier of wireless modules and accessories for remote monitoring M2M applications.
- GSM/GPRS TCP/IP modules
- Embedded GSM/GPRS modem
- Development Kits
- GPS modules
- GSM/GPS antennas
- Adapter cables
Online ordering facilities. Tel: 01728 685802

ULTRALEDS
http://www.ultraleds.co.uk
tel: 0871 7110413
Large range of low cost Ultra bright leds and LED related lighting products. Major credit cards taken online with same day dispatch.

USB INSTRUMENTS
http://www.usb-instruments.com
USB Instruments specials in PC based instrumentation products and software such as Oscilloscopes, Data Loggers, Logic Analyzers which interface to your PC via USB.

VIRTINS TECHNOLOGY
http://www.virtins.com
PC and Pocket PC based virtual instrument such as sound card real time oscilloscope, spectrum analyzer, signal generator, multimeter, sound meter, distortion analyzer, LCR meter.
Free to download and try.
Things of the past.

Elektor is now & tomorrow.

Secure a head start in electronics with a subscription!

Advantages to subscribers:

- Cheaper than 11 issues from the newsstand
- Subscribers get up to 40% discount on special Elektor products
- As a welcome gift you get a free high-performance LED flashlight worth £34.50
- No queues, travelling, parking fees or 'sold out'
- Elektor is supplied to your doorstep every month
- Always up to date – read your copy before everyone else

www.elektor-electronics.co.uk/subs
Tel. +44 (0) 208 261 4509

Or use the subscription order form near the end of the magazine.
**CD-ROM BESTSELLERS**

**USB TOOLBOX**
This CD-ROM contains technical data about the USB interface. It also includes a large collection of data sheets for specific USB components from a wide range of manufacturers. There are two ways to incorporate a USB interface in a microcontroller circuit: add a USB controller to an existing circuit, or use a microcontroller with an integrated USB interface. Included on this CD-ROM are USB Basic Facts, several useful design tools for hardware and software, and all Elektor Electronics articles on the subject of USB. £18.95 (US$ 34.95)

**Home Automation**
This CD-ROM provides an overview of what manufacturers offer today in the field of Home Networking, both wired and wireless. The CD-ROM contains specifications, standards, and protocols of commercially available bus and network systems. For developers, there are datasheets of specific components and various items with application data. End-users and hobbyists will find ready-made applications that can be used immediately. £12.95 (US$ 22.90)

**ECD Edition 3**
Elektor's Components Database gives you easy access to design data for over 5,000 ICs, more than 35,000 transistors, FETs, thyristors and triacs, just under 25,000 diodes and 1,800 optocouplers. All databank applications are fully interactive, allowing the user to add, edit and complete component data. £14.95 (US$ 24.50)

---

**Microcontroller Basics**
Microcontrollers have become an indispensable part of modern electronics. They make things possible that vastly exceed what could be done previously. Innumerable applications show that almost nothing is impossible. There's thus every reason to learn more about them. This book offers more than just a basic introduction. It clearly explains the technology using various microcontroller circuits and programs written in several different programming languages. In the course of the book, the reader gradually develops increased competence in converting his or her ideas into microcontroller circuitry.

230 Pages
£18.70 (US$ 33.70)

**Visual Basic for Electronics Engineering Applications**
This book is targeted towards those people that want to control existing or home-made hardware from their computer. After familiarizing yourself with Visual Basic, its development environment and the toolset it offers are discussed in detail. Each topic is accompanied by clear, ready to run code, and where necessary, schematics are provided that will get your projects up to speed in no time.

ISBN 0-905705-68-8
476 Pages
£27.50 (US$ 51.50)

---

**BESTSELLING BOOKS**

**Top-5**

1. **Visual Basic for Electronics Engineering Applications**
   ISBN 0-905705-68-8 £27.50 (US$ 51.50)

2. **Microcontroller Basics**
   ISBN 0-905705-67-X £18.70 (US$ 33.70)

3. **PC-Interfaces under Windows**
   ISBN 0-905705-65-3 £25.95 (US$ 52.00)

4. **Modern High-end Valve Amplifiers**
   ISBN 0-905705-63-7 £25.95 (US$ 52.00)

5. **308 Circuits**
   ISBN 0-905705-66-1 £19.20 (US$ 37.00)

More bestsellers on www.electronics.co.uk
### USB-stick with ARM and RS232 (November 2006)
- Assembled and tested board
- **Price:** £79.90 / $149.95

### PIC In-Circuit Debugger/Programmer (October 2006)
- Kit of parts including PCB, programmed controller and all components.
- **Price:** £34.50 / $64.95

### GameBoy ElectroCardioGraph (October 2006)
- PCB, ready built and tested
- **Price:** £55.20 / $103.95

### RC Servo Tester / Exerciser (July/August 2006)
- Kit of parts including PCB, programmed controller and all components.
- **Price:** £22.70 / $42.85

### MORE READY-BUILT PROJECTS

<table>
<thead>
<tr>
<th>Project Description</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>ClariTy 300-W Class-T Amplifier</td>
<td>£34.50 / $55.70</td>
</tr>
<tr>
<td>Electromag Tester</td>
<td>£50.00 / $84.25</td>
</tr>
<tr>
<td>Gameboy Digital Sampling Oscilloscope (GBD50)</td>
<td>£10.25 / $19.00</td>
</tr>
<tr>
<td>Flash Microcontroller Starter Kit</td>
<td>£69.00 / $112.50</td>
</tr>
<tr>
<td>Gameboy Digital Sampling Oscilloscope (GBD50)</td>
<td>£10.25 / $19.00</td>
</tr>
<tr>
<td>LPC210x ARMee Development System</td>
<td>£25.50 / $43.05</td>
</tr>
<tr>
<td>Micro Webserver with MSC2120 Board</td>
<td>£75.99 / $129.55</td>
</tr>
<tr>
<td>Network Extension Board, ready-assembled</td>
<td>£44.90 / $79.50</td>
</tr>
<tr>
<td>Combined package (£50.00 + £45.90 + £115.95)</td>
<td>£117.50 / $202.05</td>
</tr>
</tbody>
</table>

### NO. 382 JANUARY 2007

<table>
<thead>
<tr>
<th>Project Description</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sputnik Time Machine</td>
<td>£5.00 / $9.75</td>
</tr>
<tr>
<td>CD-ROM, project software (inc. source code)</td>
<td>£3.40 / $6.45</td>
</tr>
<tr>
<td>Very Simple Clock</td>
<td>£5.50 / $9.75</td>
</tr>
<tr>
<td>CD-ROM, project software (inc. source code)</td>
<td>£5.50 / $9.75</td>
</tr>
<tr>
<td>FPGA Course (8)</td>
<td>£5.00 / $9.75</td>
</tr>
</tbody>
</table>

### NO. 360 NOVEMBER 2006

<table>
<thead>
<tr>
<th>Project Description</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>USB Stick with ARM and RS232</td>
<td>£11.00 / $20.75</td>
</tr>
<tr>
<td>PIC In-Circuit Debugger/Programmer</td>
<td>£5.20 / $9.75</td>
</tr>
<tr>
<td>PIC In-Circuit Debugger/Programmer</td>
<td>£17.00 / $30.75</td>
</tr>
<tr>
<td>PIC In-Circuit Debugger/Programmer</td>
<td>£34.50 / $64.95</td>
</tr>
<tr>
<td>Gameboy ElectroCardioGraph</td>
<td>£55.20 / $103.95</td>
</tr>
<tr>
<td>ECG using a Sound Card</td>
<td>£5.00 / $9.75</td>
</tr>
</tbody>
</table>

### NO. 359 OCTOBER 2006

<table>
<thead>
<tr>
<th>Project Description</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elektor RFID Reader</td>
<td>£41.50 / $77.95</td>
</tr>
<tr>
<td>Standard backlit LC display</td>
<td>£7.25 / $13.05</td>
</tr>
<tr>
<td>Matching enclosure</td>
<td>£8.20 / $14.95</td>
</tr>
<tr>
<td>CD-ROM, project software</td>
<td>£5.00 / $9.75</td>
</tr>
<tr>
<td>Experimental RFID Reader</td>
<td>£5.20 / $9.75</td>
</tr>
<tr>
<td>DISEqC Monitor</td>
<td>£5.00 / $9.75</td>
</tr>
<tr>
<td>USB/DMX/512 Converter</td>
<td>£5.00 / $9.75</td>
</tr>
</tbody>
</table>

### NO. 358 SEPTEMBER 2006

<table>
<thead>
<tr>
<th>Project Description</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shortwave Capture</td>
<td>£11.40 / $21.45</td>
</tr>
<tr>
<td>PC16E628-6P, programmed</td>
<td>£5.00 / $9.75</td>
</tr>
<tr>
<td>PC16E628A-2P, programmed</td>
<td>£5.50 / $10.95</td>
</tr>
<tr>
<td>USB/DMX/512 Converter</td>
<td>£5.20 / $9.75</td>
</tr>
</tbody>
</table>

### NO. 356/357 JULY/AUGUST 2006

<table>
<thead>
<tr>
<th>Project Description</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>RC Servo Tester/Exerciser</td>
<td>£5.20 / $9.75</td>
</tr>
</tbody>
</table>
Elektor Electronics (Publishing)
Regus Brentford
1000 Great West Road
Brentford TW8 9HH
United Kingdom
Tel.: +44 (0) 208 261 4509
Fax: +44 (0) 208 261 4447
Email: sales@elektor-electronics.co.uk

Online at electronics.co.uk

Kits & Modules

GameBoy Programmable Logic Controller
(July/August 2006)

GBPLC Module
Ready-assembled and tested
GBPLC Module and Programming Interface
050190-91
£ 84.95 / $ 159.95

GBPLC I2C I/O Box
Ready assembled and tested board
060038-91
£ 84.95 / $ 159.95

Combined package
GBPLC Module and I/O Extension
£ 149.80 / $ 279.00

PRICE SLASHED!

NO: 354 MAY 2006
Onboard OBD-2 Analyser
050176-72 Kit of parts, incl. 050176-1, 050176-2, 050176-42, all components, excl. LCD and Case
050176-73 LCD, 4x20 characters with backlight
050176-74 Case, Bopla Unimars 160 with Perspex cover and mounting plate
050176-42 ATmega16, programmed
050027-72 OBD-2 Analysers, DB9 to OBD adapter cable

NO: 353 APRIL 2006
Simple rechargeable A Cell Analysers
050041-1 PCB, bare
050041-11 PCB, PC Software
Universal SPI Box
050188-41 AT9S2313-24FH, Programmed

NO: 352 MARCH 2006
Application Board for R8C/13
050117-92 Ready-assembled board
050117-97 PCB
050451-72 LCD with backlight
050451-73 Poly-LED display

Telephone Eavesdropper
030279-1 PCB

Versatile FPGA Module
040377-91 Ready assembled plug-on module
For subscribers

Products for older projects (if available) may be found on our website www.elektor-electronics.co.uk

No. 355 JUNE 2006
FM Stereo Test Transmitter
050289-1 PCB
Network Cable Analyser
050302-1 PCB
050302-11 PCB, PIC source code
050302-41 PIC16F874-20/P, programmed

NO: 354 MAY 2006

040172-41 PIC16F84A(J), programmed
040172-71 Kit, incl. PCB, controller, all parts

LED Thermometer
020190-11 4x4, project software
030190-41 PIC16F873-20/P, programmed

Toothbrush Timer
050145-11 4x4, project software
050145-41 AT9S2313-24FH, programmed

Easy Home Control
050233-11 4x4, project software
050233-41 PIC16F84, programmed

Universal LCD Module
050259-11 4x4, project software
050259-41 AT9S2313, programmed

1-Wire Thermometer with LCD
060093-11 4x4, project software
060093-41 PIC16F84A-04C/P, programmed

GBPLC - GameBoy PLC
050190-1-2 PCBs, bare, GBPLC Module & Programming Interface
050190-41 Programmed PAL: EPROM and Flash IC
050190-91 Ready-built and tested GBPLC Module and Programming Interface

Binary Clock
020390-11 4x4, project software
020390-1 PIC16F84A-04P, programmed

No. 355 JUNE 2006

FM Stereo Test Transmitter
050289-1 PCB
Network Cable Analyser
050302-1 PCB
050302-11 PCB, PIC source code
050302-41 PIC16F874-20/P, programmed

£ 41.50 / $ 77.95

LC-display
030451-72 £ 7.25 / $ 13.65

Matching enclosure
060192-71 £ 8.90 / $ 16.85

CD-ROM (all project software)
060192-81 £ 5.20 / $ 9.75
Wireless USB transceiver

Thanks to Wireless USB technology developed by Cypress it's now possible to set up over-the-air links between computer devices using low cost, type-approved and license-free RF modules. However, the system has an even larger potential! In the February 2007 issue we turn to an iBoxRF-168 module capable of communication with other devices or sensors. We've put together a 2.4-GHz Wireless USB Transceiver, an Atmel ATmega168 microcontroller and some more hardware, also comprising a duplexer for separate receive and transmit antenna working. The protocol software is compact enough to be stored in the microprocessor's memory, leaving enough space to add your own application programs.

Explorer-16 (part 2)

With the publication of the February 2007 issue Elektor readers will be able to purchase the exclusive Explorer-16 Value Pack consisting of an Explorer-16 development board, a PICkit 2 debugger & programmer, a PICtail plug-in daughterboard and a discount voucher for the mighty C30 compiler. In the second installment of our article series we'll discuss the Explorer-16 hardware and present a step-by-step guide to audio signal processing and audio file conversion using the PIC24F microcontroller. All backed up by examples, hands-on C programming and Proteus VSM for some really powerful simulation so keep that free Explorer-16 CD-ROM within reach.

Microphone Preamplifier for MP3 Players

Many sound hobbyists have a requirement for recording concerts, interviews, radio broadcasts or natural sounds. With the cassette recorder well and truly a thing of the past, other more contemporary recording equipment is called for. The analogue input found on many of the latest MP3 players enables users to make recordings in MP3 or WMA format. Unfortunately, it's not usually possible to connect a microphone directly to this input, and that's where our project comes to your rescue.

Also...

- Very Simple Clock
- Telemetry for Rockets
- Software Defined Radio (SDR); High Performance Sweep Generator/Wobbulator
- FPGA Course (9); Hexodoku

RESERVE YOUR COPY NOW!

UK mainland subscribers will receive the magazine between 18 and 20 December 2006.

The February 2007 issue goes on sale on Thursday 25 January 2007 (UK distribution only).

Article titles and magazine contents subject to change, please check www.elektor-electronics.co.uk.

NEWSAGENTS ORDER FORM

SHOP SAVE / HOME DELIVERY
Please save / deliver one copy of Elektor Electronics magazine for me each month

Name: 
Address: 
Post code: 
Telephone: 
Date: 
Signature: 

Please cut out or photocopy this form, complete details and hand to your newsagent.
Elektor Electronics is published on the third Thursday of each month, except in July.

elekctor-electronics.co.uk www.elekctor-electronics.co.uk www.elekctor-electronics.co.uk

Elektor Electronics on the web

All magazine articles back to volume 2000 are available online in pdf format. The article summary and parts list (if applicable) can be instantly viewed to help you positively identify an article. Article related items are also shown, including software downloads, circuit boards, programmed ICs and corrections and updates if applicable. Complete magazine issues may also be downloaded.

In the Elektor Electronics Shop you'll find all other products sold by the publishers, like CD-ROMs, kits and books. A powerful search function allows you to search for items and references across the entire website.

Also on the Elektor Electronics website:
- Electronics news and Elektor announcements
- Readers Forum
- PCB, software and e-magazine downloads
- Surveys and polls
- FAQ, Author Guidelines and Contact
<table>
<thead>
<tr>
<th>Description</th>
<th>Price each</th>
<th>Qty</th>
<th>Total</th>
<th>Order Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>CD-ROM USB Toolbox</td>
<td>£ 18.95</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CD-ROM Home Automation</td>
<td>£ 12.95</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visual Basic for Electronics</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Engineering Applications</td>
<td>£ 27.50</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elektor RFID Reader</td>
<td>£ 41.50</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Matching enclosure</td>
<td>£ 8.90</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Prices and item descriptions subject to change. The publishers reserve the right to change prices without prior notification. Prices and item descriptions shown here supersede those in previous issues E & O.E.

<table>
<thead>
<tr>
<th>Sub-total</th>
<th>P&amp;P</th>
<th>Total paid</th>
</tr>
</thead>
</table>

---

**METHOD OF PAYMENT**
(see reverse before ticking as appropriate)

- [ ] Bank transfer
- [ ] Cheque
  - (UK-resident customers ONLY)
- [ ] Giro transfer
  - [ ] VISA

**METHOD OF PAYMENT**
(see reverse before ticking as appropriate)

- [ ] Bank transfer
- [ ] Cheque
  - (UK-resident customers ONLY)
- [ ] Giro transfer
  - [ ] VISA

---

**Regus Brentford**
**1000 Great West Road**
**Brentford TW8 9HH**
**United Kingdom**

Tel.: +44 208 261 4509
Fax: +44 208 261 4447
www.elektor-electronics.co.uk
sales@elektor-electronics.co.uk

*USA and Canada residents may (but are not obliged to) use US prices, and send the order form to:
Old Colony Sound Lab
P.O. Box 828, Pocasset
NH 03866-0050. Tel. (603) 924-5371, 924-5255, Fax: (603) 924-3467
Email: custserv@aol.com

**Regus Brentford**
**1000 Great West Road**
**Brentford TW8 9HH**
**United Kingdom**

Tel.: +44 208 261 4509
Fax: +44 208 261 4447
www.elektor-electronics.co.uk
subscriptions@elektor-electronics.co.uk

---

Yes, I am taking out an annual subscription to Elektor Electronics and receive a free 1 W Luxeon LED Torchlight.

I would like:
- [ ] Standard Subscription (11 issues)
- [ ] Subscription-Plus (11 issues plus the Elektor Volume 2006 CD-ROM)

* Offer available to Subscribers who have not held a subscription to Elektor Electronics during the last 12 months. Offer subject to availability. See reverse for terms and conditions.

**Name**

**Address - Post code**

**Tel.**

**Email**

**Date** — — 2007  **Signature**
ORDERING INSTRUCTIONS, P&P CHARGES

Except in the USA and Canada, all orders, except for subscriptions (for which see below), must be sent BY POST or FAX to our Brentford address using the Order Form overleaf. On-line ordering: http://www.elektor-electronics.co.uk

Readers in the USA and Canada may (but are not obliged to) send orders, except for subscriptions (for which see below), to the USA address given on the order form. Please apply to Old Colony Sound for applicable P&P charges. Please allow 4-5 weeks for delivery.

Orders placed on our Brentford office must include P&P charges (Priority or Standard) as follows:
- UK: £4.00 Europe: £5.00 (Standard) or £7.00 (Priority) Outside Europe: £6.00 (Standard) or £12.00 (Priority)

HOW TO PAY

All orders must be accompanied by the full payment, including postage and packing charges as stated above or advised by Customer Services staff.

Bank transfer into account no. 40209520 held by Elektor Electronics (Publishing) / Segment b.v. with ABN-AMRO Bank, London, IBAN: GB35 ABIA 4020 3040 2095 20. BIC: ABINGB2L Currency: sterling (UK). Please ensure your full name and address gets communicated to us.

Cheque sent by post, made payable to Elektor Electronics (Publishing) / Segment b.v. We can only accept sterling cheques and bank drafts from UK-resident customers or subscribers. We regret that no cheques can be accepted from customers or subscribers in any other country.

Giro transfer into account no. 34-152-3801, held by Elektor Electronics (Publishing) / Segment b.v. Please do not send giro transfer/deposit forms directly to us, but instead use the National Giro postcard paid envelope and send it to your National Giro Centre.

Credit card VISA, Access, MasterCard, JCB Card and Switch cards can be processed by mail, email, web, fax and telephone. On-line ordering through our website is SSL-protected for your security.

COMPONENTS

Components for projects appearing in Elektor Electronics are usually available from certain advertisers in this magazine. If difficulties in the supply of components are envisaged, a source will normally be advised in the article. Note, however, that the source(s) given is (are) not exclusive.

TERMS OF BUSINESS

Delivery Although every effort will be made to dispatch your order within 2-3 weeks from receipt of your instructions, we cannot guarantee this time scale for all orders. Returns Faulty goods or goods sent in error may be returned for replacement or refund, but not before obtaining our consent. All goods returned should be packed securely in a padded bag or box, enclosing a covering letter stating the dispatch note number. If the goods are returned because of a mistake on our part, we will refund the return postage. Damaged goods Claims for damaged goods must be received at our Brentford office within 10-days (UK), 14-days (Europe) or 21-days (all other countries). Cancelled orders All cancelled orders will be subject to a 10% handling charge with a minimum charge of £3.00. Patents Patent protection may exist in respect of circuits, devices, components, and so on, described in our books and magazines. Elektor Electronics (Publishing) does not accept responsibility or liability for failing to identify such patent or other protection. Copyright All drawings, photographs, articles, printed circuit boards, programmed integrated circuits, diskettes and software carriers published in our books and magazines (other than in third-party advertisements) are copyright and may not be reproduced or transmitted in any form or by any means, including photocopying and recording, in whole or in part, without the prior permission of Elektor Electronics (Publishing) in writing. Such written permission must also be obtained before any part of these publications is stored in a retrieval system of any nature. Notwithstanding the above, printed circuit boards may be produced for private and personal use without prior permission. Limitation of liability Elektor Electronics (Publishing) shall not be liable in contract, tort, or otherwise, for any loss or damage suffered by the purchaser whatsoever or howsoever arising out of, or in connection with, the supply of goods or services by Elektor Electronics (Publishing) other than to supply goods as described or, at the option of Elektor Electronics (Publishing), to refund the purchaser any money paid in respect of the goods. Law Any question relating to the supply of goods and services by Elektor Electronics (Publishing) shall be determined in all respects by the laws of England.

January 2007

SUBSCRIPTION RATES FOR ANNUAL SUBSCRIPTION

<table>
<thead>
<tr>
<th></th>
<th>Standard</th>
<th>Plus</th>
</tr>
</thead>
<tbody>
<tr>
<td>United Kingdom</td>
<td>£41.90</td>
<td>£48.80</td>
</tr>
<tr>
<td>Surface Mail</td>
<td>£54.50</td>
<td>£61.40</td>
</tr>
<tr>
<td>USA &amp; Canada</td>
<td>US$ 95.50</td>
<td>US$106.50</td>
</tr>
<tr>
<td>Airmail</td>
<td>£68.90</td>
<td>£75.80</td>
</tr>
<tr>
<td>USA &amp; Canada</td>
<td>US$120.00</td>
<td>US$131.00</td>
</tr>
</tbody>
</table>

HOW TO PAY

Bank transfer into account no. 40209520 held by Elektor Electronics (Publishing) / Segment b.v. with ABN-AMRO Bank, London, IBAN: GB35 ABIA 4020 3040 2095 20. BIC: ABINGB2L Currency: sterling (UK). Please ensure your full name and address gets communicated to us.

Cheque sent by post, made payable to Elektor Electronics (Publishing) / Segment b.v. We can only accept sterling cheques and bank drafts from UK-resident customers or subscribers. We regret that no cheques can be accepted from customers or subscribers in any other country.

Giro transfer into account no. 34-152-3801, held by Elektor Electronics (Publishing) / Segment b.v. Please do not send giro transfer/deposit forms directly to us, but instead use the National Giro postcard paid envelope and send it to your National Giro Centre.

Credit card VISA, Access, MasterCard, JCB Card and Switch cards can be processed by mail, email, web, fax and telephone. On-line ordering through our website is SSL-protected for your security.

SUBSCRIPTION CONDITIONS

The standard subscription order period is twelve months. If a permanent change of address during the subscription period means that copies have to be dispatched by a more expensive service, no extra charge will be made. Conversely, no refund will be made, nor expiry date extended, if a change of address allows the use of a cheaper service.

Student applications, which qualify for a 20% (twenty per cent) reduction in current rates, must be supported by evidence of student status signed by the head of the college, school or university faculty. A standard Student Subscription costs £33.50, a Student Subscription Plus costs £40.40 (UK only).

Please note that new subscriptions take about four weeks from receipt of order to become effective.

Cancelled subscriptions will be subject to a charge of 25% (twenty-five per cent) of the full subscription price or £7.50, whichever is the higher, plus the cost of any issues already dispatched. Subscriptions cannot be cancelled after they have run for six months or more.

January 2007
New

CD-ROM
USB TOOLBOX

This CD-ROM contains all the essential information a designer needs to start working with the USB interface. It includes a large collection of data sheets for specific USB components from a wide range of manufacturers.

There are two ways to incorporate a USB interface in a microcontroller circuit. You can add a USB controller to an existing circuit, or use a microcontroller with an integrated USB interface. Both options are available on this CD-ROM.

USB Toolbox provides information on all ICs suitable for different applications. A sub-division has been made in controllers, hubs, microcontrollers and others. What is perhaps more interesting for many designers however, is the extremely extensive software collection which contains drivers, tools and components for Windows, Delphi and various microcontroller families. Of course, none of the Elektor Electronics articles on the subject of USB are missing on this CD-ROM.

INDEX OF ADVERTISERS

AC Semitec Ltd, Showcase ......... www.atosemitec.co.uk ........... 78
Avit Research, Showcase ......... www.avitresearch.co.uk ....... 78
BARD, Showcase ............... http://bardi.tripod.com ........... 78
Beijing Draco ................. www.expch.com ............... 13
Betal Layout, Showcase ........ www.pcb-pool.com ................. 19, 78
Bisscope Designs ............ www.bisscope.com ............. 78
ByVac ............. www.byvac.co.uk ............. 19
Compulogic, Showcase ............ www.compulogic.co.uk .... 78
Conford Electronics, Showcase .... www.confordtec.co.uk .... 78
Crickwood ................... www.cctcentre.co.uk .......... 26
Danbury, Showcase ............. www.DanburyElectronics.co.uk .... 78
Easysync, Showcase ............ www.easysync.co.uk .......... 78
Elcor, Showcase ............. www.elcor.com ............. 78
Episcoft ..................... www.episcoft.com ............ 28
Eurocircuits .................. www.eurocircuits.com .......... 6
First Technology Transfer Ltd, Showcase .... www.ftt.co.uk .......... 78
Forest ......................... www.tored.co.uk ........... 13
Future Technology Devices, Showcase .... www.futurechip.com ...... 58, 59, 78
Futuretec, Showcase ........... www.futuretec.com ........... 78
Heroe Technology, Showcase .... www.heroeotechnology.co.uk .... 78
Intronix Test Instruments ........ www.intronixtestinstruments.com .......... 19
Jaycar Electronics .......... www.jaycarelectronics.co.uk .... 2
JB Systems, Showcase ........ www.modetron.com ............. 79
JLB Electronics, Showcase .... www.jlbelectronics.com .......... 78
KGS TraceMe ................. www.TraceMe.eu ................. 58, 53
KMK Technologies Ltd, Showcase .... www.kmk.com.hk ............. 78
Labcenter ..................... www.labcenter.co.uk ........ 88
Lichfield Electronics .......... www.lichfieldelectronics.co.uk ...... 37
London Electronics College, Showcase .... www.lec.org.uk .......... 79
Micronet ................. www.micronetchip.com/16bit ...... 27
MJP Electronics, Showcase .... www.mjp_eletronics.co.uk ........ 79
New Wave Concepts, Showcase .... www.newwave-concepts.com ........ 79
Newbury Electronics .......... www.newburyelectronics.co.uk ...... 11
Number One Systems ........ www.numberonesystems.com .......... 7
Pactronics .................. www.pactronics.com ........... 33
PCB World, Showcase ........ www.pcbworld.org.uk .......... 78
Pico ......................... www.picotech.com ............. 7
Quasar Electronics .......... www.quasarelectronics.com ........ 47
Robot Electronics, Showcase .... www.robot-electronics.co.uk .......... 79
Scantool ..................... www.ElmScantool.com ........ 5
SourceMAG, Showcase ........ www.sourcemag.com ........... 79
Sytronic Technology Ltd, Showcase .... www.sytronic.com .......... 79
UltraTouch, Showcase .......... www.ultratouch.co.uk .......... 79
USB Instruments, Showcase .... www.usbins土耳其nstruments.com .......... 79
Virmos Technology, Showcase .... www.virmos.com ............. 79

Advertising space for the issue of 19 February 2007 may be reserved not later than 23 January 2007.
**PROTEUS**

**ELECTRONIC DESIGN**

**FROM CONCEPT**

**TO COMPLETION**

---

**SCHEMATIC CAPTURE**

A powerful capture package tailored for today's engineer and designed to allow rapid entry of complex schematics for simulation and PCB Layout.

**PROSPICE MIXED MODE SIMULATOR**

A customised implementation of the industry standard Berkeley SPICE 3F5 engine with extensive optimisations and enhancements for true mixed mode simulation and circuit animation.

**VSM VIRTUAL SYSTEM MODELLING**

The world's first and best schematic based microcontroller co-simulation software. Proteus VSM allows you to simulate the interaction between software running on a microcontroller and any analog or digital electronics connected to it. This streamlines the project lifecycle and obviates the need for expensive hardware analysis tools.

**ARES PCB DESIGN**

A modern and professional layout package which seamlessly integrates with the ISIS capture software. Features such as autoplacement and autorouting, interactive DRC, and an intuitive interface all serve to maximise productivity and reduce time to market.

---

**LABCENTER ELECTRONICS LTD.**

A technology pioneer in the EDA industry since 1988.

Technical support direct from the program authors.

Flexible packages and pricing tailored to customer requirements.

---

**CONTACT US NOW**

to discuss requirements or request a FREE evaluation copy.

Tel: 01756 753440
Fax: 01756 752857
Email: info@labcenter.co.uk

---

www.labcenter.co.uk

Labcenter Electronics Ltd., 53-55 Main Street, Grassington, North Yorks, BD23 5AA. Registered in England 4692454