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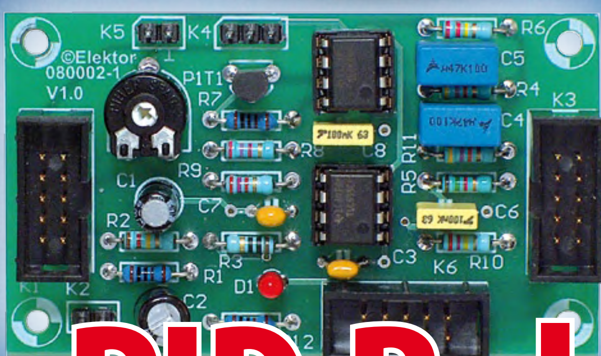
elektor

electronics worldwide

e-CAD Software FREE DOWNLOAD



PID Balancing Act

...a real challenge...

Think that Cursor!

brain-driven user interface

...LED BICYCLE LIGHT...BASCOM AVR COURSE...DCC CONTROLLER...ULTRASONIC DETECT

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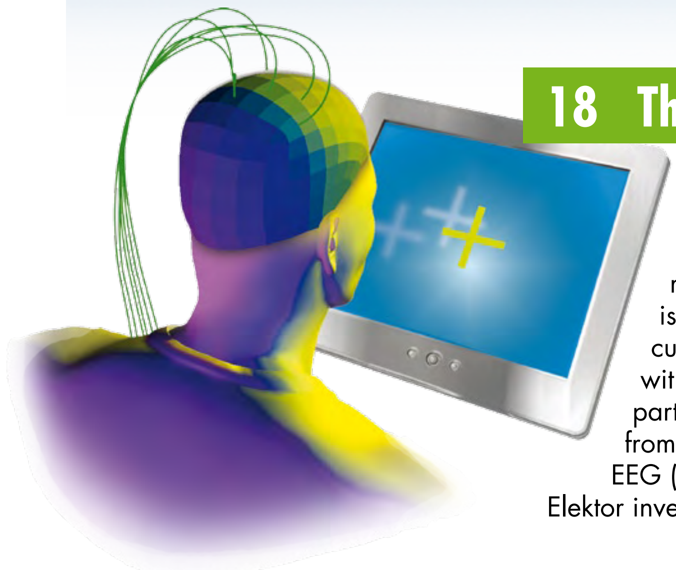
Crossing the Pyrenees, Alps, Atlantic & the Great Wall

Electronics is a now a largely borderless activity as far as publishing and exchange of information are concerned. The only barrier that seems to exist (mostly in people's heads) is language, but hey no problem as English is the *lingua franca* of electronics, everyone knows their *printers* and *datasheets* and Elektor is available in several translated editions to those preferring their mother tongue. That is not to say the *couleur locale* can be dispensed with and consequently all our international editors and advertisers do their best to localise the magazine to their markets.
The Spanish edition of Elektor, admirably edited by Eduardo Corral, was launched one year ago to reach readers not just in Spain, but also in the US and a number of south-American countries. The same basically for the Portuguese licenced edition, of which a special version is produced for Brazil. By the time you read this, Elektor's Italian licence partner Inware Edizioni srl should have their website and subscriptions intake up and running and we can look forward to seeing an authorised Italian Elektor again after a dozen or so years.
Elektor is also crossing the Atlantic, now trialling the US market with a slightly adapted, locally printed and distributed version of this, the international English version of the magazine. Although our entry into the `States is still in the 'block diagram' phase, I'm convinced that adding North American subscribers and advertisers holds a promise of significantly widening the circle of enthusiasts, professionals and companies serviced by our magazine, website, products and events.
Speaking of e-vents, we're now taking reservations (via the Elektor website) for our second business trip to China in November of this year. The second round will comprise a business conference with local industrialists and a visit to the only government-authorised market for electronics trade and manufacturing. A visit to the Great Wall is also scheduled in — if only to see for yourself that it failed both ways as a barrier to modern electronics.

Jan Buiting
Editor

The idea behind this College project is to try to balance a ball on a beam using a PID control loop. If the ball is pushed, the system moves the beam to return the ball to its initial position.
So get out your USB DAQ card and a PC, and show off!

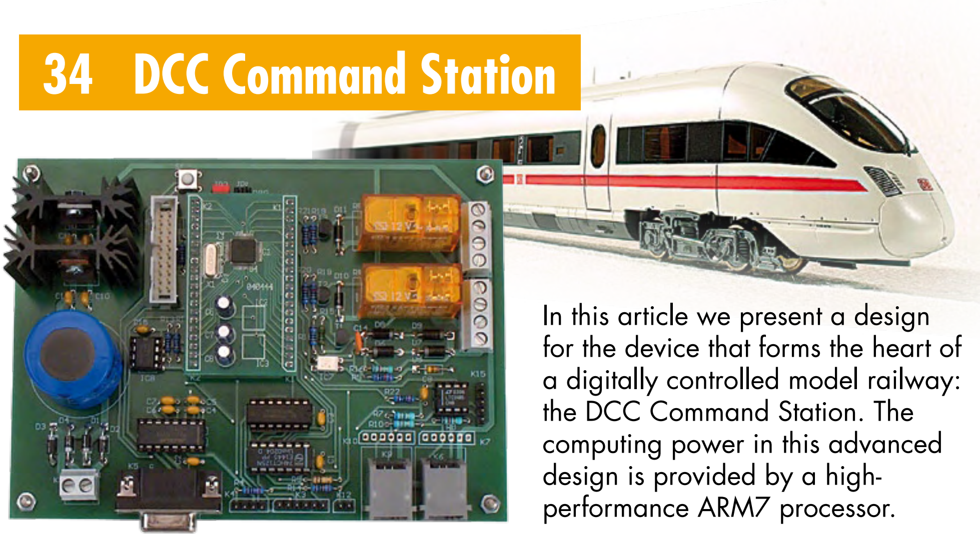
BALL & BEAM for Elektor USB DAQ Card



18 The Thought Cursor

Controlling a computer using the power of thought alone is less far-fetched than you might believe. The easy part is to measure precisely the tiny currents in the brain associated with thought processes; the hard part is to extract the thoughts from the morass of multi-channel EEG (electroencephalogram) data. Elektor investigates.

34 DCC Command Station



In this article we present a design for the device that forms the heart of a digitally controlled model railway: the DCC Command Station. The computing power in this advanced design is provided by a high-performance ARM7 processor.

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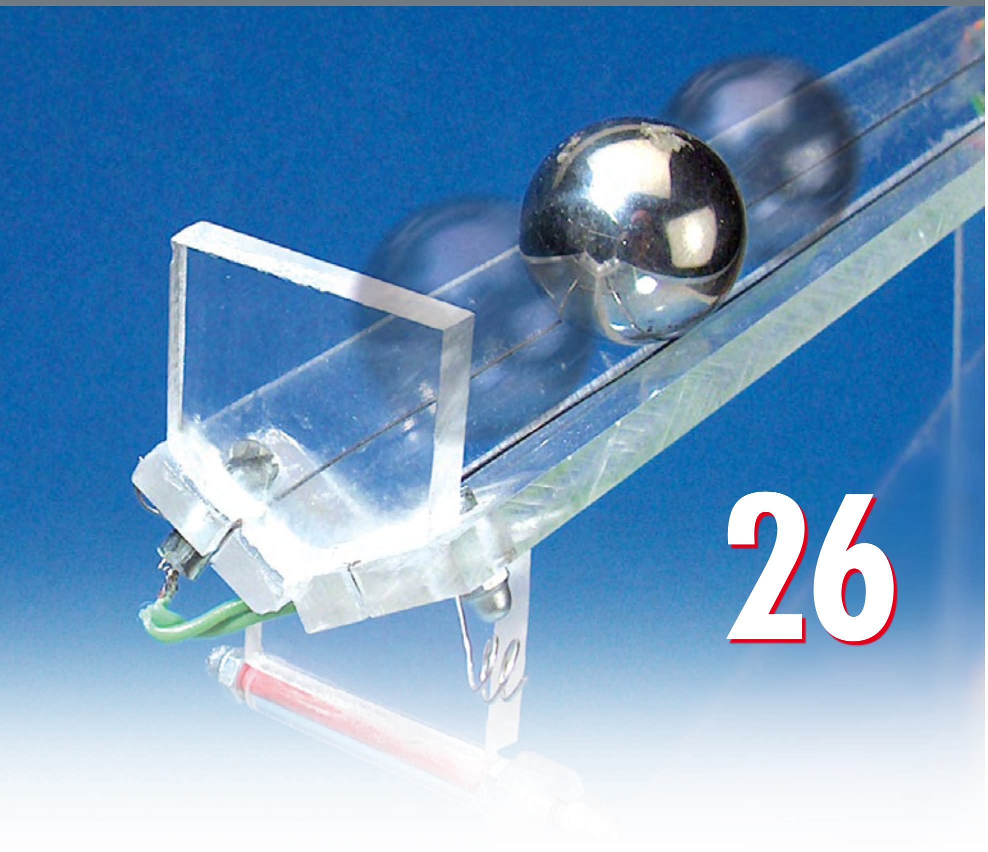
September 2008
no. 381



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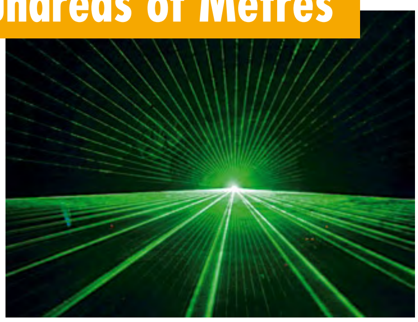
20 Panorama: e-CAD Anthology

The November 2005 'Kaleidoscope' DVD with 30-odd programs relating to electronics CAD (Computer-Aided Design) was a huge success. Three years on, we decided to repeat the exercise. This time round, instead of physical DVD with the magazine, the programs come as free downloads!

60 Projection over Hundreds of Metres



With a few servos, a laser module from eBay, a microcontroller and a little dexterity we can make a laser projector which, depending on the laser, can be seen from several hundreds of metres.

elektor international media

Elektor International Media provides a multimedia and interactive platform for everyone interested in electronics.
From professionals passionate about their work to enthusiasts with professional ambitions.
From beginner to diehard, from student to lecturer. Information, education, inspiration and entertainment.
Analogue and digital; practical and theoretical; software and hardware.

Volume 34, Number 381, September 2008 ISSN 1757-0875

Elektor aims at inspiring people to master electronics at any personal level by presenting construction projects and spotting developments in electronics and information technology.

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Age, technology and education

Dear Editor — in response to the quite extensive article 'UK University Courses for Electronics & Electrical Engineering' in the February 2008 issue of *Elektor*, and recognising that the problem is not exclusive to the UK, I'd like to present the subject with a slightly different perspective: what kind of education shall the University bestow on the 'new students'?

Although a learning curve is always related to the complexity of the subject matter, fields like electronics, communications or computers have an added difficulty; the technology advances do not agree very well with unstructured or occasional study. In fact, age is a difficulty which will influence more the newcomers or new candidates to a job.

As an example of applied mobile communications, let's look at a third generation mobile phone (3G). From project design right up to manufacturing, just how many disciplines are involved?

Of course nobody can be an expert covering everything from the functional architecture right up to the case design and ergonomic matters, although the team leader should have clear ideas about such vastly different subjects as VLSI or camera lenses. He or she will be supported by an extensive group of experts for each main part, whether a power supply controller, a multilayer PCB or the battery to be used.

We can move the problem to another layer, allowing the project leader to get support from the product supplier, as is often the case, but then he or she forfeits freedom of choice and time. Consequently it is often decided to mix in-house expertise, supplier support and external sources to carry out well defined tasks.

It's often heard that "there is nothing new today"; the latest mobile phone being no more than the previous one enriched with better features or implementing new technologies, more frequently some 'feature' to keep up with the competition.

Hence brand new products need know-how, which basically is the cumulative experience of successful projects, innovation and creativity.

Innovation and creativity often goes on account of newcomers, graduated or not. Not being stuck in past, they just have ideas — maybe old concepts, but new for them!

The screening has to be done by experienced experts, but a question arises, are they prepared to understand a brilliant idea? The notion of 'education and then a job' is not motivating for creative people, they want to be part of the action.

Today, technologies advance much faster than any practical application, so insisting on education followed by more education without presenting an opportunity to experiment in practice, causes many students to either drop out or go for a short time graduation path.

New students must have deep knowledge of the fundamentals related to any technology or field of application. A graduate in history or languages doing an MA on Computer Science will know a lot of 'names' but most probably still not understand why the work of Jack Kilby was so important for today's degree of integration in ICs.

The panorama is not exclusive to electronics, communications or computers. If we think about biotech, nanotech or any other emergent technologies the situation is worse. For years, scientists, universities and private labs worked hard on nanotube growth — today we can buy such tools off the shelf; that's the reality. After 20 years of R&D and lump sums invested, nanotechnology today is a well established industry, and the return will be high.

With real-life needs and applications often neglected as opposed to pure technology research, I wonder if the industry will be able to cope with its need to find sufficient skilled professionals in the near future. It's time for the industry, the universities and private labs to get together and start reflecting.

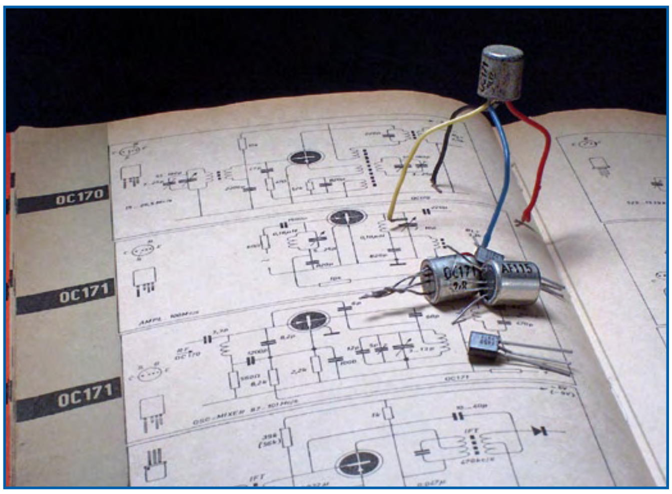
The European countries are too hierarchically minded for some matters, and too tolerant for others. But we are not alone in the competition.

Rui Figueiredo (Portugal)

The OC171 Mystery (solved) (1)

Dear Jan — referring to your article in the Summer Circuits 2008 edition I would question the 'solved' part of the title as the cause of the growth of the fibres is still subject to speculation in the article.

I was involved in the investigation of similar sounding metallic fibre growth inside a metal can, in my case it was a VCO module, eventually causing failure by shorting to the circuit inside the can. The fibres were shown to be crystalline tin and grew usually straight (though some were curly) from the can out into the air space at various angles. The cause was traced to the can being made of tin plated brass and the growth of such fibres is apparently a well known phenomenon. These fibres grow more quickly in a cold environment which matched our experience with this VCO.



The article does not state the composition of the OC171 metal can, but there are pictures and a video here

www.vintage-radio.info/whiskers/ for a similar effect in an AF117 which states that the can is tin plated and that the whiskers are tin.
It would seem that tin plating is not such a good idea when applied to enclosures for electronic circuits!
Jim Thurgood (UK)

Thanks for the response to my article Jim — it seems to have generated an unexpected amount of feedback. Also thanks for the interesting link. I am also grateful to Andy Emmerson for his advice that the history of electronics contains a few mistakes and it is useful to write about them!
For more scientifically based theories, you might want to have a look at www.springerlink.com/content/v77jl33102116274/ which indicates that the cause of this dendritic growth problem may be undercooling, but I am not sufficiently well informed to know how relevant this article is.
This may be related also: www.nature.com/nature/journal/v216/n5115/abs/216574b0.html
I agree that the exact nature of the microscopic hair growth inside these transistors is still a matter of debate or research but in the title I was referring to the mystery of circuits suddenly failing after 25-40 years, and that has been solved as far as I am concerned.

The OC171 Mystery (solved) (2)

Hi Elektor — thanks for an interesting Summer Circuits edition; lots of nice, small projects off the beaten track.
By the way, those funny short-circuits in the old OC trannies may be 'tin whiskers' i.e. e growth of tin hairs from tinned surfaces. A nasty problem with PCB tracks, too! Lots of information out there on the web if you Google for tin + whisker.
Jan Philipp Wuesten (AskJanFirst) (Germany)

That's right Jan Philipp, 'whisker' is a correct term to use in this case.

The OC171 Mystery (solved) (3)

Dear Editor — I just received my July/August 2008 edition and read the above article with interest. It mentions 'hairs' growing. IMHO these are whiskers, i.e., needle-shaped monocrystals growing out of layers separated by galvanic or pyrolitic effects.
The hairs are just a few micrometers thick and may be removed by a current surge (alas, this may end transistor's life).
I was curious to read that several theories had been created around this effect, realizing that 'whiskers' formation is a well known problem.
H. Kobow (Germany)

Thank you for your response to my article, which also appeared in translation in the German Elektor. Whisker growth is indeed a correct term to describe the effects. Although the theories behind pyrolitic growth and dendrite formation from tin and metal junctions and compounds have been covered by advanced metallurgy for many years, I can only assume that the makers of the OC170/171 transistors had no way of knowing in the early 1960s. After all, it takes about 25-40 years for the hairs to become long enough to cause short-circuits, the period well exceeding the useful lifetime of a transistor radio.
As I wrote, 'zapping' the whiskers is not a permanent solution.

A stable audio signal (2)

Dear Sir — this refers to the request of Mr. Monteban for a stable a.f. signal source for audio measurements (Mailbox, June 2008). A construction project called 'Spot Sinewave Generator' was published in the May and June 1985 issues of *Elektor*, which hopefully will cover Mr. Monteban's requirements.
Darius Toorkey (India)

Thanks for helping Mr. Monteban, Darius.

Marconi rebranding of FUP1D

Hi Jan — Retronics is always a very interesting section. I have a good few pieces of test equipment of that age and older myself. I may start writing about them when I retire next year!
Referring to the June 2008 instalment I have the FUP1D, with the additional UHF band. It is branded 'MI', which stands for Marconi Instruments and would originate in the UK. It is identical to your photo but is labelled TF2950, which was the Marconi series of numbers for test equipment.
Ed Dinning (UK)

Many thanks Ed an looking forward to seeing some articles from you. Thanks also to Ludo ON4AIO from Belgium who mailed me a copy of the TF2950 product information sheet.

Good old 8051

Dear Editor — I still see a lot of projects based on some 8051 derivative. And almost everybody uses some C compiler or assembler.
For those who like programming in Pascal here is Turbo51 — a free Pascal compiler for the 8051 family of microcontrollers. It's found at http://turbo51.com and features a fast single pass optimizing compiler, Borland Turbo Pascal 7 syntax, full floating point support, mixed Pascal and assembler programming, full use of register banks, advanced multi-pass optimizer, smart linker, generates compact high quality code, output formats include binary, Intel HEX and assembler source.
I wrote Turbo51 because I like Pascal programming language, still work a lot with 8051 and couldn't find any good Pascal compiler for 8051. I believe that sooner or later there will be some project published in your magazine that will use Turbo51.
Igor Funa

Corrections & Updates

Portable Thermometer
July & August 2008, p. 19, ref. 080418-1
The type number shown in the circuit diagram for IC5 should be: PIC16F684.

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New 2 MB & 8 MB nvSRAMs from Cypress

Cypress Semiconductor Corp. recently introduced 2-Mbit and 8-Mbit non-volatile static random access memories (nvSRAMs), extending their nvSRAM portfolio from 16 kbit to 8 Mbit. The new devices feature access times as low as 20 ns, infinite read, write and recall cycles, and 20-year data retention. They offer the best solution for applications requiring continuous high-speed writing of data and absolute non-volatile data security. Systems requiring nvSRAM functionality include servers, RAID applications, harsh-environment industrial controls, automotive, medical and data communications.

The 2-Mbit nvSRAM and CY14B108 8-Mbit nvSRAM are ROHS-compliant and directly replace SRAM, battery-backed SRAM, EPROM and EEPROM devices, offering reliable non-volatile data storage without batteries. Data transfers from the SRAM to the device's non-volatile elements take place automatically at power down. On power up, data is restored to the SRAM from the non-volatile memory. Both operations are also available under software control. The new nvSRAMs are manufactured on Cypress's S8(tm) 0.13-micron SONOS (Silicon Oxide Nitride Oxide Silicon) embedded non-volatile memory technology, enabling greater densities and improved access times and performance.

The new devices have an available Real Time Clock feature that combines the industry's lowest standby oscillator current with the highest performance integrated memory, enabling event time-stamping supported by non-volatile memory.

www.cypress.com/NVM

(080624-I)

Elektor E-vent: Study Trip to China

Elektor's second Study Trip to China is planned for 9–18 November 2008.

We will visit the China Electronics Fair in Shanghai with an exhibition area of 60,000 m² representing the electronics industrial chain set up for one-stop purchasing of high-end components. This authoritative electronics show is the only one with full support from the Chinese Ministry of Information Industry and Ministry of Commerce. It was classed 'A' exhibition in 2003 by the Ministry of Commerce.

Also on the programme is a visit to the largest electronics-packed street in Beijing and/or Shanghai. The shops, often 4 to 5 floors tall, are choc-a-bloc with components, microcontrollers, experimenter's boards, modules, electric plugs, LEDs in assorted colours, LCDs and much more. Everything an electronics enthusiast can dream up can be found here!

A business conference is also organized as part of the tour, providing an insight into trade opportunities in China.

Of course there is again room for culture like the Forbidden City, Tiananmen Square, the Great Wall, the Maglev train, and more.

The price of this all-inclusive tour is € 3,995 (plus VAT) per person.

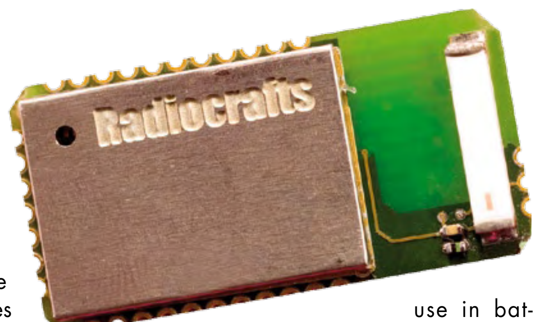
If you are interested in joining us in November, please register now on www.elektor.com and you will receive more detailed information.

ZigBee® network module

Radiocrafts AS expand their product line with a compact ZigBee Network Module (ZNM) for use in ZigBee based mesh networks. The ZNM module offers the complete ZigBee network protocol in a small module with an easy to use API interface. By using the new ZNM module, ZigBee applications can be built with minimum effort, reducing time to market.

The RC2300-ZNM module is a compact surface-mounted high performance module measuring only 12.7×25.4×2.5 mm including EMC shielding and integrated antenna. The module is delivered on tape and reel for volume production.

The module is very easy to use having a UART or SPI interface for serial communication and configuration. The ZigBee application runs in any external controller, communicating with the module by an easy-to-use API. With only 10 API calls, a complete application can be made. The new module supports all features of the ZigBee 2006 standard.



The RC2300-ZNM module is pre-certified for operation under the European, FCC and ARIB radio regulations for license-free use. It operates at 16 channels in the 2.45 GHz frequency band. When used with quarter-wave antennas a line-of-sight range of 250 metres can be achieved. Indoor range is typically 10–30 metres. The module is designed for use in battery operated systems using sleep mode with less than 1 μA.

The module, Demo Kits and PC development tools are available now.

www.radiocrafts.com

(080624-III)

Multinational Micromouse championship showcases a new generation of robotic talent

Teams from Singapore, India, Iran and the Netherlands joined competitors from across the UK, at this summer's UK Micromouse robotics championship. Organised by Birmingham City University, the event saw over 50 mini robots competing in maze-solving, wall-following, drag racing and mini-sumo challenges.

The senior maze-solving final featured a tense battle between Derek Hall, the 2007 champion, and his regular UK Micromouse adversary, Peter Harrison. The maze-solver challenge sees the autonomous mini-robot 'mice', racing unaided to the centre of a specially constructed maze over a series of timed runs. Derek successfully defended his title, with his 'MouseX' and 'MouseX2' robots claiming the top two places, registering the competition's fastest run-time of 6.98 seconds.

A new generation of robotic talent demonstrated their skills in the UK Micromouse categories for junior and schools competitors. The robotics club from Singapore's Woodlands Ring Secondary School dominated the top places

Competitors gather at the end of the event to compare robots.

in the schools drag racing challenge. Their fastest stepper-motor powered challenger completed the course in a time of 2.13 seconds. The honours in the wall-following and line-following categories were shared by the UK's John Hampden Grammar School and Hillcrest Community School.

Micromouse championships have been held annually in the UK for nearly 30 years, with similar events also taking place in the USA and across East Asia. The original aim of stimulating interest in the then fledgling fields of software and electronics is now more relevant than ever. The increasing prevalence of these technologies in industry and society has led to widely-acknowledged skills shortages in these areas.

UK Micromouse organiser, Birmingham City University's Dr Tony Wilcox says: "It was really encouraging to see this new generation of competitors in action. Mini-robots are a great way to get 'hands-on' and explore software and electronics technologies, which is the most effective way to spark new interest in these areas."

Further details about the event and building mini-robots can also be found at www.tic.ac.uk/micromouse.

RS Components for energy efficient products

RS Components recently launched its Solutions for Energy Efficiency range, allowing electronic design engineers to view and choose from over 1,600 of the best-in-class power-efficiency products, encompassing 40 technologies from 60 leading manufacturers. All products are available direct from rswww.com/electronics, enabling the speedy creation of energy efficient designs.

Product highlights include:

Texas Instruments

- TPS63000 voltage regulator for extremely low power applications such as PDAs, MP3 players and LEDs
- MSP430 ultra low power microcontroller range optimised to deliver extended battery life in portable applications
- CC2520 low power Zigbee transceiver and development kit for RF engineers designing wireless networks in applications such as automatic meter reading.

National Semiconductor

NI's PowerWise range of energy efficient products includes a wide selection of products from amplifiers that guarantee the lowest input bias current in the industry to data-converters that consume 30% less power than competitive devices.

NXP

- GreenChip ICs for power supplies, designed specifically for Laptop computers and LDC TVs, reducing no-load standby power consumption to 0.2-0.3W.

RS Components

Ultra-miniature switch mode power supply units that provide no-load power consumption of <0.5W.

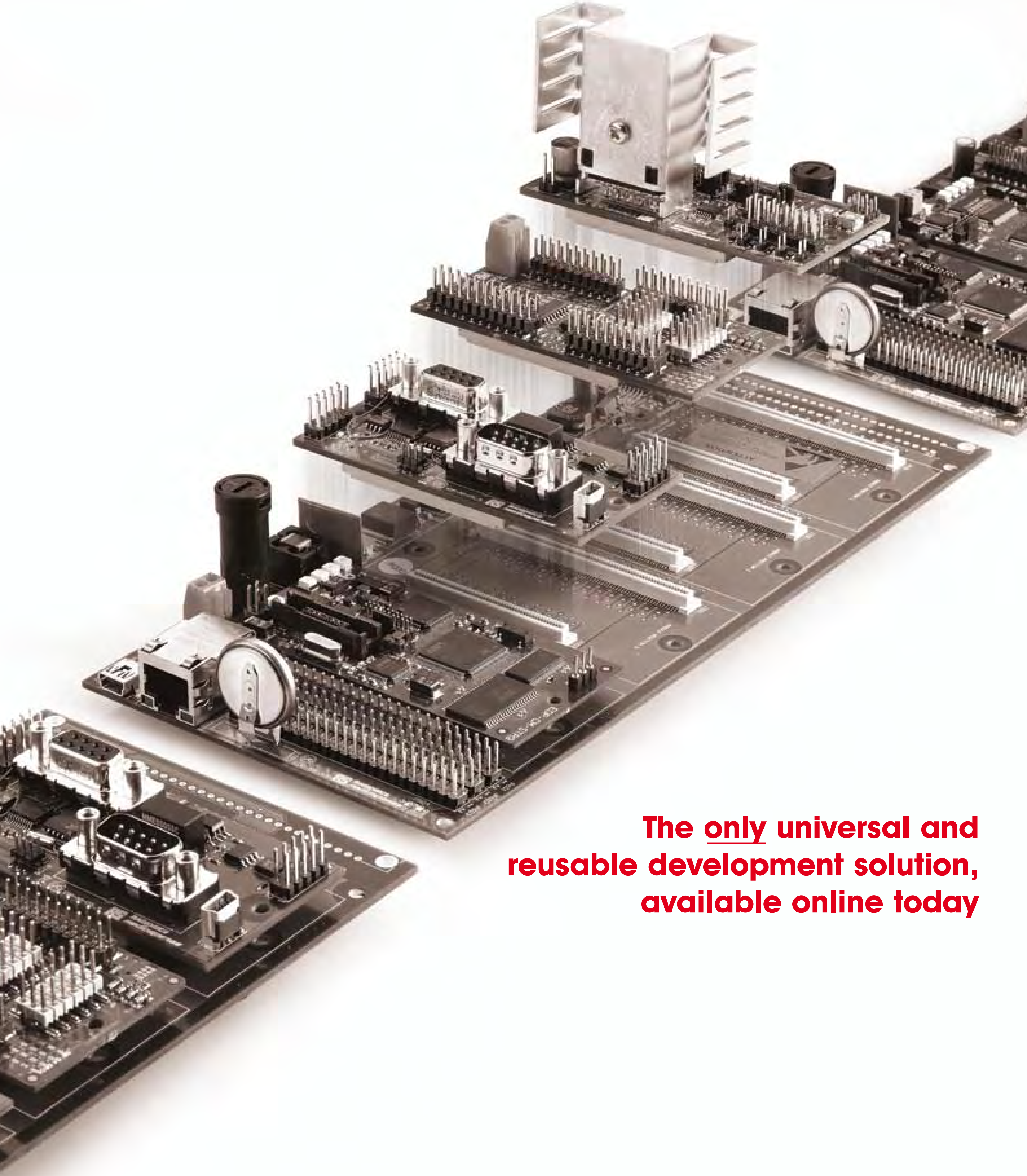
Integral to the range are a number of energy harvesting products to exploit natural, renewable energy sources. These include wind and solar power products together with their associated regulators and batteries. Also featured are EnOcean wireless control, switching and sensing products that don't need external power or batteries as all the power is generated internally.

Passives are also available including ultra compact power inductors from Würth.

A selection of peripheral devices complements the entire offering with various wireless and display options for the engineer to choose from. RS has also selected the Golden Dragon LED range from Osram, one of the market leaders in solid state lighting solutions.

http://rswww.com/electronics

(080624-II)



Elektor Workshop: Graphical Programming of Microcontrollers using Flowcode

Date: 4 October 2008, from 09.00 – 16.00 hours.
Location: Birmingham City University, Technology Innovation Centre, Millennium Point, Curzon Street, Birmingham B4 7XG.

Lecture and workshop presenters:
Dr. Nick Holden BSc(Hons) PhD CEng MIET, Senior Lecturer in the Centre for Electronics and Software, Technology Innovation Centre, Birmingham City University.

Mr. Parmjit Chima BEng PgDip, Manager, Centre for Electronics and Software, Technology Innovation Centre, Birmingham City University.

Dr. Nick Holden

Mr. Parmjit Chima

The purpose of this one-day course is to program and apply PIC microcontrollers in an accessible and practical way.
The participants will learn how to use Flowcode to exercise some of the functionality of these modern microcontrollers using peripherals such as timers, counters, digital port I/O, A/D and USART, with polling and interrupt techniques.
The course will use the E-blocks hardware with one of the common 40-pin PIC microcontrollers. The graphical programming of the microcontroller is done with the revolutionary new software Flowcode version 3. The knowledge gained can also be applied to other 8-bit microcontrollers such as the AVR from Atmel.

The participant will at the end of the day be able to build embedded systems with analogue values and switches as inputs and output via LCD and LEDs.
This workshop is also a very thorough preparation for programming these microcontrollers in C.

Prerequisites:
- some electronics skills
- digital technologies
- computer proficiency (Windows)

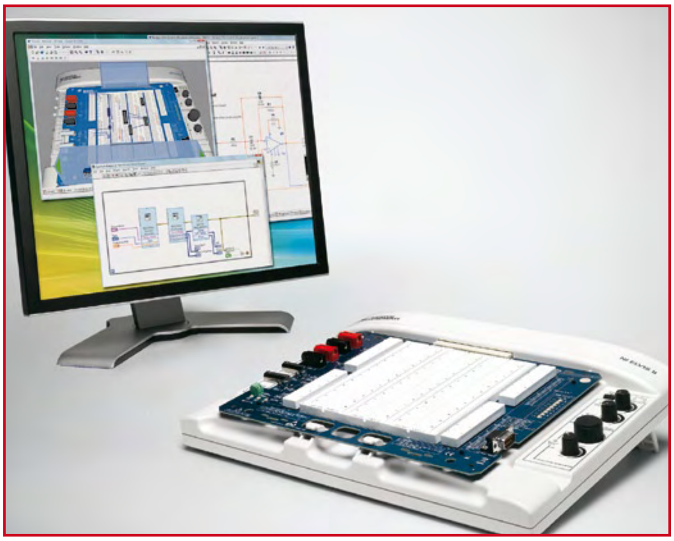
The course fee is £ 160, including lunch and certificate.
Every participant also receives the CD Flowcode software version 3 (value £ 48.30). Elektor subscribers are entitled to a 5% discount.
Note: the number of seats is limited. There is space for only 16 participants! Be quick to register, places are strictly limited.

Programme and registration on www.elektor.com

NI ELVIS II offers USB Plug and Play, full NI Multisim Integration

National Instruments has announced NI ELVIS II, the latest version of the design and prototyping platform that educators worldwide have adopted for hands-on, project-based learning. Based on the powerful LabVIEW graphical system design software, NI ELVIS II gives educators 12 new USB plug-and-play instruments and complete integration with Multisim 10.1 software for SPICE simulation to simplify the teaching of circuit design. In addition, educators can use NI ELVIS II with a suite of third-party boards and curriculum resources to teach control design, telecommunications and microcontroller concepts.

The new NI ELVIS II includes backward compatibility with the previous version, laboratory-friendly features such as USB plug-and-play connectivity and a smaller form factor to simplify setup and lab maintenance. NI ELVIS II also features 12 of the most commonly used instruments in engineering and science laboratories, including an oscilloscope, function generator, variable power supply and isolated digital multimeter, in one low-cost, easy-to-use platform. Because NI ELVIS II is based on LabVIEW, educators can easily customise the 12 instruments or create their own using the provided source code for the instruments.
NI ELVIS II also features complete integration with new Multisim 10.1 software, leading SPICE simulation and schematic capture software. Educators and students can use Multisim 10.1 with NI ELVIS II to seamlessly switch between simulated and acquired data, overlay simulated and measured data in the same instrument and use a single platform when simulating or testing to provide a holistic view of the circuit design process – from designing and prototyping to deployment. Multisim also includes other pedagogically relevant features such as custom in-circuit quizzes and a 3-D NI ELVIS II feature that students can use to wire their circuits on a virtual replica of the system, increasing efficiency in the laboratory.



With an extensive network of plug-in boards from leading vendors in education and industry, educators can use NI ELVIS II to teach a variety of classes, from circuit design, measurement and instrumentation to design, telecommunications and embedded/microcontroller design. Quanser provides three different plants for teaching control design and mechatronics with NI ELVIS II and LabVIEW. Emona Instruments introduced the DATEx telecommunications trainer to teach telecommunications concepts using NI ELVIS II and LabVIEW.

Additionally, Freescale Semiconductor's Microcontroller Student Learning Kits with flexible 8-, 16-

and 32-bit microcontroller modules is fully compatible with NI ELVIS II and leverages the 12 new integrated instruments to teach embedded and microcontroller design.
National Instruments is committed to enhancing engineering and science education worldwide by providing educators and students with powerful graphical system design software and modular hardware to connect the curriculum with the real world. Professors and students benefit from powerful, professional tools such as NI LabVIEW graphical development software, which helps students visualise and implement engineering concepts. The integration of LabVIEW in the classroom creates an effective, dynamic learning environment – from LEGO® MINDSTORMS® NXT in primary schools to research laboratories in universities.

www.ni.com/academic
www.ni.com/nielvis

(080264-IV)

Industry's most secure WiFi embedded networking module

Alpha Micro Components has added the MatchPort b/g Pro to its extensive portfolio of networking products. The MatchPort b/g Pro allows a wide range of machines to be managed and controlled remotely over a network with an added level of security.

MatchPort b/g Pro is claimed to be the industry's most secure embedded WiFi networking module designed for applications that require the safest and most reliable technology for secure data transfer in sensitive applications such as medical records and government data transmissions and financial transactions.

Security features include:

- IEEE 802.11i compliant radio with AES-CCMP (Advanced Encryption Standard-Counter Mode with Cipher Block Chaining Message Authentication Code Protocol) and TKIP (Temporal Key Integrity Protocol)
- Complete suite of 802.1x EAP (Extensible Authentication Protocols) including EAP-TLS (Transport Layer Security), EAP-TTLS (Tunneled Transport Layer Security), PEAP (Open standard from Cisco Systems, Microsoft and RSA Security), LEAP (Lightweight Extensible Authentication Protocol)
- End-to-end TLS/SSL 3.0 (Secure Sockets Layer) and SSH (Secure Shell) tunneling
- End-to-end AES (Advanced Encryption Standard) 128-bit encrypted tunneling

MatchPort b/g Pro handles the most computationally demanding or data intensive applications effortlessly with a 32-bit, 159 MIPS (Dhrystone 2.1) 166 MHz processor. With 8 MB of SDRAM and 8 MB flash, it provides enough memory capacity for OEM customisation, loading web pages, and data 'store and forward' applications. It features two serial input ports with 230 kbps data rate capability, seven control pins (CP/GPIO), and a wide operational temperature range of –40° to 70°C, with the option to operate up to 85°C with lower MTBF.

www.alphamicro.net

(080624-V)

Elektor Workshop: PIC Programming using 'C' — hands-on for beginners

Date: 4 October 2008, from 09.00 – 16.00 hours.
Location: Birmingham City University, Technology Innovation Centre, Millennium Point, Curzon Street, Birmingham B4 7XG.

Lecture and workshop presenters:
Dr. Anthony Wilcox GRIC PhD CEng MIET, Consultant and Principal Lecturer, Centre for Electronics and Software, Technology Innovation Centre, Birmingham City University.

Mr Andrew Hill BSc MIET, Consultant and Principal Lecturer, Technology Innovation Centre, Birmingham City University.

Dr. Antony Wilcox

Mr. Andrew Hill

The main goal of this one-day course is to provide an introduction to the programming of PIC microcontrollers in the C programming language. The course is mainly aimed at participants who are unfamiliar with the C programming language, but who would like to learn to use it in an embedded environment.
The participant will be introduced to those aspects of the C language that are most relevant to the programming of microcontrollers. The hardware used in the course consists of E-blocks.

Course objectives:
- The participant can make a simple C program
- The participant can program a PIC-microcontroller in C

Prerequisites:
- Some experience in programming is recommended, such as (Visual) Basic, Pascal, Assembly or another language. No prior knowledge of C is expected.
- Some familiarity with electronics, digital technology and computer proficiency (Windows)

The course fee is £ 160, including lunch and certificate.
Every participant also receives the CD C for PIC Microcontrollers (value £ 48.30). Elektor subscribers are entitled to a 5% discount.

Note: the number of seats is limited. There is space for only 16 participants! Be quick to register, places are strictly limited.

Programme and registration on www.elektor.com

Altium joins European fight against piracy

Altium Limited, the electronics design industry's leading developer of unified electronic product development solutions, has extended its Business Software Alliance (BSA) membership to include the Europe, Middle East and Africa (EMEA) region. The move will strengthen Altium's IP protection and complement its anti-piracy movements in China and the rest of Asia.

The move will see Altium join BSA's efforts to crack down on the $US48 billion black hole caused by piracy – with over 40% of these losses stemming from the EMEA region alone. Many European countries have shown an overall decline in piracy rates since 2003, however characteristics vary with each country and market. For example, Greece which has a piracy rate of 58% experienced industry losses of $198 million last year, while the United Kingdom which has a piracy rate of 26% — one of the lowest in the EMEA region — experienced losses of more than $1.8 billion. But software piracy not only has a detrimental effect on the software industry, it also poses a threat to the IT industry, ultimately affecting local job opportunities and investments into research and development.

The EMEA region is a very large market for Altium, making up more than 33% of total sales in the financial year ending June 30, 2007. Altium's increased support for the BSA is a positive step forward, helping Altium to protect its IP and secure future innovations in electronics design.

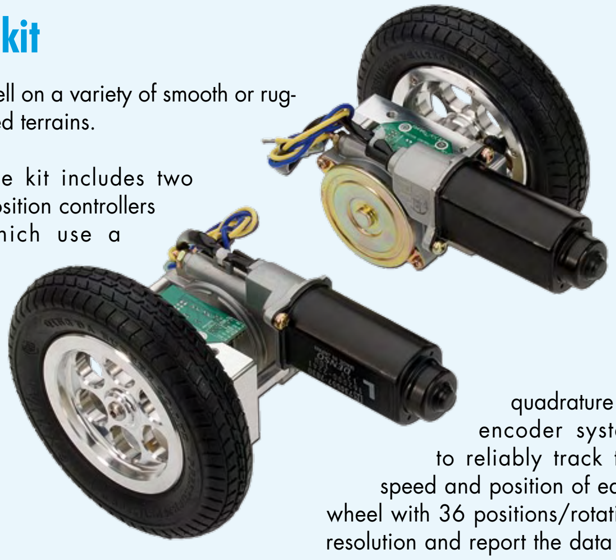
www.altium.com

(080624-VI)

Motor Mount & Wheel kit

It's time to give your robot the mobility and style it deserves with the new Motor Mount and Wheel Kit with position controller from Parallax. Powerful 12 VDC, 150 rpm motors are combined with precision machined 6061 aluminium hardware to provide enough power, strength, and beauty to make other robots jealous.

Conveniently positioned screw holes in the bearing block make mounting this kit a breeze, and the included 6-inch (15 cm) pneumatic rubber tires perform well on a variety of smooth or rugged terrains.



The kit includes two position controllers which use a quadrature encoder system to reliably track the speed and position of each wheel with 36 positions/rotation resolution and report the data on command via a 19.2 kbps serial bus. The position controllers can also be interfaced with HB-25 motor controllers (sold separately) to automatically provide user-definable smooth speed ramping and accurate position control, which frees up the main processor to handle more important tasks.

www.Parallax.com

(080624-VIII)

Turner, Constable and a Lascar data logger

As well as exhibiting works by great British artists such as J.M.W. Turner and John Constable, the Bury Art Gallery, Museum and Archive also contains a number of Lascar's EL-USB-2 temperature and humidity data loggers. And whilst a data logger won't pull the crowds in like a Turner masterpiece, it will do its bit to ensure these works are kept in the best condition for generations to come.

Alison Green, Museum Assistant explains, "It's taken over a hundred years to build up this collection and its value, historically and socially, is enormous. It's very important we monitor the environment in which the collections are housed. Exposure to extremes of heat, cold, aridity or humidity can cause textiles, canvas, wood and other materials to quickly deteriorate."

A search on the internet turned up a product by Lascar Electronics — a data logger — designed to measure and record both temperature and humidity over a specified period of time. "This is a great product", says Alison. "I can simply plug it into my computer's USB port, give it a name, set some alarms and choose a sampling rate. When it's programmed, it's small enough that I can pop it back into a case without it taking over the display and away it goes measuring temperature and humidity levels. When the logger is full of data or I see an alarm level has been reached because its red alarm light is flashing, I take it back to the computer and download all the recordings to see what environment our exhibits have been exposed to. It's not just in the best interest of the exhibits — we're a publicly funded organization and we have to actually prove we're looking after everything in the museum."

The EL-USB-2 is available immediately directly from Lascar Electronics at a price of £ 49.95. Discounts for quantity are available upon request.

www.lascarelectronics.com

(080624-VI

The Thought Cursor

Brain-computer interfaces and how they work

Jens Nickel

Controlling a computer using the power of thought alone is less far-fetched than you might believe. The easy part is to measure precisely the tiny currents in the brain associated with thought processes; the hard part is to extract the thoughts from the morass of multi-channel EEG (electroencephalogram) data.

Research groups all over the world [1, 2, 3] are working on how to tease out useful control information from an intricately interdependent array of measured brain currents. One ultimate aim is to allow a patient to control a motor in a prosthetic limb using just a thought, allowing tetraplegic people to stand independently and go about their daily business more easily. It will be a few years before such systems are ready for widespread use, but they are already functioning in the laboratory.

Measuring, amplifying and digitising the tiny currents involved does not require special equipment. The job the researchers are tackling is to distil the multitude of sampled data channels down to a simple command, which requires plenty of processing power and some clever software algorithms.

The Berlin Brain-Computer Interface (BBCI) [1] is a cooperative project between the intelligent data analysis group at FIRST, part of the Fraunhofer Institute, the neurology clinic neurophysics group at Charité University Hospital, Berlin, and the Technical University of Berlin. The prestigious project is funded by the EU, by the DFG research foundation, and by the German government.

How it works

The BBCI uses the 'pre-movement' principle, whereby the patient must imagine themselves wanting to move a finger, hand or foot, in order to execute a command. The brain currents are measured using electrodes attached to the skin of the subject's head. Using this principle and connection method limits the system to just a couple of movement commands ('left' and 'right', for example) as otherwise the error rate becomes too high. Nevertheless, this is enough to control a simple computer game using the power of thought alone. Robot control has also been demonstrated [4]. Using a simple cursor-based system, writing has been shown to be possible at speeds of up to about seven characters per minute [5]. For this example the user must be able to see the cursor on the screen to allow feedback from the computer.

Many brain-computer interfaces demand that the subject undergo training (possibly lasting as long as one week!) to learn the thought patterns that give rise to brain currents that the machine can discriminate reliably. The BBCI, however, shifts the burden of learning to the computer, which can shorten the adaptation process to just half an hour, with the subject imagining themselves moving either their left or their right index finger (for example) for periods of a second or so at a time. About one third of subjects tested manage to defeat the ability of the system to learn their thought patterns, for reasons that are not yet understood.

❷ Amplifiers and A/D converter

The signals are taken via a flat cable to four amplifier units, each comprising 32 channels. The signals are digitised at 5 kHz to a resolution of 16 bits and then sent to a PC over a fibre optic link. These units are readily available on the market, with a price in the tens of thousands of pounds.

❶ Electrodes

In the BBCI brain currents are measured using 128 Ag/AgCl (silver/silver chloride) electrodes, mounted together in a cap to fit over the head [6]. Caps of this kind are also used in medical research and cost a couple of thousand pounds. The electrodes are distributed over the whole of the upper part of the head, each making contact with the skin over a patch approximately 5 mm across. Within the project a cap has been developed that does not need gel to improve the electrical contact between electrode and skin but which can still measure and continuously record potential difference fluctuations of around 50 µV.

The brain currents fluctuate with typical frequencies between 0.5 Hz and 50 Hz, with the distribution being dependent on the nature of the brain's activity. 'Alpha waves', between 8 Hz and 13 Hz, are well known and are seen in the EEG when the brain is relaxed. When preparing to make a movement, lower frequencies (below 4 Hz) also come into the picture.

❸ Preprocessing

The recorder PC takes the signals from the A/D converters and carries out some preprocessing operations which help to reduce the computational demands of the subsequent stages. The signals are band-pass filtered (between 0.05 Hz and 200 Hz) and then downsampled to 1000 Hz. Raw data packets are then sent to the next computer over the network, and simultaneously are stored in a database.

❹ Signal analysis

The analysis stage starts with further preprocessing, whereby the signal is downsampled again to 100 Hz. From thinking about making a movement to executing it takes around a second: this means that it is best to collect one second's worth of data to analyse the corresponding fluctuations in brain currents. Data from periods of 128 samples (corresponding to about 1.2 s) are collected and multiplied by a window function chosen to give greater weight to the later samples. A Fourier transform is then applied, and from this the frequency components below 7 Hz are extracted. An inverse transformation reconstructs the signal, which is now resampled at 20 Hz. This forms the result of the signal analysis stage.

❺ Classification

The classification module is implemented in C++ and in MATLAB, and embodies the majority of the technology that has been developed. Two threads running in parallel on the signal analysis computer examine the signals, each looking for evidence of one of the two possible control commands. The results from the two threads are combined, and any detected control command is transmitted over the network every 40 ms.

❻ Feedback

The control commands are used to drive a multimedia program that runs on a further computer (the 'feedback client'). This then enables the subject to see the effect of their thoughts directly on the screen.

Computer network

Because of the large amount of computing power required, the BBCI employs several off-the-shelf PCs connected together over a 100 Mbit Ethernet network [6].

Internet Links

[1] http://ida.first.fraunhofer.de/bbci/index_en.html

[2] http://bci.tugraz.at

[3] www.bci-info.tugraz.at

[4] www.first.fraunhofer.de/owx_1_3836_2_2_0_e19487f27e917f.html

[5] http://ida.first.fhg.de/publications/BlaDorKraSchWilMurMue06.pdf

[6] http://ida.first.fhg.de/publications/KreBlaCurMue07.pdf

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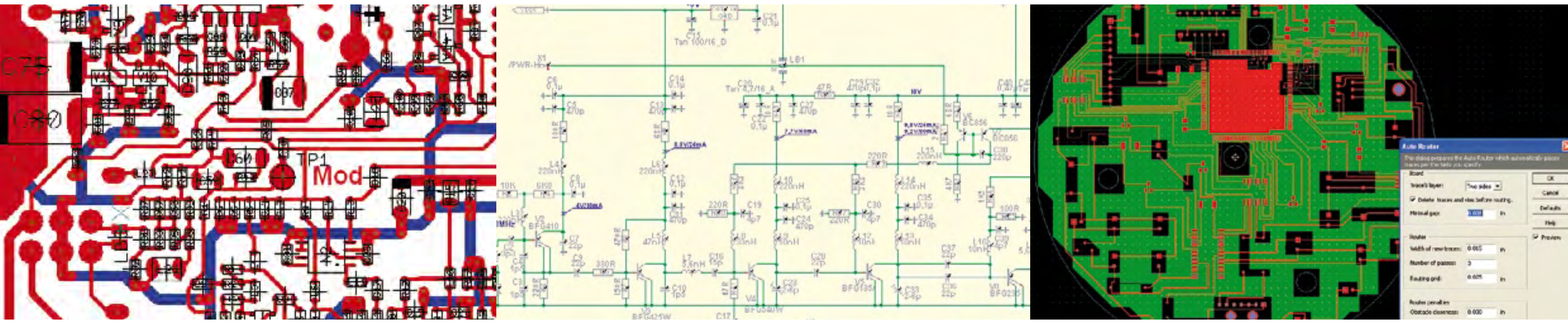


Panorama
An anthology of CAD programs

Guy Raedersdorf (Elektor France)

In November 2005 we published an article ‘Kaleidoscope’, accompanied by a DVD-ROM that included almost thirty programs relating to CAD (Computer-Aided Design). Given its success, we decided to repeat the exercise. Only this time round, for several different reasons, there’s no DVD with the magazine.

In our hunt for CAD software, we tried to collect as many evaluation versions as possible – demos with greater or lesser restrictions, but also 100% functional versions of programs – within this family of software. We’re well aware it’s impossible to be exhaustive and there are still some that have ‘slipped through our net’. But don’t worry, that’s doubtless just till next time round…

Ed.: don’t hesitate to tell us about your finds, favourites, etc., we’ll share them with all our readers.

Unfortunately, it’s just not possible for us to go into all the details of the dozens of CAD programs available on the market. So we’ll have to content ourselves with just mentioning certain features that struck us while we were installing and getting to know them.

Finally, let’s just add that ibfriedrich (Target3001!) and Seetrax (Ranger2 XL) have offered us ‘Elektor special’ versions with possibilities that go beyond their usual evaluation versions. We’re sure our readers will be able to make the most of these.

Why no physical DVD?

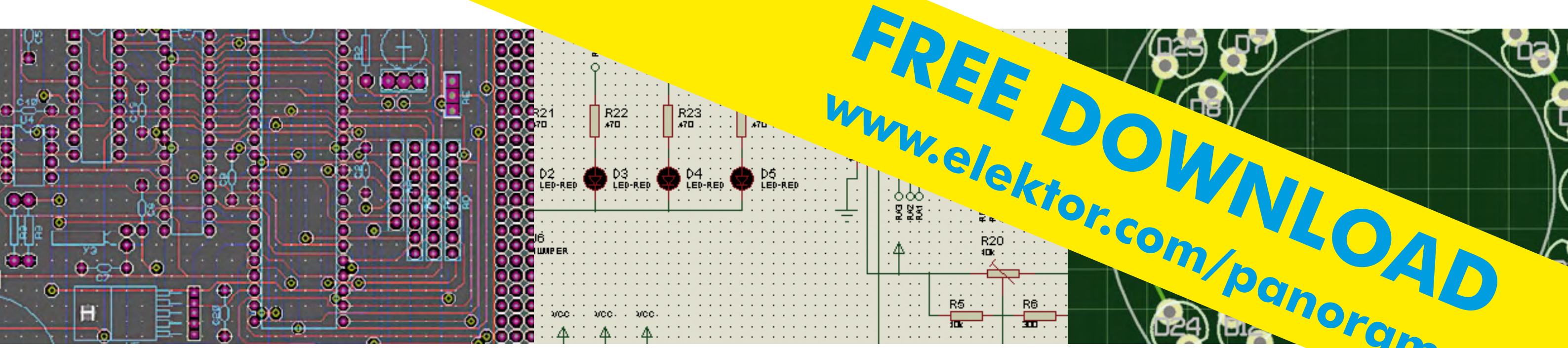
At the current price of blank writable DVDs, we didn’t feel it was justified (either from an economic point of view, or indeed an environmental one) to issue a physical DVD with each of the 150,000 copies of this September 2008 issue (a Spanish edition was added to the European group three years ago). So we’re suggesting a dual approach:

1. the various programs can be downloaded individually (particularly suitable for those readers who don’t have a fast internet connection); all you have to do is go into the ‘virtual DVD’ and download the .zip file from the relevant directory.
2. or there’s a ‘virtual DVD’ that appears ‘physically’ as an .iso file to download from our website (warning: it’s almost 1.7 GB, which means a broadband connection is virtually obligatory!) and then burn onto a DVD using the burn software of your choice, Nero or Burning Studio. All you then have to do is put the DVD into your drive and it will auto-run (if your operating system is suitably configured), or you can just manually run the **index.htm** file in the root directory of the DVD drive containing your newly-burned DVD.

Now let’s move on to our review – the programs are arranged in alphabetical order.

Abacom

sPlan 6.0, the circuit entry application from Abacom, lets you create a circuit diagram easily and cleanly thanks to an extensive and expandable component library. Worth noting: the possibility of defining the form of the circuit sheets,



automatic component numbering (standard in most of the software in this category), component search, and the use of variables.
Sprint-Layout 5.0 is an easy-to-learn PCB design program with all the standard functions for this type of activity. It takes only a few minutes to grasp how it works.
Note the co-availability of French and German versions.
Extra on the Panorama 'DVD':
LochMaster 3.0 for your projects on prototype board.
FrontDesigner 3.0 for designing board overlays.

AMS

AMS (Advanced Microcomputer Systems) offers **CircuitCREATOR**, an application that handles circuit entry, PCB design, and the other usual functions. Like most current programs, it supports SMD components. Options for several fonts per layer and for changing the shape of lands between layers. You can define supply and ground planes with or without thermal dissipation option. Interactive component placement. The rat's nest suggests optimum component layout, but also makes manual routing easy. Has a DRC (Design Rule Checking) function used to check the built-in design rules; it flags up an error and shows where it is. Their program also includes a simulation application **SpiceCreator**, also available as an **extra** on the DVD.

Baas

Many of our readers are familiar with the name **Layo1PCB**; it was in fact one of the first PCB design programs with more than one language to choose from. This is still the case with this latest version, Layo1PCB version 10.19 on offer from Baas Electronics. The version on offer here is the simplest version. As it is not linked to a netlist, this program lets you place your components wherever you want and draw tracks the way you want. To be able to read a netlist generated by a circuit entry program such as those created by Mentor, multiSim, Calay, Protel, or Tango, you need to move up to the professional version, Layo1 PCB Design.

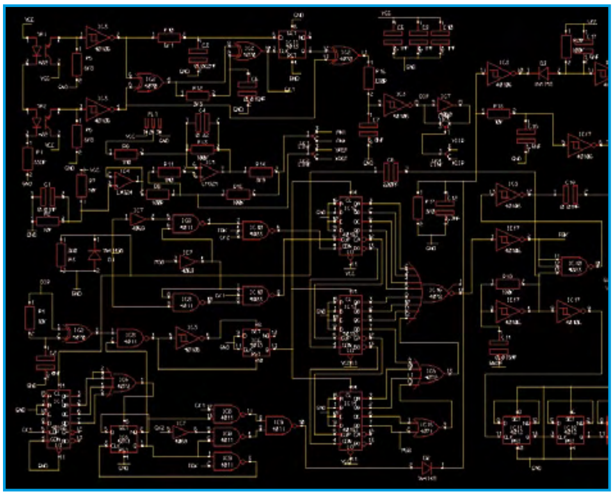
Capilano

As part of the Panorama download we're offering you two products from the Capilano stable, the **DesignWorks Express for Windows** program and the evaluation version of **DesignWorks Professional 5**. DesignWorks Express for Windows (free) is a handy application for circuit entry (single-sided) as long as the number of pins remains under 500. All options are open to you: editing, saving, print-out, and even producing netlists for loading into a PCB design program, for example **Pad2Pad** (also free) described below.

Like its little brother, DesignWorks Professional 5 is a circuit entry application. 100% hierarchical design, standard and custom netlist formats, extensive component library, are just a few of its features.
Let's just note that there is also a version of DesignWorks Professional 5 with a simulation function.

Cadence

The **OrCAD® PCB Designer** suite from Cadence, the 'proto-genitor' of circuit entry software, is now at version 16.0. Integration has reached its highest point, meaning a remarkable consistency in the commands common to the

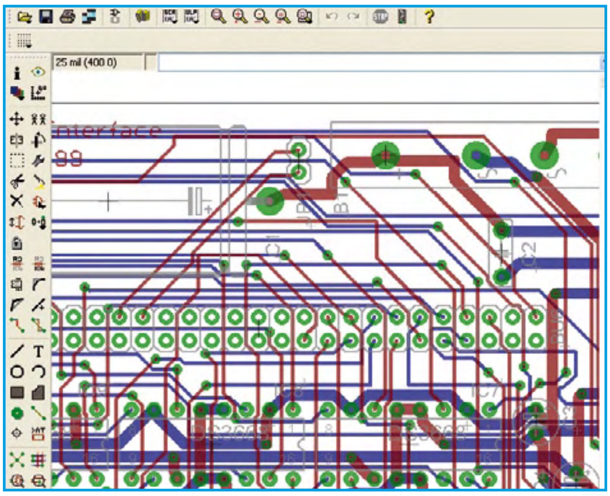


various modules that make up OrCAD PCB Designer, in this way making it possible to design a project from start to finish, from entering the circuit, via component drawing, to designing the PCB. It includes an interactive autorouter SPECCTRA (re-named Allegro PCB Router), a piece of software that seems to be becoming the must-have solution in the field of autorouting.
Once installed, the software appears in the form of two programs, **OrCAD Capture CIS** for circuit entry (with a DRC function that lets you eliminate the majority of errors right from the outset) and **OrCAD PCB Editor** for PCB design and routing. A new ActiveParts function lets you search for information about an OrCAD component using various criteria.

Cadsoft

Eagle 5.0 from Cadsoft is one of the most popular circuit entry and PCB design programs amongst hobbyists in Europe. It owes its popularity to the ease of use and performance of the non-commercial version (see table). It exists in several versions, including a Freeware version limited to a board area of 100 × 80 mm, 2 signal layers, and 1 circuit sheet. Apart from these limitations, you can do everything that can be done with the Professional version. If you want to have a manual (in English or German), a CD-ROM, and unconditional technical support, then it's worth purchasing a license (€ 49).

It's worth noting that Eagle is one of the few CAD applications, if not the only one as far as we are aware, to exist in Windows, Linux, and Mac versions.



FreePCB 1.20

Allan Wrights's **FreePCB** is a free PCB design program. The Manual available on the author's website is an excellent resource for finding out what's involved when you want to design a printed circuit. There's no circuit entry function, so you'll either need to use a circuit entry program, or else create your own netlist, making sure it can be imported into FreePCB. The existence of a rat's nest helps a great deal in positioning the components properly, thus making it possible to avoid unnecessary track lengths. The presence of a shape editor is quite surprising in such an environment, but FreePCB's specific function is to make printed circuits, and it does this well.

ibFriedrich

TARGET 3001! V13 is the worthy successor to its predecessor V12, covered in November 2005.

A few points of interest:

- 3D view of the project (lets you see if a project is viable)
- Reverse-engineering (you really have to discover this amazing tool, now included in more and more programs)
- Multi-lingual (board markings and documentation!)
- Assistant for aligning components geometrically (placing 7 LEDs along an arc from 20° to 120° becomes child's play).
- Fuller library of 'standard' components
- Automatic library updating, etc.

Note: The version on offer here is an 'Elektor special' version that lets you do a lot more than the standard demo version.

KiCad

The only fully OpenSource program in this 'Panorama', **Kicad** is actually a suite of four programs under an overall project manager, Kicad. It is fully functional, comprising all the modules needed, from circuit entry, **Eeschema**, to PCB design, **Pcbnew** (which also lets you visualize it in 3D), via the Gerber file viewer **Gerbview** and **Cvpcb**, the form selection program for the components used in the project. Even though it's OpenSource, KiCad is far from being a second-rate piece of software; it's very comprehensive and even includes autorouting.

The documentation includes a very instructive and well-presented tutorial.

LabCenter

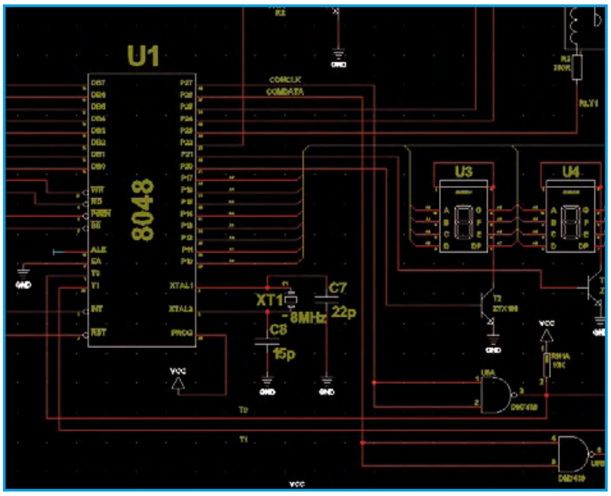
The latest offering from LabCenter is **Proteus Design Suite 7.2**. Proteus is in fact a combination of two programs in one: **ISIS** for circuit entry and **ARES** for PCB design with autorouting and 3D visualisation. Together, these form a powerful, highly-integrated environment. There are several versions, from the Starter Kit, with a netlist limited to 500 pins, to the Level 3 version which handles unlimited pins and layers.

ISIS supports hierarchical design and can be used to create busses; ARES is based on netlists, and is able to use physical DRC.

Like many current applications, the libraries include over 10,000 different components.

McCAD

McCad has made a reputation for itself in the Mac world as the first manufacturer of CAD software to run on Mac

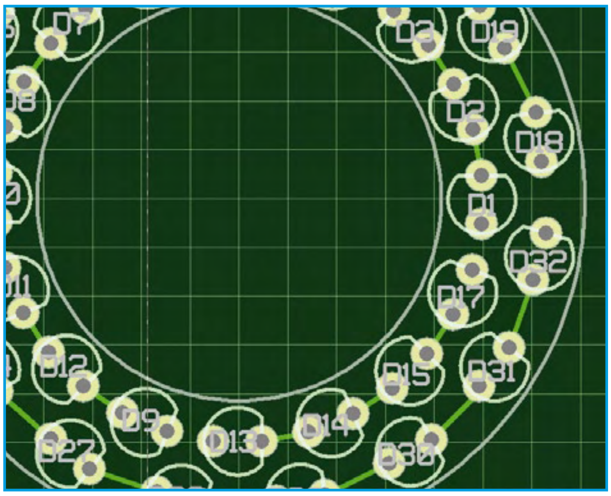


– at a time when our PCs were still only running on DOS! McCAD offers 2 programs for Windows, **EDS-1** and a higher-performance version of this software, **EDS-plus**. The evaluation version is for EDS-1. McCAD has opted for a modular approach, customers buying just those modules they need: basic or advanced circuit entry, digital/analogue simulation, PCB design, autorouting, Gerber conversion, etc. There is also a free version, EDS Lite.

Worth noting: the possibility of downloading a very instructive e-book 'Quickstart to Simulation' devoted to simulation.

National Instruments

Multisim from National Instruments is an old acquaintance to the Elektor designers. For years, they've been working with Ultiboard, the forerunner of this program. Multisim, the latest offering from the Electronic Workbench Group – which has now become part of NI – has evolved into a multi-faceted tool combining circuit entry, interactive circuit simulation, PCB design, and compliance testing. Multisim is available in different versions: Base, Full, and Power Pro. We are offering you a trial of the Base version.
Multisim in fact comprises two modules, Multisim for circuit entry and SPICE simulation, and **Ultiboard,** in its new livery, for PCB design with built-in routing. The possibility of using LabVIEW measuring instruments adds an extra dimension to this software.



Number One Systems

Easy-PC from Number One Systems has been well-known for years, and is now at version 11.0. What struck us with this new version is the existence of Design Calculators that let you perform various operations like defining track size according to current, and calculating their impedance, as well as the temperature rise in operation. Naturally, DRC is available here too.
One of the interesting options – found in other software too, albeit under a different name – is the Intelligent Gerber Import, which lets you re-create, from a Gerber file from any source, an Easy-PC PCB from which it is then even possible to derive a full circuit diagram.
In addition, you'll also find a demo version of **Easy-Spice**, a simulation program.

Seetrax

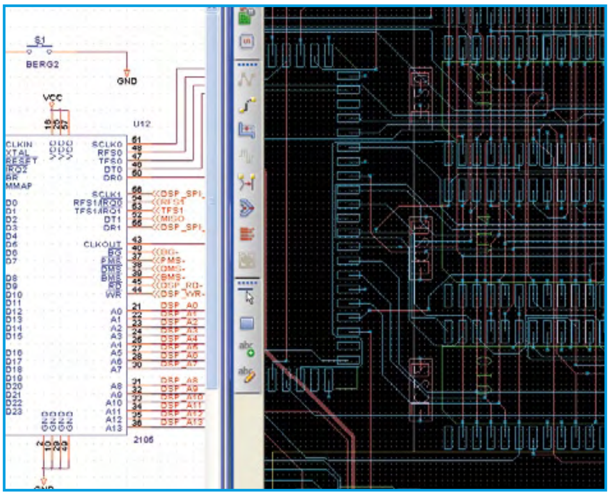
Seetrax has added two of its programs to our list: **Ranger2 XL** and **Seetrax XL Designe**r (SXLD to its friends).
To install Ranger2 XL, all you have to do is run the *setup.exe* file; once installation is over, you'll have the demo version of Ranger2 XL with its original restrictions.
To now change your demo version into the 500-pin version (a present from Seetrax), all you need do is copy the *licence.dat* licence file (from the 'Licence' subdirectory; make sure the name is right, without any other additional suffix) into the ...\seetrax\ranger2xl\data directory.
Seetrax XL Designer is the second program from Seetrax. To install the demo version, all you need do is run the *XLDesignerDemo_1.49.exe* file. Licence installation takes place during this operation, so the program works right away. This version is limited to projects comprising a maximum of 30 components and 50 nets (it is otherwise identical to the full version). When the program is run, it offers a button to search for updates.
Note: After transfer of the licence file, the version of Ranger2 XL offered here is the '&500' version that normally sells for £90.

Those Engineers

Spicycle is a full program that lets you design a PCB directly from a netlist or in more conventional fashion from a circuit diagram. As all the operations are carried out under Active X control, it is possible to perform back annotation between the circuit diagram, the netlist, and the simulation parameters. One interesting aspect of Spicycle is that it includes a very comprehensive symbol library, making it possible to design not only an electronic circuit, but even to create a sort of schematic diagram of any kind of system (for a wind tunnel, for example).
Spicycle offers a simulation in 'mixed' mode (integrates seamlessly with the **SpiceAge** simulator). Data transfer to the circuit diagrams is bidirectional, meaning you can import a SPICE netlist which is then presented in the form of interconnected circuit symbols. Back annotation becomes a real pleasure.

Tsien

BoardMaker3 has come a long way since it came out in 2000, and has been regularly updated. The V1.33.0022 version on offer here dates from 24 June 2008. BoardMaker3 is an integrated environment for PCB design; it has high-performance tools for circuit entry, Spice simulation, 3D visualisation, and autorouting.



Worth noting: on the www.tsien.info/guide.php site there is a series of pages that explain extremely well what's involved when you start to tackle a circuit entry and PCB design application.

Visionics

EDwinXP includes all the tools you could wish for required to produce a printed circuit: the circuit editor, PCB editor (with autoplacement and autorouting), simulators in EDSpice mixed mode, the library manager, and all the rest.
Worth noting: the presence of a thermal analyser (with sig-

nal integrity and field analysis), and a test for the effects of electromagnetic radiation on the circuit. The installation of this program alone is already a real feast for the eyes.
Note: It's important for the directory where the EDwinXP161 files are going to be decompressed to have a name of 8 characters or less (e.g. EDwinXP) if you want to be able to install the program (see the readme.txt file that comes with the program).

So where are the missing ones?

Despite all our efforts, we didn't manage to 'nail' all the CAD software manufacturers we'd have liked for our round-up. Some of them weren't in a position to make an evaluation version of their programs available to us (for example, **Altium**, which does however boast a most attractive virtual demonstration centre at www.altium.com/evaluate/demo-center/# and choose your language), others simply chose not to.

Conclusion

Reviewing almost 20 programs, whether comprehensive or specializing in just PCB design, really brought home to us the increasing complexity of this type of software. Using such programs demands a relatively up-to-date PC, if you

Manufacturer	Program name	Circuits	PCB	Autorouting	Simulation
Abacom	sPlan 6.0 *	yes	–	–	–
	Sprint-Layout *	–	yes	yes	–
	Frontdesigner 3.0 *	–	–	–	–
	Lochmaster 3.0 *	–	–	–	–
Advanced Microcomputer Systems	Circuit Creator *	yes	yes	yes	yes
	Spice Creator *	–	–	–	yes
Baas Electronics	Layo1PCB 10.0 *	–	yes	–	–
Cadence	OrCAD 16.0 *	yes	yes	yes	option
CADSoft	Eagle 5.0 1)				
	Light *	yes	yes	yes	–
	Standard	yes	yes	yes	–
	Professional	yes	yes	yes	–
Capilano	DesignWorks Express * 2)	yes	via Pad2Pad	–	–
	DesignWorks 5.0 *	yes	via Pad2Pad	with add. module	with add. module
FreePCB	Free PCB 12.0 *	–	yes	with add. module	
IBFriedrich	TARGET3001! 3)				
	Light *	yes	yes	yes	yes
	Smart	yes	yes	yes	yes
	Economy	yes	yes	yes	yes
	Professional	yes	yes	yes	yes
	Design Station	yes	yes	yes	yes
KiCAD	KICAD *	yes	yes	yes	–
LabCenter	Proteus 7.2 *	yes	yes	yes	yes
McCAD	EDS-1 *	yes	yes	with add. module	with add. module
	McCAD 3SPICE Lite *	–	–	–	yes
	SimPlus *	–	–	–	yes
National Instruments	NI Circuit Design Suite 10.1 *	yes	yes	yes	yes
Number One Systems	Easy PC *	yes	yes	with Router +	Easy-Spice
Others	Easy-Spice *	–	–	–	yes
Pad2Pad	Pad2Pad *	–	yes	–	–
Seetrax	Ranger2 XL 4)	yes	yes	with add. module	–
	XL Designer *	yes	yes	with add. module	–
Those Engineers	Spicyle *	yes	yes	–	SpiceAge
	SpiceAge *	–	–	–	yes
Tsien	BoardMaker 3 *	yes	yes	gateway	yes
Visionics	EDWinXP 11.6 *	yes	yes	yes	yes

* = included on Panorama virtual DVD, N.I. = No info, – = No or Not Applicable
1) Versions also available for Mac and Linux (see under 'Extra')
2) Free version
3) This is an upgraded Elektor special version
4) The version on the virtual DVD is the Ranger2 XL/500 version (normally worth £90)

want to avoid its turning into a real trial of patience. In any case, you'll need quite a lot of that to get to grips with any of these programs. Most of the top-end programs (price-wise too!) are hardly very different in terms of what they offer, except in terms of certain details.

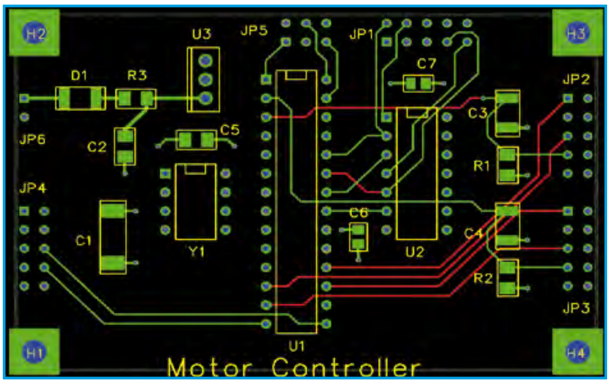
And what for one user may seem to be an unforgivable omission may be an option that another user has no need of. It's a question of taste and requirements. You are the best judge of that. So why not take a look at our website and download the .iso file to create your own DVD, or pick the programme you'd like to try out…
Happy exploring!

Ed.: In view of the time that elapsed between writing this article and the 'gathering' of the software appearing on the virtual DVD, it's still a good idea to look and see if there may be a new version of any of the software described in this article you may be interested in (hence the links given in the table).

(080356-I)

The author would like to thank Cadence Design Systems, Inc. for allowing Elektor to distribute OrCAD software from their site and a virtual DVD.
By the same token, he would like to thank all the other companies for their unconditional permission.

Price (rrp)	Homepage
€ 39.90	www.abacom-online.de/fr/
€ 39.90	
€ 39.90	
€ 39.90	
$ 99 to $ 995	www.advancedmsinc.com/
$ 99	or www.circuitcreator.com/
€ 99 to € 950	www.baas.nl/
N.C.	www.cadence.com/
	www.cadsoft.de/
€ 49	
€ 750	
€ 1,499	
free	www.capilano.com/
$ 395 to $ 790	
free	www.freepcb.com/
	www.ibfriedrich.com/
€ 59	
€ 159	
€ 569	
€ 1,649	
€ 2,999	
free	www.lis.inpg.fr/realise_au_lis/kicad/
£ 150 to £ 1,225	www.labcenter.co.uk/index.cfm/
$1,095 to $ 1,395	www.mccad.com/
$ 395	
$ 695	
N.I.	www.ni.com/
£ 247 to £ 447	www.numberone.com/
£ 295	
free	www.pad2pad.com/
£ 90 to £ 460	www.seetrax.com/
£ 100 to £1,000	
£ 45 to £ 195	www.spiceage.com/
£ 45	
£ 350/yr or 6x price	www.tsien.info/index.php
$ 110 to (N.I.)	www.visionics.a.se/



Internet Links

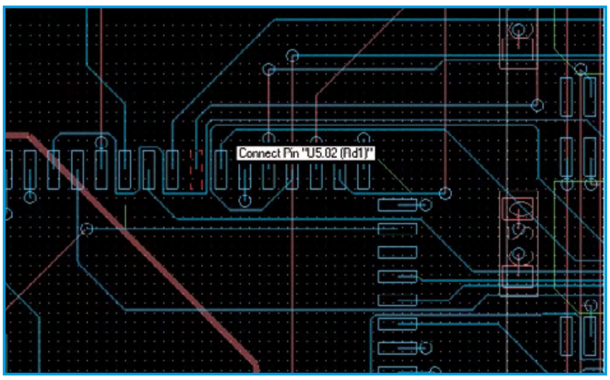
The manufacturers' addresses are given in the table.

CAD software manufacturers

Altium www.altium.com
Ariadne www.cad-ul.de/ariadne/index.html
Autotrax www.kov.com
CADint www.cadint.se
CirCAD www.holophase.com
DesignSoft www.designsoftware.com
Express PCB www.expresspcb.com
Mentor Graphics www.mentorg.com
Merco electronics www.mercoelectronics.info
PCB Editor www.waldherr.com
Pulsonix www.pulsonix.com/index.asp
The PCB Designer www.cad-design.com
Vutrax www.vutrax.co.uk/
Zuken www.zuken.com

General source links

www.terrypin.dial.pipex.com/ECADList.html
www.abcelectronique.com/annuaire/societes_52.php
http://etronics.free.fr/dossiers/softs/soft00.htm



Ball & Beam for Ele

Grind your teeth on PID design and programming

Jose Luis Rupérez Fombellida & José Manuel Escobosa Bravo

Like it or not, Ball & Beam is a compulsory item on the Electronics Engineering curriculum, specifically for classes on PID (proportional-integral-derivative) control systems. The idea is to try to balance a ball on a beam using a control loop. If the ball is pushed, the system moves the beam to return the ball to its initial position. So let's get out our USB DAQ card and a PC to show off!

Apart from your curiosity and eagerness to learn about PID (one of the great pillars of electronic engineering), the ingredients of this project can be summarised as

- the Elektor USB Data Acquisition (DAQ) Card [1];
- a circuit which acts as interface between the DAQ and the mechanical system;
- mechanics, i.e. construction of the ball & beam system, which is very easy and cheap compared to commercial units;
- A personal computer running a program.

This project can be interesting for anyone keen on electronics and/or computers; even more so if he or she is curious about control and regulation systems or about discrete PID controllers using Windows C++/CLI programming. It may also trigger old hands at electronics to re-live the PID experiments they once did at College in the dim past.

The project has a low threshold as there is no need to do any Laplace or Z transform. There is no need to do any calculation either; apart perhaps from an empirical tweaking of the PID controller by adjusting certain controls in the PC program. Of course, those of you with solid mathematics education can rigorously analyse the system.

On the other hand, seeing how a ball remains stable in a certain position on the beam not only has didactic or academic interest! Aircraft of the vertical takeoff type such as the Harrier employ similar control loop systems to maintain stability while stationary in the air.

Watch the Elektor Ball & Beam scale model on YouTube

Recipe for the system

The Ball & Beam system consists of electronics, software and mechanical elements and so makes a nice project to run by a group of students from different fields of study. The elements are shown in **Figure 1**.

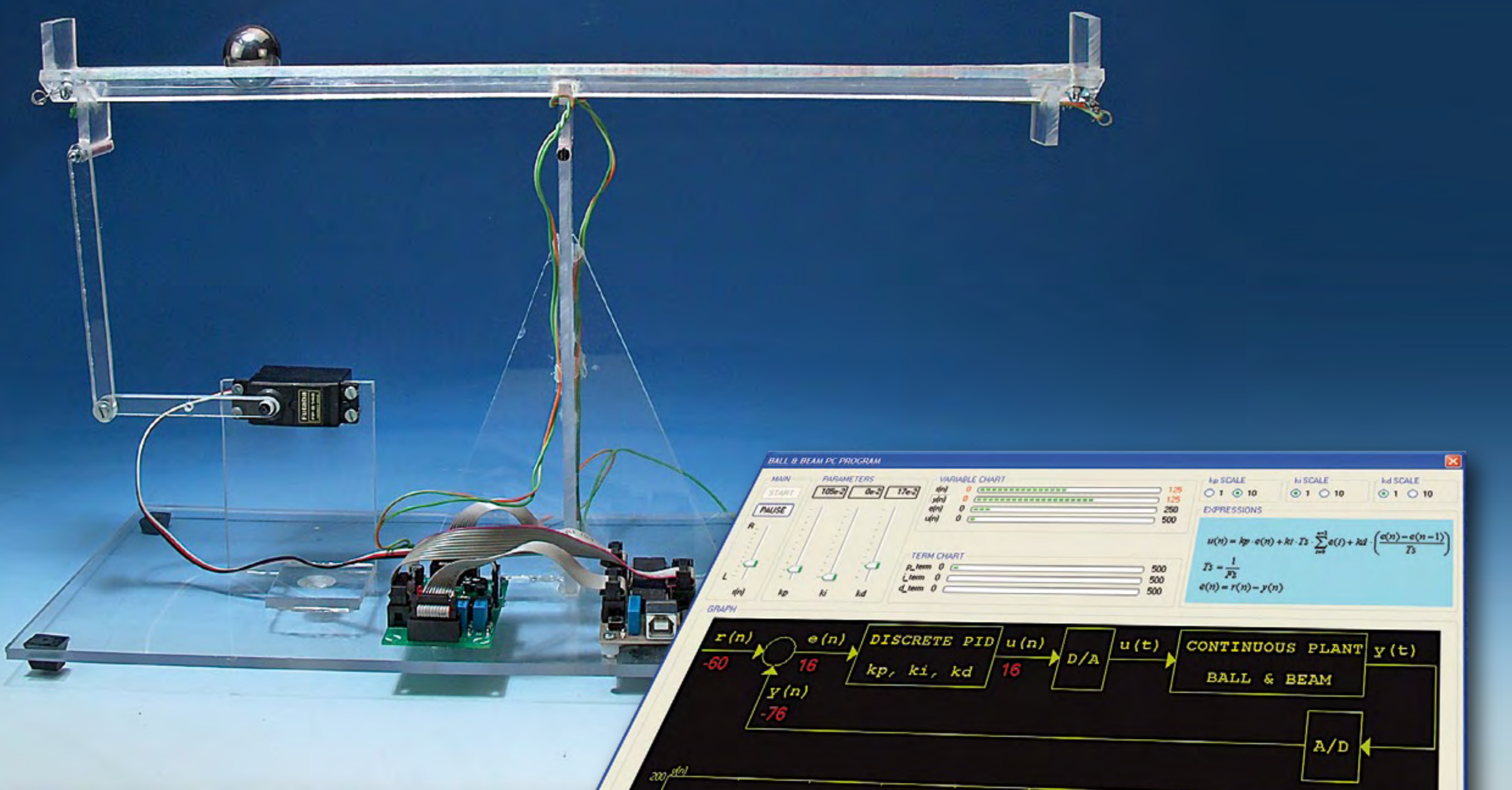
The electronics comprises two printed circuit boards:

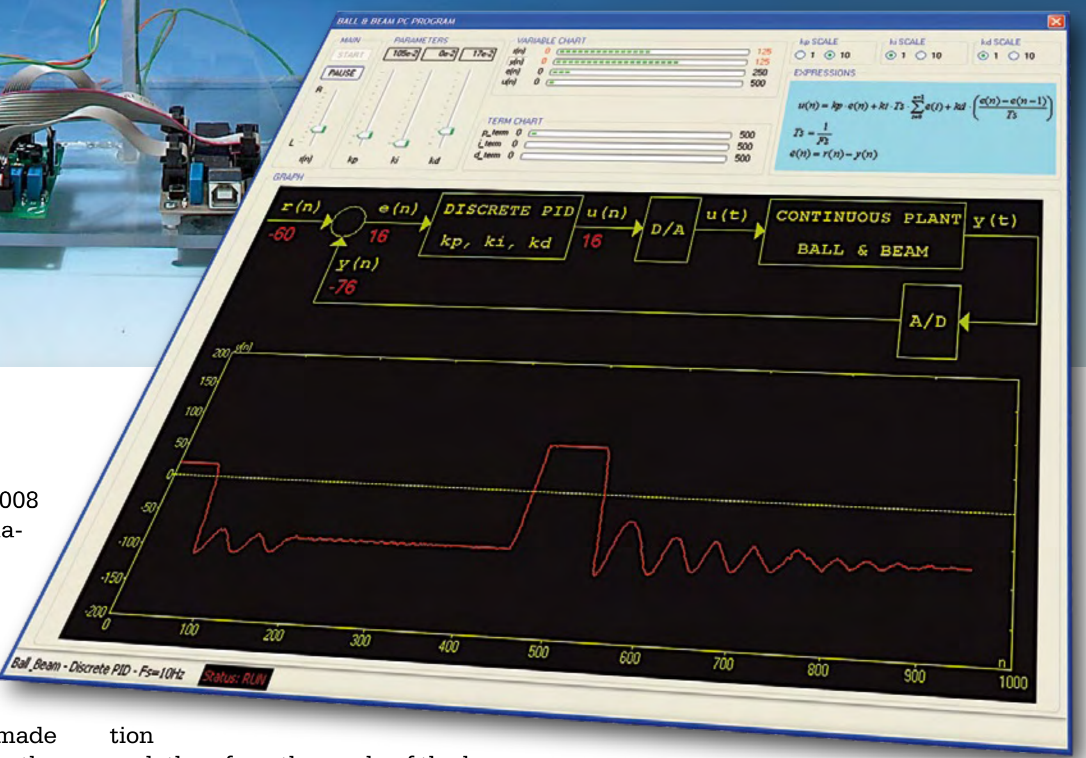
1. Elektor USB Data Acquisition Card (November 2007). This card has 8 digital inputs, 8 digital outputs, 8 analogue inputs and 2 analogue outputs. From all this I/O capacity we employ just one digital output, one analogue output and one analogue input. For a deeper knowledge of this card, the article in ref. [1] should be read.

2. Ball & Beam Interface Card. The card described in this article is used to adapt the Ball & Beam Mechanics to the USB Data Acquisition Card.

For software, we add the **Ball & Beam PC Program**. This application for PC communicates with the Data Acquisition Card to send and receive information from the Ball & Beam mechanical assembly through the Ball & Beam Interface Card. It is developed in C++/

ktor USB DAQ Card





CLI with the free Visual C++ 2008 compiler (Express Edition) available on the Microsoft website). Lastly, the mechanical assembly is a scale model made of methylacrylate (methacrylate or Perspex™) which has a V-shaped beam in which a steel ball can roll. It includes a potentiometer (made from resistance wire) to determine the position of the ball on the beam, and a servo to make the beam swing up and down.

USB data acquisition card

From the USB Data Acquisition Card, the following resources are used:

1. AN0 — this analogue input is available via pin 1 of connector K5 on the card. This input receives a voltage proportional to the position of the ball on the beam.

2. CCP1 — this analogue output is found on the pin 1 of connector K4. It is programmed to control the servo position and, therefore, the angle of the beam.

3. RD0 — this digital output is available on pin 1 of K1. An LED is connected to it, which will blink at the PID sampling frequency F_s when the system is operating.

Ball & Beam interface card

The Ball & Beam Interface Card was purposely kept a simple as possible, using cheap and easy to find components. The price to be paid for this simplicity is some tolerance but that's not a problem since we have an adjustment process available.

The circuit diagram of the interface card is shown in Figure 2. It can be thought of as consisting of three parts.

1. LED — this indicator (with its associated current limiting resistor) is connected to the RD0 digital output on the USB Data Acquisition Card. The Ball & Beam PC program will make this LED blink to the sampling frequency F_s.

2. Filter — this is for the ball position 'potentiometer'. As the steel ball touches two lengths of Nickel-Chrome wire, on occasions false contacts will be produced which would give wrong values. To counteract erratic values as much as possible, a low-pass filter consisting of R1 and C1 is included.

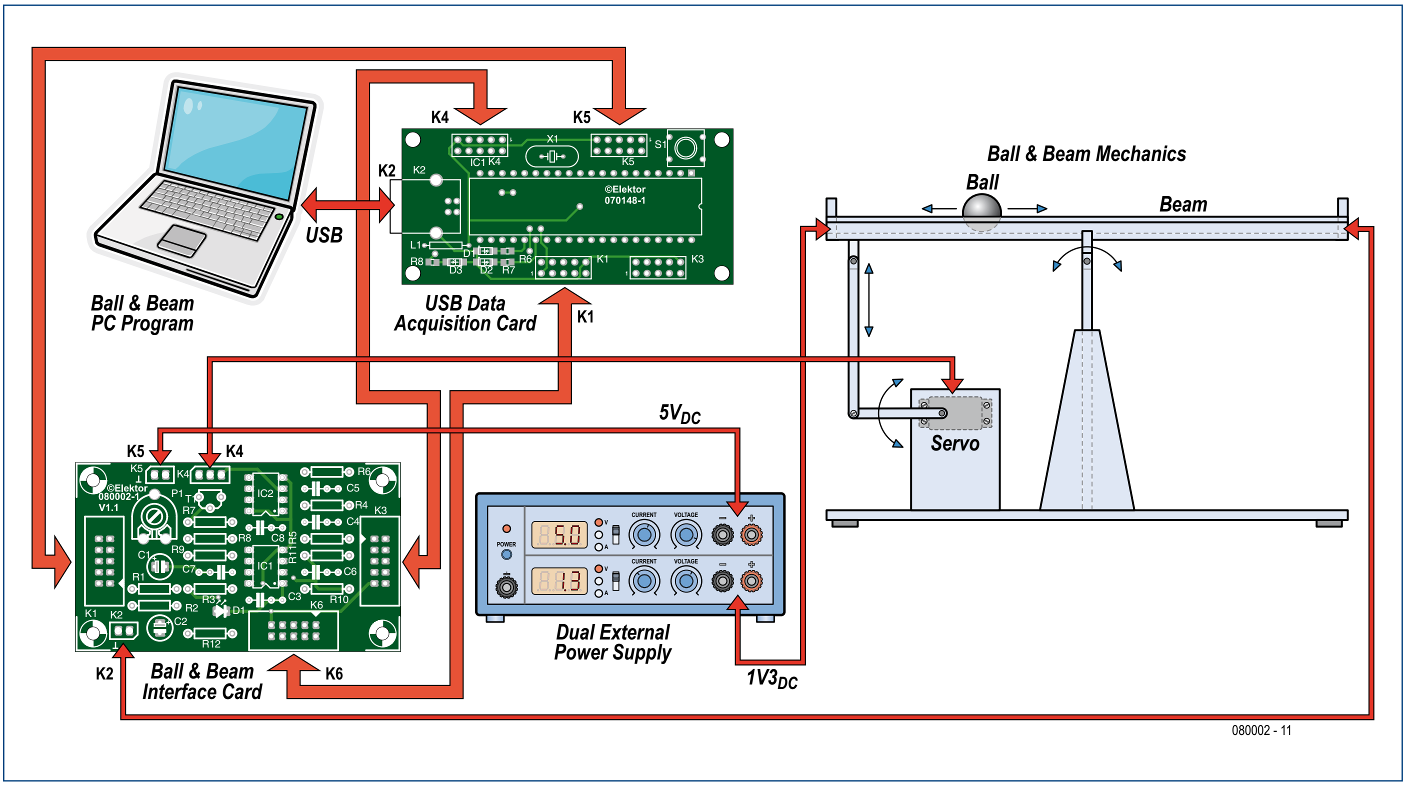


Figure 1. Overview of electronic and mechanical components connected up.

This 6 dB/octave (first order) filter effectively sits between the ball position 'potentiometer' and the AN0 analogue input on the USB Data Acquisition Card. The simulation result of this filter is shown in **Figure 3**. Note that the roll-off frequency is very low at just 7.5 Hz, but enough to perfectly register the ball position due to the movement by the beam.

3. Pulse generator to the servo — the beam slope is determined by the position of a servo. The beam will remain horizontal if the servo is in the centre position. If the servo spindle is at one extreme, the beam slopes some 15°. If it is at the other extreme, the beam slopes 15° opposite.

The signal fed to a servo is composed of pulses with a frequency between 50 Hz and 60 Hz. The pulsewidth determines the servo position and varies between 1 ms and 2 ms. The servo's central position corresponds to 1.5 ms. These times may vary slightly from a servo manufacturer to another. The pulsewidth is controlled by the CCP1 analogue output on the USB DAQ Card.

The relevant electronics is simple: one astable and one monostable implemented using the ICM7555 or TLC555, i.e., the low-power CMOS version of the famous LM/NE555 (which, by the way, should not be used). Both IC1 and IC2 are supplied from the USB port on your computer through the USB DAQ Card. More on the 7555 and relevant calculations in the **inset**.

Around IC2 a monostable has been assembled. Its trigger signal is provided by IC1; that is why the pulses generated by the monostable have the same frequency as the IC1 astable. The output pulsewidth controls the servo position and must have a frequency between 50 Hz and 60 Hz. The monostable pulsewidth should vary between 1 ms and 2 ms (typically).

The pulsewidth is determined by the CCP1 analogue output. CCP1 supplies a PWM signal with a frequency of about 2.9 kHz whose average in volts can be calculated with the expression:

$$U_{CCP1} = 5D$$

Where D is a constant between 0 and 1. As the CCP1 signal is going to modulate the monostable's pulsewidth, it is necessary to filter it to turn it into a continuous level. This is done by R5, C4, R4 and C5, the components forming a low-pass filter of modest features with a roll-off at about 30 Hz. That's high enough for the sampling frequency F_s and low enough for suppressing harmonics of the 2.9 kHz PWM signal on CCP1. The slope of the filter is 12 dB/octave (2nd order). Notice that the charging of the monostable's capacitor is not done with the usual simple resistor — here, a constant-current source is used. Built around T1, it keeps the capacitor's charge build-up linear, enabling the monostable pulsewidth to vary in linear fashion with the CCP1 signal. The constant current flows in T1's collector line and is adjusted by P1. See the **Monostable IC2 dimensioning inset** for the component value calculations.

The servo, besides the pulse signal, needs a supply voltage. As its current consumption is rather high (hundreds

Provide video proof to Elektor if you did the project with a ball heavier than 1 kg.

of milliamps), it is impossible to supply it from the USB DAQ Card (remember where that card gets its power from?). Hence it is essential to power the servo from an external supply rated at 5 V and 1 A, connected up to K5.

Construction

The component mounting plan of the circuit board designed for the interface card is shown in **Figure 4**. As usual the true-scale copper track layout (reflected and non-reflected) is in a free .pdf file found on www.elektor.com/080002 i.e. .the web page for the project.
Construction of this board should be a breeze as only traditional through-hole components are involved.

The Ball & Beam PC program

The program developed for the project implements a discrete PID controller with an F_s (sampling frequency) of 10 Hz. The PID mathematical derivation is given in the **PID maths inset**. The PC program is also a free download from the project web page.
All PID parameters can be controlled and observed in the program, see **Figure 5**. A brief program description is given below.

- MAIN. Using START, you launch the system and with PAUSE you stop it. You can adjust the reference (desired position of the ball on the beam) by adjusting *r(n)*.

- PARAMETERS. Here the PID controller's *kp, ki,* and *kd* constants can be adjusted. For each of these there are two scales: 1 and 10.

- VARIABLE CHART. This shows the evolution of *r(n), y(n), e(n), u(n)* signals. These are, respectively: reference (desired position of the ball on the beam); real position of the ball on the beam; error and PID controller output to the servo. The starting numbers and end of scale remain in black if the value is positive and they change into red for negative values.

- TERM CHART. Here you can view the evolution of proportional, integral, derivative (PID) terms, as parts of the controller maths. As before, black is positive and red is negative.

- EXPRESSIONS: In a frame you view the mathematical expression used for the PID controller implementation.

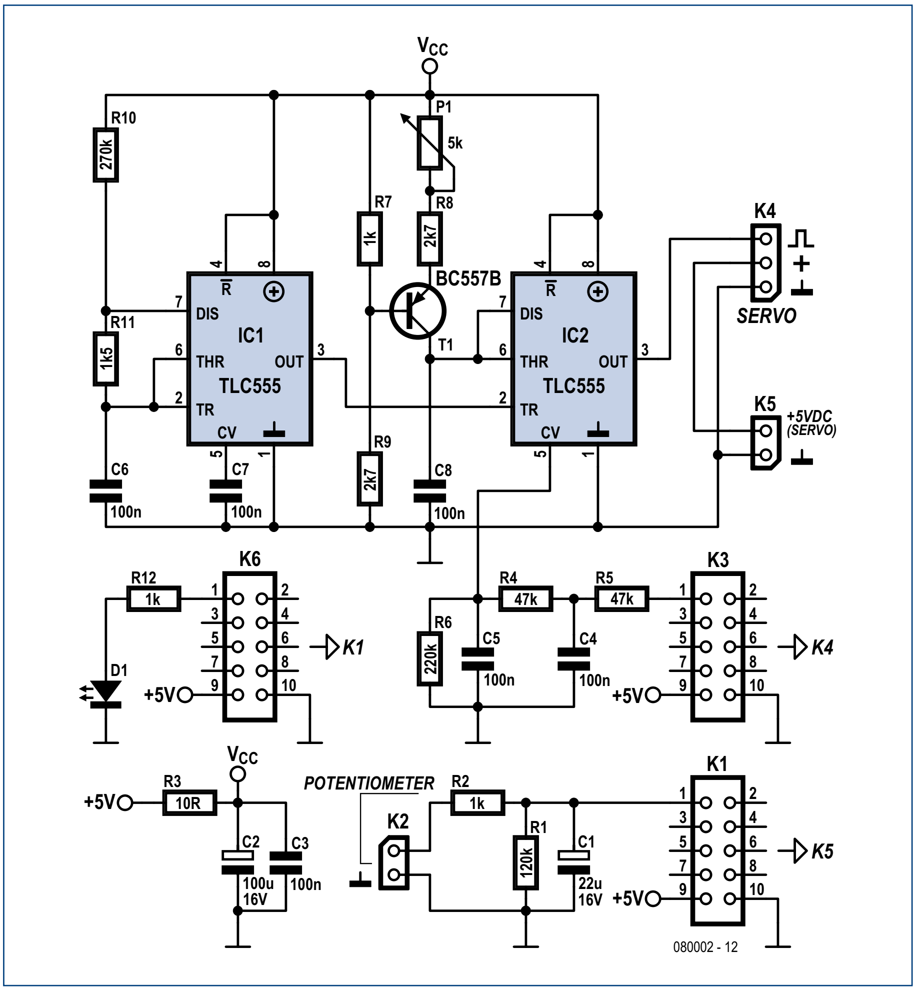


Figure 2. Circuit diagram of the Ball & Beam interface card.

- GRAPH. There are two charts: the first one is the whole system's block diagram consisting of the discrete PID controller (implemented by software in the Ball & Beam Program), a D/A converter and an A/D (both on the USB DAQ) and the 'continuous plant' which is the Ball & Beam mechanical assembly. The Ball & Beam Interface Card only adapts the USB Data Acquisition Card to the Ball and Beam mechanics, that's why it does not appear in the

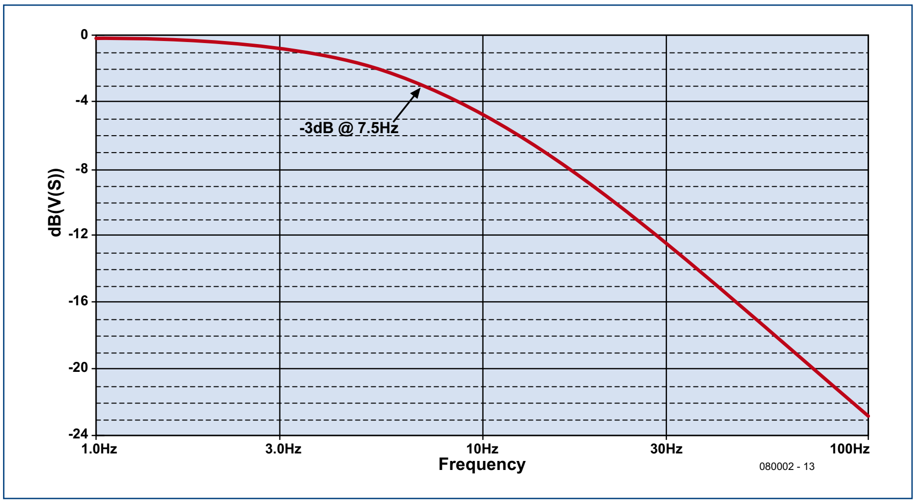


Figure 3. Frequency response of the filter designed for the wire potentiometer.

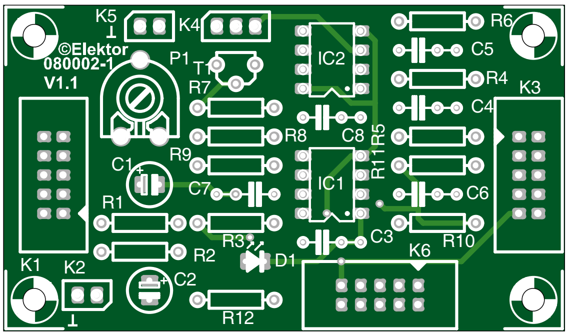


Figure 4. PCB design for the interface. The copper track layout is a free download.

COMPONENTS LIST

Resistors
R1 = 120kΩ
R2,R7,R12 = 1kΩ
R3 = 10Ω
R4,R5 = 47kΩ
R6 = 220kΩ
R8,R9 = 2kΩ7
R10 = 270kΩ
R11 = 1kΩ5
P1 = 5kΩ preset

Capacitors
C1 = 22µF 16V radial
C2 = 100µF 16V radial
C3,C6,C7,C8 = 100nF
C4,C5 = 100nF

Semiconductors
D1 = LED, low current, 3mm
T1 = BC557B
IC1,IC2 = TLC555 or ICM7555 (do not use plain 555)

Miscellaneous
K1,K3,K6 = 10-way boxheader
K2,K5 = 2-way SIL pinheader
K4 = 3-way SIL pinheader
PCB, ref. 080002-1 from www.thepcbshop.com
PCB artwork, free download from www.elektor.com/080002
Project software, free download from www.elektor.com/080002

block schematic.
The second chart, located in the lower part of the screen, shows the evolution of a selected (n) function. The signal can be any one of those included in the VARIABLE or TERM CHART. By clicking on its name, it will appear represented.

The program was written using C++/CLI with the free of charge Visual C++ 2008 (Express Edition) compiler. The most important function is called 'Void timer1_Tick' and it is found in the archive 'Form1.h'. In this function, among others, sits the discrete PID controller code.
The free of charge .NET XYGraph was also used for the control of componentXtra.com.

Ball & Beam mechanics

Parts lists, parts photos and details of the mechanical assembly of the Ball & Beam scale model may be found in a supplementary document that can be downloaded free of charge from the project web page as archive file **080002-W.zip**. The document also has an interesting discussion on selection of the ball material (steel) and its weight (approx. 64 g).

The beam has two wires made of nickel-chrome (NiCr 80%/20%) between which the ball rolls. The steel ball representing the wiper, the lot acts like a linear potentiometer (or 'rheostat') that's perfect to determine the ball position on the beam. The resistance wire is normally used for manufacturing and repairing heating elements. The wire has a diameter of 0.5 mm. Resistivity for the nickel-chrome wire at 80%/20% is about 1.1 Ω·mm²/m. The beam length being 40 cm, the resistance works out as

$$R = \rho \cdot \frac{L}{S} =$$

$$1.1 \cdot \frac{40 \cdot 10^{-2}}{196.35 \cdot 10^{-3}} = 2.24\Omega$$

$$S = \pi \cdot r^2 =$$

$$\pi \cdot \left(\frac{0.5}{2}\right)^2 = 196.35 mm^2$$

How this acts like a potentiometer is illustrated in **Figure 6**. If the ball is at the left end of the beam, the voltage between the wires is (close to) 0 V. This voltage keeps increasing as the ball moves to the right, until getting to a maximum of 1.3 V.
The servo used is the Futaba type S148 or equivalent. It is connected to K4 on the Ball & Beam Interface Card. The servo's white wire connects to pin 1 of K4, the red one to pin 2 and the black one to pin 3.

Starting up

The USB DAQ Card connection to the PC and the installation of the corresponding driver is explained in [1].
Once the USB DAQ is installed, you can launch the Ball & Beam PC program. Make sure that the application is stopped (Status: STOP). Connect the 5 V, 1 A external power supply and adjust preset P1 until the 'C' arm (see mechanical assembly document) gets horizontal — the beam must be horizontal too. Click on the START button (Status: RUN); this will take controls *r(n)* and *kp* to their highest position (the latter in the ×10 scale), whilst checking that the 'C' arm is at an angle of 30° to 50° relative to the base. Then stop the application (Status: STOP).
Now put the ball on the beam and connect the 1.3 V/1 A auxiliary power supply. Move the ball by hand to the far right of the beam, keeping it there, and write down the voltage measured across resistor R2. This should be approximately 1.3 V. Adjust the aux power supply to get exactly 1.3 V. Now everything is ready for the first try.

Maiden run

Push the START button on the program and slide reference *r(n)* to the middle. Slowly raise the *kp* proportional constant until the ball rocks slowly on the beam. Carefully increase the derivative constant until the ball is stable. If so, push it a little by hand — the system should respond by keeping the ball steady.
Now increase the integral constant little by little until the error is eliminated and the ball is steady as before, but this time approximately in the middle of the beam. Got it! PID in action… tell everyone about it at College and in the Elektor forum!

From here, you and your classmates can try as much you want, for example:

• choose different positions for the ball using *r(n)*.
• Make the system respond slower or quicker, with increased or reduced accuracy, with more or fewer tendency to oscillation, and so on, by changing *kp*, *kd* and *ki*.
• study the system's maths and adjust the constants for determined starting premises.

About Windows

MS Windows is not a real-time operating system. In fact, it's constantly waiting for events coming from peripherals (keyboard, mouse, etc.) and from applications. This can affect our system's sampling frequency F_s hence cause irregularities in the operation (the Ball & Beam Interface Card LED will be our witness).

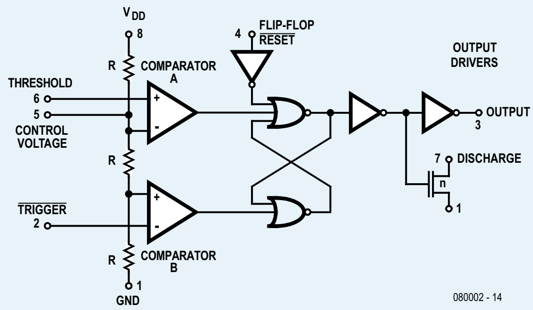
To counteract this inconvenience as much as possible, certain precautions must be taken:

• Use a PC with fast CPU and a vast amount of RAM memory.
• Execute the Ball & Beam PC program only. Pull the plug on MSN & Co.
• Give your application a high level of priority in the Windows multitasking scheme (this is done by the program).
• While the Ball & Beam PC program application is executing, do not maximize not minimize windows or push the Start button, etc. Allow the PC to interact with the application only.

If you stick to the above guidelines, the sampling frequency will be practically free from irregularities.

(ICM)7555 astable multivibrator

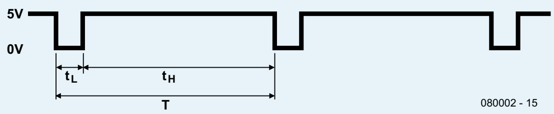
The (ICM)7555 chip is the CMOS low-power version of the renowned LM555/NE555. With it, RC timers can be easily designed. Its functional schematic is given below.



For some later calculations, it is necessary to know the value of R. For the present application, measurements indicate that a value of 100 kΩ is best.

The signal generated by the astable multivibrator around IC1 is periodical but with the High level time much longer than the Low level time. The Low level pulse is used for triggering a second 7555 (IC2) wired as a monostable multivibrator.

Theoretically, the signal the astable should supply at its output (pin 3 of IC1) is:



$$t_H = (R10 + R11) \cdot C6 \cdot \ln 2 = (270k + 1k5) \cdot 100n \cdot 0.69 = 18.7ms$$

$$t_L = R11 \cdot C6 \cdot \ln 2 = 1k5 \cdot 100n \cdot 0.69 = 103.5\quad s$$

$$T = t_H + t_L = 18.7ms + 103.5\quad s = 18.8ms$$

$$F = \frac{1}{T} = \frac{1}{18.8ms} = 53.2Hz$$

The actually measured values are:

t_H=18 ms

t_L=100 μs

T= t_H + t_L =18.1ms, hence F = 1/T = 55.2 Hz

If something does not properly work

If something does not work, take some time to read this section, it will help you locate the cause either in the PC program, the interface card, or the mechanical assembly.

First, make sure of a running, fully updated Windows XP or Vista. Ball & Beam does not work under Windows 2000 or lower. Also check if you have the latest update of .NET Framework (from version 3.5).
The executable program Ball_Beam.exe is in the same folder as mpusbapi.dll and XYGraph.dll. To run the program under Windows Vista, right-click on 'Ball_Beam.exe' and from the context menu choose 'Execute as Administrator'.

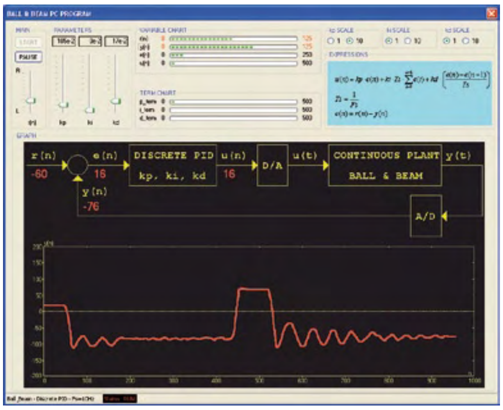
The program has been successfully tested on Windows XP and Vista PCs without encountering any problem. However, the program may indicate some error if there is a problem with the USB Data Acquisition Card. If so, go back to ref. [1]. Note that a correction was published for the project.

If the program is modified, it must be compiled again with the Visual C++ 2008 Express Edition — do not use the 2005 version. Besides, you should have NET XYGraph and Visual C++ 2008 Express Edition, all correctly registered.

The program needs a screen resolution of at least 1280×1024 so send the old 15 inch CRT off to recycling along with the 486 or Win98 PC.

On the Ball & Beam Interface Card it may happen that it is impossible to get the adjustment done properly. This is probably due to tolerances, mainly in the internal voltage divisor of the (ICM)7555 or TLC555 integrated circuit (in the prototype we used a Philips IC). With an oscilloscope, check up the signal on IC1 pin 3 (0 V and 5 V levels, frequency between 50 Hz and 60 Hz, low level of some 100 μs). If not, IC1 is probably at fault or you have mounted a wrong component value.

If it proves impossible the get the 'C' arm horizontal by adjusting P1, change C8 to a different value (47 nF or 150 nF).
If during the start-up the 'C' arm is noticeably higher than 30-50° relative to the base, try different values for R4 and R5 (68 kΩ or 100 kΩ).



If
it's

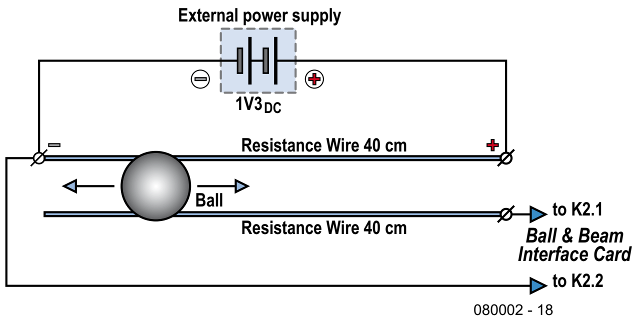
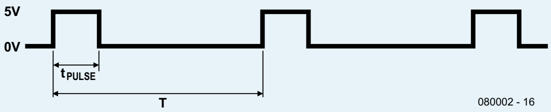


Figure 5. The Ball & Beam PC software in action. Food for C++ programmers and quite a lot to tweak to get the ball stable on the beam!

Figure 6. The position of the ball on the beam is read by a DIY rheostat or wire potentiometer.

Monostable IC2 dimensioning

The expected signal at the monostable output (pin 3 of IC2) is:



Allowing for a little headroom at either extreme, the servo timing range of 1.0 - 2.0 ms is calculated from

$$t_{PULSE} = \frac{C8 \cdot U_{CV}}{I_{Q1}}$$

$$U_{CV} = 5 \cdot \frac{(2 \cdot R) \| R6 \| (R4 + R5)}{R + \left[(2 \cdot R) \| R6 \| (R4 + R5)\right]} + U_{CCP1} \cdot \frac{R \| R6 \| (2 \cdot R)}{(R4 + R5) + \left[R \| R6 \| (2 \cdot R)\right]} = 1.65 + 0.54 \cdot U_{CCP1}$$

R=100K

$$I_{Q1(\alpha=0.2)} = \frac{\left(\frac{5 \cdot R7}{R9 + R7} - U\gamma\right)}{(R8 + \alpha \cdot P1)} = 203 \quad A$$

Uγ=0.6V

$$t_{PULSE} = \frac{C8 \cdot U_{CV}}{I_{Q1}} = \frac{100nF \cdot (1.65 + 0.54 \cdot U_{CCP1})}{203 \quad A} = \begin{matrix} 0.8ms @ U_{CCP1} = 0V \\ 1.5ms @ U_{CCP1} = 2.5V \\ 2.1ms @ U_{CCP1} = 5V \end{matrix}$$

Note that the variation of t_{PULSE} is linear with respect to U_{CCP1}. In practice, the pulse durations obtained after adjusting P1 are well within the range 1ms to 2ms.

PID maths

$$u(n) = k_p \cdot e(n) + k_i \cdot Ts \cdot \sum_{i=0}^{n-1} e(i) + k_d \cdot \left(\frac{e(n) - e(n-1)}{Ts}\right)$$

$$Ts = \frac{1}{Fs}$$

$$e(n) = r(n) - y(n)$$

been necessary to change C8, R4 and R5, check the signal at IC2 pin 3 (levels 0 V and 5 V, frequency between 50 and 60 Hz, high level of 1.5 ms). For this last measurement, the Ball & Beam PC program has to be halted (Status: STOP) and P1 adjusted to reach the indicated 1.5 ms.

If everything is correct so far, ask yourself if the Ball & Beam Interface Card and the servo are properly powered, the latter from the 5 V / 1 A supply. Finally, are you powering the wire potentiometer with an external power supply of approximately 1.3 V and a minimum current of 1 A? If so, all that's left to do is verify the mechanical assembly.

(080002-I)

Reference

[1] USB Data Acquisition Card, Elektor November 2007. www.elektor.com/070148

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DCC Command Stati

Digital model control with the ARM7

Patrick Smout

Electronics is making more and more inroads into the domain of model trains. Trains are now controlled with digital codes, and in many cases the entire system can be operated from a computer. In this article we present a design for the device that forms the heart of a digitally controlled model railway: the DCC Command Station. The computing power in this design is provided by a high-performance ARM7 processor.

One of the key elements of a modern digitally controlled model railway is the control unit that produces the digital signals for controlling the locomotives. This device also has several secondary functions, such as communicating with a PC.

This article describes a control unit (called a 'Command Station' in model railway jargon) that employs the DCC standard and is built around a powerful ARM7 processor, which is also used on the *Elektor* 'ARMee' board.

First a brief introduction to the topic.

With conventional analogue control of a model railway system, the speed of the locomotives is adjusted by varying the voltage on the track. The simplest arrangement consists of a transformer and a potentiometer, possibly complemented by a rectifier. More advanced systems use pulse-width modulated (PWM) signals. The principal advantage of this approach is improved running characteristics. This is quite nice, but even with these systems it is very difficult to control other functions in a locomotive, such as sound effects or a smoke generator.

If a decoder is fitted in the locomotive and the transformer is replaced by an electronic control unit with a track booster, we enter the realm of digitally controlled model railways.

The electronic controller that makes all this possible is called a 'Command Station'. The Command Station described here is suitable for systems that employ what is called the 'DCC standard'. DCC is not the only method for digital control of model railways, but it is one of the few methods that is not tied to a specific manufacturer.

The advantages of digital train control can be summarised as follows:

- Dramatically improved locomotive running characteristics, especially at low speeds and on uphill grades.
- Individually switchable auxiliary functions in locomotives, such as sound effects, smoke generators, remote decoupling, and lighting (including when the train is standing still).
- Several trains can travel on the track or in the same block at the same time.
- A computer can be added for easy automation of control and protection functions.

An additional benefit of the system described here is:

- The standard is widely used, so products from different suppliers can be used 'mix and match' in the same system.

A brief history of DCC

Despite what you might think, DCC (which stands for 'Digital Command Control') is not new. The history of DCC goes back to the late 1980s. At that time a working group of the National Model Railroad Association (NMRA), an umbrella organisation of model railway enthusiasts in the USA, was looking for a standard that could be used on

micro

for digital control of model trains. The commercially available systems at that time were proprietary and mutually incompatible.
After an extensive study of the available systems and a few diversions, in the early 1990s the NMRA decided on a system developed by Lenz, a German company. Reliable data transfer and interference-free operation were naturally the most important criteria for their choice. In addition, the new standard had to be able to evolve with the available technology and satisfy new requirements arising in the model railway world.
The requirements and expectations that the new standard must fulfil were specified by the DCC working group of the NMRA in documents called 'Standards' and 'Recommended Practices' (RPs). The electrical properties that the signals must fulfil, as well as the form and content of the transferred data, are defined precisely. Among other things, the recommended practices define the requirements that must be met by the digital boosters that supply power to the model railway.

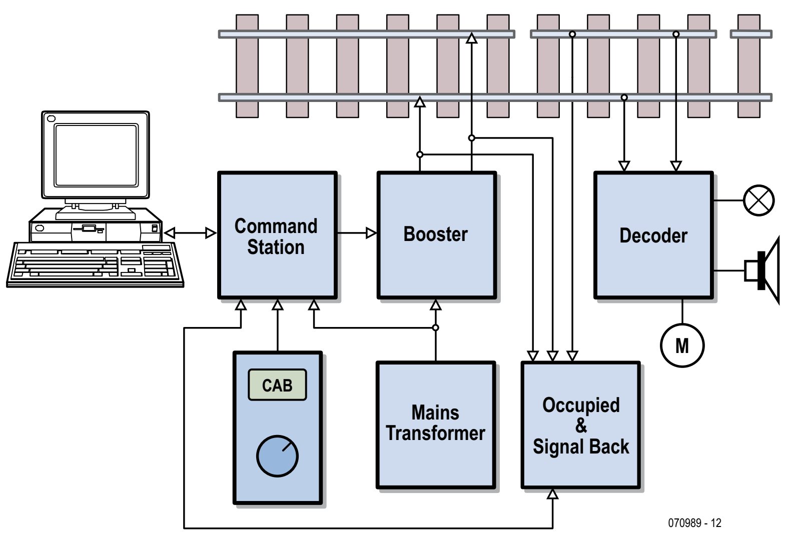


Figure 1. Block diagram of a model railway system with digital control.

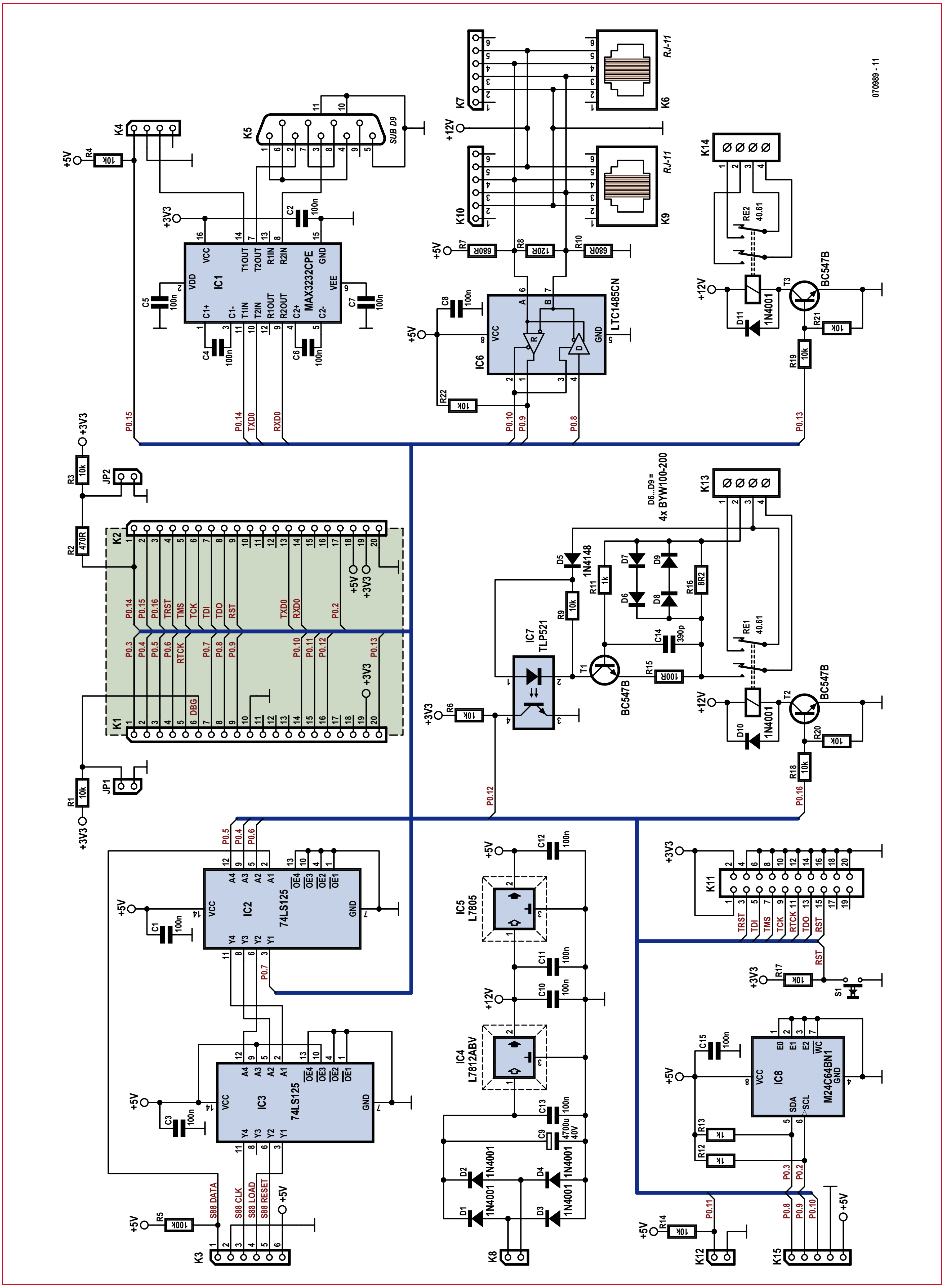
Structure of a digitally controlled model railway

A digitally controlled model railway consists of the following functional blocks (see **Figure 1**):

- **Transformer**. Every system needs a source of power.

- **Decoder**. This processes the signals that originate from the Command Station and are placed on the track by the booster. A decoder can be fitted in a locomotive, but it can also be used in a fixed location for controlling components such as turnouts and signals (in the latter case, it is called an accessory decoder). A remarkable aspect of these decoders is that they receive power and digital signals via the same leads, so there is no need for separate power leads. As each decoder has a unique, configurable address, it is easy to connect several decoders to the same track. Each decoder only responds to the information intended for it.

- **Occupancy feedback detectors**. These are used to keep track of which parts of the track are occupied or free. For this purpose, the track is divided into a number of small sections, with one rail of each section electrically insulated from the adjacent sections. The insulated rail of each section is connected to an occupancy feedback circuit. In its simplest form, this is a current detector. If a section is occu-



IC1
MAX3232CPE
IC2
74LS125
IC3
74LS125
IC4
L7812ABV
IC5
L7805
IC6
LTC1485CN
IC7
TLP521
IC8
M24C64BN1
BC547B
1N4001
1N4148
D6...D9 =
4x BYW100-200
RE1
40.61
RE2
40.61
RJ-11
SUB D9
S88 DATA
S88 CLK
S88 LOAD
S88 RESET
TXD0
RXD0
070989 - 11

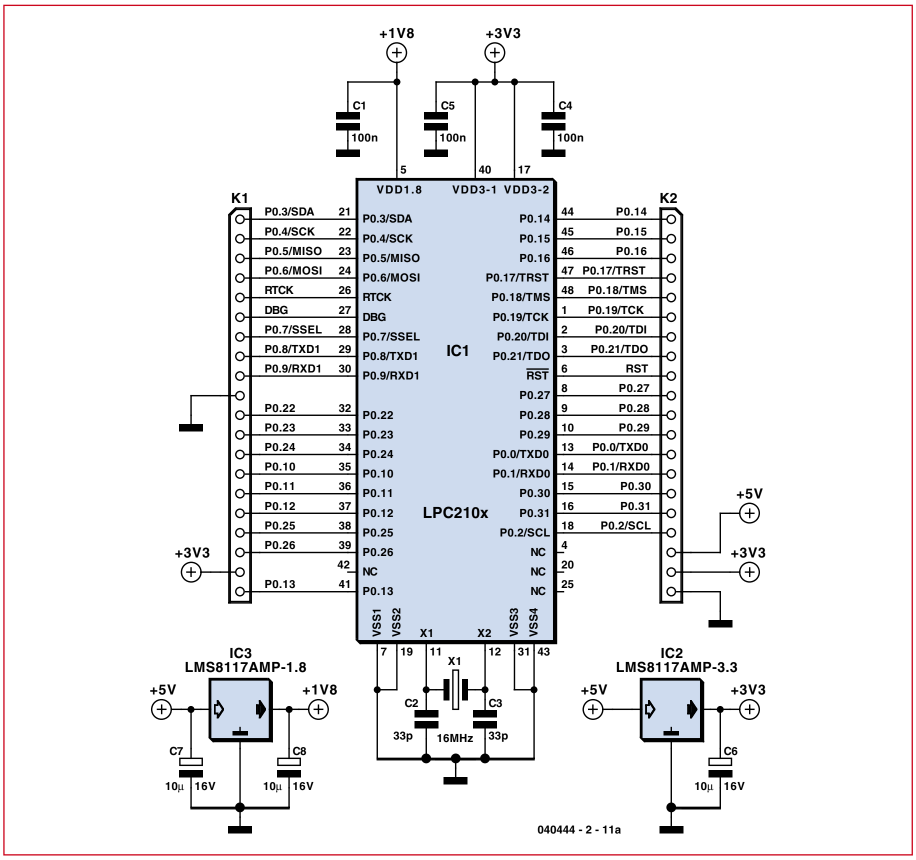


Figure 2b. Schematic diagram of the ARM module.

pied, there will be a measurable current consumption (even if it is relatively small). The measured signal is usually sent to the Command Station in the form of a binary signal.

- **Hand controller** (also called a cab controller, after the driver's cab of a locomotive). The hand controller replaces the traditional rotary knob on the transformer, and it also provides some extra functions, such as switching lights and sound effects on and off. Each controller can control its own locomotive, but it is also possible to operate several locomotives with a single controller.

- **PC**. Although a PC is not absolutely necessary, including a computer in the system adds a lot of extra scope to digital model railroading. In the simplest case, it can be used to display the track occupancy data. Naturally, a lot more is possible. There are various software packages available, both commercial and free, that can handle the entire control and protection functions of a railway. This certainly doesn't have to spoil the fun of a model railway – while you are piloting a goods train through the marshalling yard just like a real engine driver, the PC ensures that no disasters occur in other parts of the system.

- **Booster**. As a respectable model railway system can consume a considerably amount of current, one or more boosters are used to supply power to the track. If several boosters are used, they are all driven from the same Command Station. In this case, each booster supplies power to a portion of the track system.

- **Command Station**: the heart of the system. Its most important task is generating the digital signals that control the locomotives and all other digital components in the railway system. In addition, the Command Station looks after communication with one or more hand controllers, which are usually connected to a bus. The bus used here is called XpressNET, which is a polled single-master EIA 485 bus. A link to the occupancy feedback detectors is also essential. A separate bus can be used for this purpose, but in

Figure 2a. Schematic diagram of the DCC Command Station. The ARM module is fitted onto connectors K1 and K2.

DCC: what and how

A DCC signal consists of an AC voltage in which the digital information is encoded in the lengths of a series of pulses.

The half-bit time for a '1' bit is 58 µs, so the transmission time for a '1' bit is 116 µs.

The half-bit time for a '0' bit is at least 100 µs. In principle, the two half-bit times for a '0' bit should be the same to avoid producing a DC potential on the track. However, the standard allows the stretching of '0' bits in order to intentionally superimpose a DC voltage on the traction voltage. This can be used to operate an analogue locomotive without a decoder on the track at the same time. This possibility is not utilised in the Command Station described here, and the half-bit time for a logic '0' is set to a fixed value of 116 µs. The transmission time for a '0' bit is thus 232 µs with this Command Station.

Messages are sent in the form of data packets. The structure of a standard packet can be described briefly as follows:

- Preamble: a series of at least 14 '1' bits preceding the start of a new packet.
- Packet Start Bit: a '0' bit that marks the end of the preamble and the start of the address.
- Address Byte: a series of 8 bits that indicates the address (or part of the address) of the decoder for which the data is intended.
- Data Byte Start Bit: a '0' bit that marks the start of the data.
- Data Bytes: several groups of 8 data bits with '0' bits as separators between the groups. This part of the package contains the supplementary address, instructions, data, and a checksum.
- Packet End Bit: a '1' bit that marks the end of the packet.

Example:
An order for setting the direction of travel and the speed (in 28 individual steps) is constructed as follows:

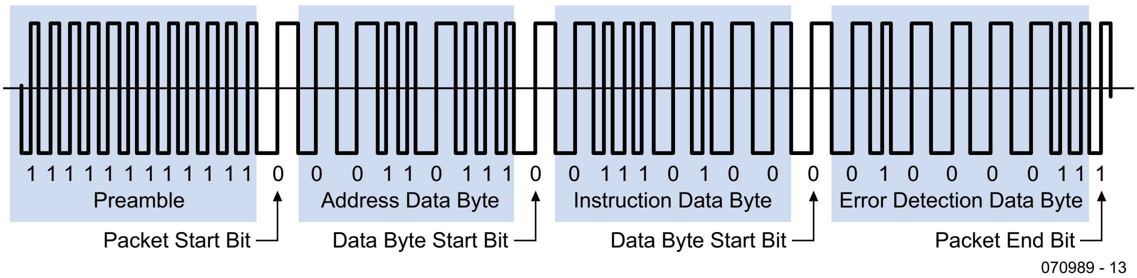
11111111111111	0	AAAAAAAA	0	01DSSSSS	0	EEEEEEEE	1
Preamble		Address		Instruction		Checksum	

AAAAAAAA	Address of the target locomotive for the instruction
D	Direction of travel (1 = forward)
SSSSS	Speed
EEEEEEEE	Checksum (XOR of the previous bytes excluding the preamble – in this case [AAAAAAAA] ^ [01DSSSSS])

A bit stream for setting locomotive number 83 to forward motion with a speed of 0 thus takes the form:

11111111111111	0	01010011	0	01100000	0	00110011	1

The signal waveform of an order could be:



A complete description of the standard, including a summary of all the instructions, is available at the NMRA website (www.nmra.org) on the DCC working group activities page

practice these devices sometimes share the cab bus. We decided to use a separate bus for this in our design: the S88 bus.

Finally, there is the link to the computer, which in this case is an RS232 port. Thanks to the use of an open protocol that is supported by a variety of software packages, expansion is problem-free.

Schematic diagram

The circuit shown in **Figure 2** is built around an LPC2106. This is a powerful 16/32-bit NXP microcontroller based on an ARM7TDMI-S processor core with a maximum clock rate of 60 MHz. The microcontroller has 128 kB of flash EEPROM and 64 kB of RAM, which are more than adequate for quite a few projects. There are also two 16C550-compatible serial ports, two versatile 16-bit timers, an I²C interface, and an SPI interface. A maximum of 32 I/O lines are available for connection to the outside world.

The microcontroller is shown in the middle of the schematic diagram in the form of a separate daughterboard, which some readers will certainly find familiar. This board (o/n 040444-1) was used earlier in another *Elektor* design: the ‘ARMee’ project published in April 2005. Practically all important signals are fed out via two connectors (K1 and K2). The board is powered from +5 V. The 1.8-V and 3.3-V supply voltages required by the microcontroller are generated on-board. The 3.3-V supply is also made available via the connectors for I/O devices that require a lower supply voltage.

Unfortunately, the LPC2106 does not have an internal EEPROM. As quite a few things must be stored in non-volatile memory in the Command Station, we remedied this shortcoming by using a small external EEPROM (IC8, 8 k × 8). Fortunately, the link to the microcontroller is quite simple because we can take advantage of the microcontroller’s standard I²C interface. As there is only one device on the I²C bus, addressing is unnecessary, so the E0, E1 and E2 address pins of the EEPROM are tied to ground. R12 and R13 are pull-up resistors, which are necessary for proper bus operation.

An RS232 interface is provided for communication with the computer. Half of a MAX3232 powered from the 3.3-V rail provides level shifting for the Transmit and Receive lines of UART 0. Using UART 0 for the computer link also provides a convenient way to download new software via the built-in boot loader. The pin assignments of K5 correspond to a DCE (such as a modem), so a standard one-to-one cable (available in every computer shop) can be used for the connection between the control unit and the computer.

The other half of the MAX3232 provides the level shifting necessary for driving an external track booster. This signal is fed out via K4. This connector also has a pin for a short-circuit feedback signal. If the signal on pin 1 is pulled to ground (by the booster), the control unit will disable the output.

The connectors for the hand controllers, which are driven via XpressNET, are located at the right. The hardware is a standard EIA 485 port implementation. Driver IC8 (LTC1485) provides the signal shaping. Resistor R8 ensures that the line is terminated properly. Although this is not especially critical at the data rate used here, it’s better to be safe than sorry. Resistors R7 and R10 hold the Transmit and Receive lines in a defined state when they are not being driven by a device on the bus. This prevents the receivers from picking up invalid data due to interference coupled into the floating bus lines. RJ-12 6P/4C modular connectors or plug-and-socket connecters can be used to connect the hand controllers to the network.

There are two relays at the bottom middle. The contacts of relay RE2 can be used to connect the traction voltage from the booster to the main line, while the contacts of RE1 can be used to connect the booster output to a separate programming track. This relay is only engaged if the Command Station receives special programming instructions from the programming software. When this happens, relay RE2 is released. This ensures that programming instructions for a locomotive on the programming track are not sent to other locomotives on the main track as well.

This difference in the intended uses of the two relays is the reason for the additional circuitry around relay RE1. This is a simple current detector that senses the acknowledgment pulses generated by the decoder during a programming session. An acknowledgement pulse is generated by causing the current consumption to rise to at least 60 mA for a defined time (approximately 6 ms), for example by briefly switching on the motor. The presence (or absence) of these acknowledgement pulses enables the control unit to put together the response from the decoder. The decoder current flows through R16 during the programming session. This resistor thus determines the sensitivity of the detector. Four fast diodes (two pairs of diodes connected head to tail, since the track booster supplies an AC voltage) limit the voltage across the sense resistor to twice their forward voltage drop. Two diodes connected in series are used here to ensure that T1 can be driven into conduction at a suitable level. R11 and C4 form a low-pass filter that suppresses noise pulses. The LED in optocoupler IC7 is driven by the signal on the collector of T1. The collector current, and thus the current through the LED, is determined by resistor R15. The optocoupler (which provides electrical isolation from the traction voltage) supplies the ack pulses to the microcontroller.

Connector K11 is used for the JTAG port. S1 is reset button. If you want to develop your own software for this

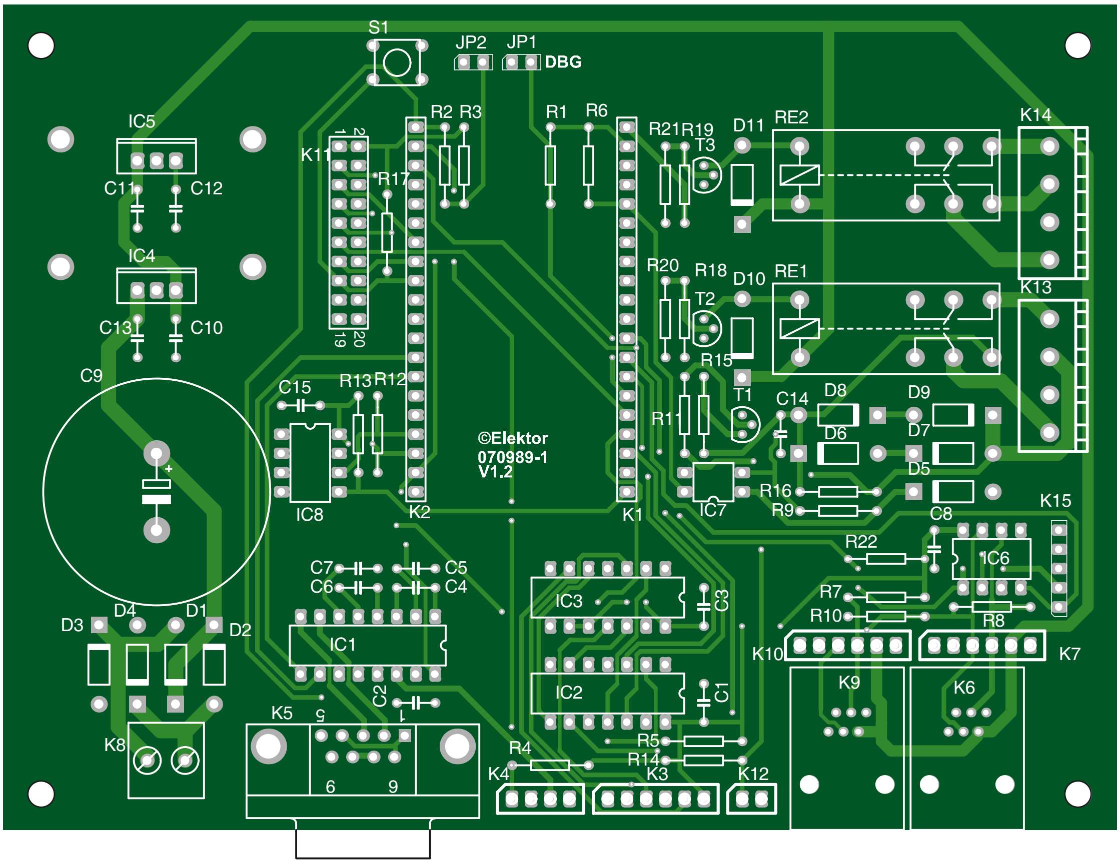


Figure 3. The PCB is designed with a spacious layout to make assembly easy.

project and you have the right tools, you can use this port for downloading and debugging the program code. It is not used during normal operation in and around a model railway.

The circuit is powered by a transformer with a secondary voltage of 13 to 14 V connected to K8. A transformer rated at 16 to 20 VA is more than adequate. A standard model train transformer is not especially suitable for this purpose, since it has a slightly higher output voltage (14–16 V_{AC}), which will cause IC4 to become rather warm. The transformer voltage is full-wave rectified by a set of four diodes, and the DC voltage is smoothed by C9. This voltage is then reduced in two stages, first to +12 V and then to +5 V. The 12-V supply voltage is used directly to power the two relays and the hand controllers connected to the XpressNET bus. The +5-V supply voltage powers the microcontroller and its peripheral logic. Four ceramic capacitors provide effective suppression of undesirable oscillations.

COMPONENTS LIST

Resistors

R1,R3,R4,R6,R9,R14,R17-R22 = 10kΩ
R2 = 470Ω
R5 = 100kΩ
R7,R10 = 680Ω
R8 = 120Ω
R11,R12,R13 = 1kΩ
R15 = 100Ω
R16 = 8Ω2

Capacitors

C1-C8,C10=C13,C15 = 100nF
C9 = 4700µF 40V radial
C14 = 390pF

Semiconductors

D1-D4,D10,D11 = 1N4001
D5 = 1N4148
D6-D9 = BYW100-200
T1,T2,T3 = BC547
IC1 = MAX3232CPE
IC2 = 74HCT125
IC3 = 74LS125
IC4 = 7812
IC5 = 7805
IC6 = LTC1485CN
IC7 = TLP521-1
IC8 = 24C64

Miscellaneous

S1 = pushbutton, 6mm, PCB mount
RE1,RE2 = 12-V relay, 2x changeover, e.g. Finder type 40.52
Heatsink, Fischer type SK104, 25mm, for IC5
Heatsink, Fischer type SK104, 35mm, for IC4
K1,K2 = 20-way SIL socket
K3,K7,K10 = 6-way SIL pinheader
K4 = 4-way SIL pinheader
K5 = 9-way sub-D socket (female), angled pins, PCB mounting
K8 = 2-way PCB terminal block, lead pitch 5mm
K6,K9 = 6P4C modular connector, PCB mount, e.g. Hirose TM5RE1-66
K11 = 20-way DIL pinheader
K12,JP1,JP2 = 2-way pinheader
K13,K14 = 4-way PCB terminal block, lead pitch 5mm
K15 = 5-way SIL pinheader
ARM CPU module (unprogrammed); Elektor SHOP item **040444-91**
PCB, Elektor SHOP item **070989-11**
Kit of parts incl. programmed ARM module; Elektor SHOP item **070989-71** (see www.elektor.com)

The circuitry around IC2 and IC3 is used to read the data from the S88 feedback detectors. The S88 bus is designed as a giant shift register composed of the S/R flip-flops of the individual feedback detectors, which register their 'occupied/free' status until they have been read out serially. Most of this work is done by software running in the microcontroller. The contribution of the hardware to this process is limited to buffering the control signals. IC3 buffers the outgoing signals (Clk, Load, and Reset), while IC2 buffers the incoming signal (Data). The serial data is clocked in at rate of 5 kHz. With the maximum number of detectors that can be connected to the bus (4096 inputs), this means that a full set of inputs can be read 10 times each second.
This all works as follows:

- Data supplied to the feedback detectors in parallel format is loaded from the S/R flip-flops into the shift register by setting the Load signal high and issuing a clock pulse on the Clk line.
- The S/R flip-flops are reset by setting Reset High, after which they are ready to register new data.
- The microcontroller then reads in the serial data by issuing a series of clock pulses on the Clk line.

These signals are output by a 6-way connector (K3). The +5-V supply voltage on this connector is used to power the connected feedback detectors.
Finally, there is one more connector (K15) at the bottom left of the drawing. It supports an alternative bus for the hand controllers and feedback detectors. Stay tuned for more information about this.

PCB assembly

The PCB layout for the Command Station is shown in **Figure 3**. Assembling the board is quite straightforward, as there are no components that require special attention. If you allow yourself sufficient time and work attentively, you are bound to achieve a good result. Fit the low-profile components first, followed by the high-profile components. As the final step, solder the electrolytic capacitor, IC4 and IC5 with their heat sinks, and relays RE1 and RE2.

It is advisable to fit IC1, IC2, IC3 and IC6 in sockets, since they provide the interfaces to the outside world. They bear the brunt of any inadvertent short circuit, and you can replace them easily if they are fitted in sockets.
The following components are optional:

- JP1 and K11 can be omitted if you do not intend to use the JTAG interface.

- For K7/K8 and K9/K10, fit only the connector or connectors that you personally prefer. All four of these connectors are wired in parallel.

Initial use and testing

Connect the transformer to K8 and switch on the mains voltage. Check the +5-V supply voltage (e.g. between pins 5 and 8 of IC6) and the +3.3-V supply voltage (e.g. between pins 15 and 16 of IC1).

The next step is to download the application code to the DCC Command Station. You can use a standard NXP tool for this (LPC2000 Flash ISP Utility). This tool enables you to download code to the processor via the PC serial port. The instructions for using this tool are described in detail in the supplementary information for this article on the *Elektor* website. You can also download the hex code for programming the processor from the website. Alternatively, if you buy the *Elektor* kit for this project you will receive a preprogrammed module.

When the Command Station is started up the first time, it reconfigures the non-volatile data stored in the EEPROM. This can take a while (around 20 seconds), so you can take a short break before continuing with the next step.

Now connect a pushbutton with a make contact (normally-open) between the two pins of K12. This is the Stop / Go / Cold Start button.
If you press this button, relay RE2 should engage so the digital signal for driving the booster is present on connector K4. Now the DCC Command Station is ready for normal operation.
If you press the button again, relay RE2 is released, and the digital signal is no longer routed to K4.

You can also use the pushbutton to perform a system reset. If the Command Station stops responding, even after the supply voltage is interrupted, you can restore it to proper operation by holding the button depressed while switching on the power. This causes all non-volatile data stored in the Command Station to be reset to its default values. This process takes approximately 20 seconds.

Now you're ready to connect the Command Station to the track booster. You can use a DIY booster, such as the one described already in *Elektor* (EEDTs or EEDTs Pro Booster), or you can use a commercial model (such as the Lenz LV102). The basic setup requires two leads to be connected between the Command Station and the booster: 0 V from pin 2 of K4 and the DCC signal from pin 3. The short-circuit feedback signal can be connected to pin 1 if desired. When a short circuit occurs, this pin must be pulled to ground, which causes the Command Station to disable the digital signal.

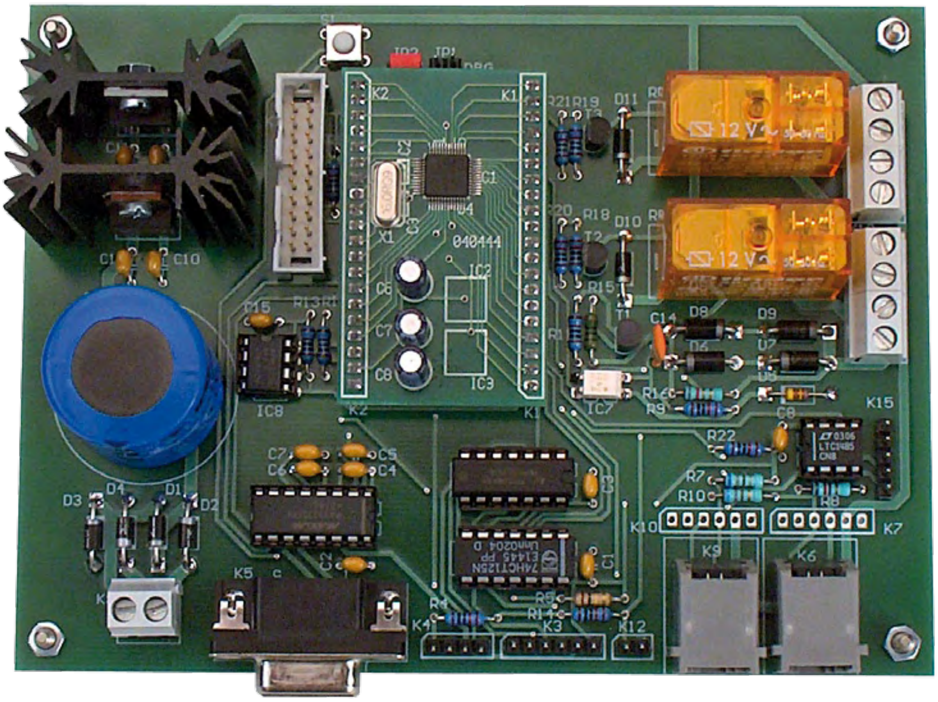


Figure 4. Fully assembled prototype with the ARMee module installed.

Control software

Various programs are available for using the Command Station described here with a PC to control a model railway system. There is a very nice 'native Dutch' program available called 'Koploper', which is entirely free (www.pahasoft.nl). It is supported by an active forum where users can find answers to their questions (www.koploperforum.nl). We're sure these users won't mind the odd question in English.

You can use the 'PT' program (also a Dutch product) to program DCC decoders. This program also provides extensive functions for testing feedback detectors and accessory decoders. You'll find it at http://people.zeelandnet.nl/rosoft.

You can also use ADaPT (Advanced Driving and Programming Tool) from STP Software (www.stp-software.at) to program decoders. Although this software (available in English and German versions) is not free, it can also be used for locomotive management.

Of course, you can also take on the challenge of writing your own software. A sample program for Microsoft Visual Studio Express 2008 is available and can be downloaded free of charge from the project page on the Elektor website.

Let us and other readers know how you get on — a simple message in the *Elektor* forum does the trick.

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Web Links

DCC: www.nmra.org/standards
XpressNET: www.lenz.com
P50x: www.uhlenbrock.com
Koploper: www.pahasoft.nl
PT: http://people.zeelandnet.nl/rosoft
NXP: www.nxp.com

About the author

After the completion of his studies in Telecommunication & Microprocessors, Patrick Smout has been actively involved in electronics product development (hardware and software) since 1985. In recent years his focus has moved away form hands-on engineering, and he is now the coordinator of the development department.

His first electronic construction projects included the Elektor Junior Computer and all of its subsequently published extensions. These were complemented by DIY extensions, such as a graphics card.

His hobbies are model trains and (naturally) electronics and embedded software.

According to Patrick, the nicest thing about this profession is seeing how a design slowly comes to life, right from the incipient stage, and then watching it travel around the world as a full-fledged product.

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Luxury LED Bicycle

Brighten your beam and banish burnt-out bulb blues

Dr Thomas Scherer

Having treated himself to a new bicycle fitted out with all mod cons including a shiny hub dynamo, the author was looking forward to many miles of pedalling pleasure. But then disaster struck: after just a couple of hours use the bulb in the front light burned out! Not finding the prospect of repeated replacement attractive, he set out to substitute a power LED for the bulb.

It is not in an engineer's nature to be satisfied with a simple solution, such as replacing the bulb.

It is much more satisfactory to understand the problem properly from the ground up, and of course a problem like this can be viewed as an opportunity for a good rummage in the junk box to look for components that might be useful in devising a proper solution.

Tuning up

It often saves considerable effort to spend a few moments with Google before trying to solve a problem for oneself. The author found that the properties of hub dynamos had already been investigated in great depth by others, such as at [1].
However, the Internet is not a complete substitute for a proper fault diagnosis. **Figure 1** shows that on the author's lighting set a semiconductor device is wired across the bulb. The type P6KE7.5CA 'transient voltage suppressor' [2] is in effect two Zener diodes back-to-back, designed to clamp excess voltages. From the information in [1] it became clear what had happened. A hub dynamo, even at normal speeds, develops more than the specified 6 V. The suppres-

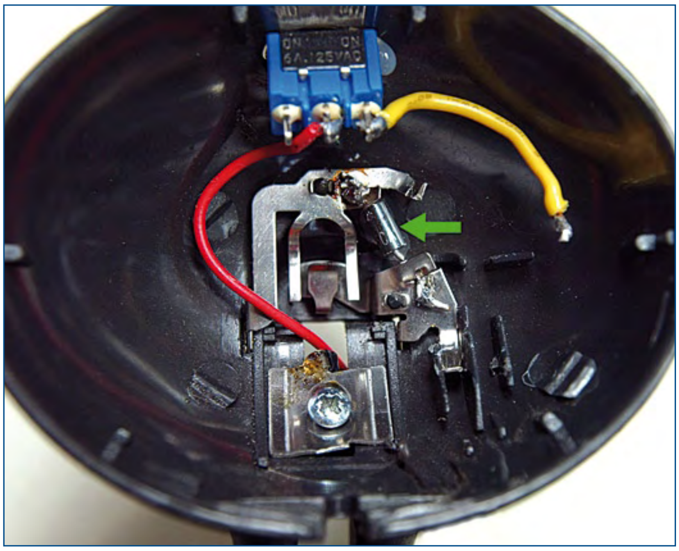


Figure 1. A suppression diode is wired in parallel with the filament lamp in the front bicycle light.

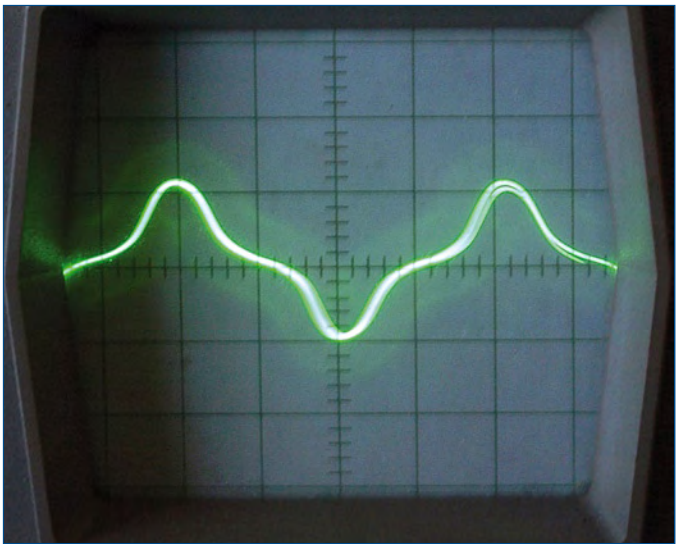


Figure 2. The voltage waveform from a hub dynamo is far from sinusoidal.

Light

sor, which is supposed to protect the bulb, is specified for a dissipation of 5 W, and begins to conduct at 6.5 V. At 0.5 A the voltage across the device will be about 7.5 V. (The dynamo can be thought of as a current source; without the suppressor a voltage of between 8 V and 10 V would appear across the bulb.) Even 7.5 V was, in the author's case, enough to destroy the bulb. Furthermore, the plot of dynamo output voltage against time (see **Figure 2**) is far from sinusoidal. An enquiry at a nearby shop confirmed the author's hunch that he was not alone in his experience: 6 V bulbs were strong sellers.

It was interesting to note that the rear light, which used LEDs, had not failed. LEDs with a series current limit resistor dissipate a power that increases linearly with applied voltage rather than exponentially, and so are more resilient to excessive voltages than bulbs.

Overture

The author had previously experimented with white power LEDs for bicycle lighting. At that time only 1 W devices were available, and, when used with a rim dynamo, the LED was not bright enough. Despite its higher efficiency the 1 W LED was not as bright as a 2.4 W filament bulb, although the whiter light was distinctly more noticeable and lifetime was of course better.

Act I: Power LED

Since then, 3 W LEDs have become available with efficiencies of over 110 lm/W, which is better than fluorescent lamps: a good start. A simple circuit using a 3 W LED is shown in **Figure 3**. The circuit achieves just slightly greater brightness than a halogen bulb. The current sourced by a hub dynamo is rarely much more than 0.5 A, and so a typical 3 W LED with a forward voltage of 3.3 V will be dissipating only around 1.6 W. However, the high efficiency of the device means that its light output is nevertheless greater than that of a 2.4 W halogen bulb.

Entr'acte

For maximum brightness the 6 V output of the dynamo needs to be converted down to 3.3 V to 3.8 V for the

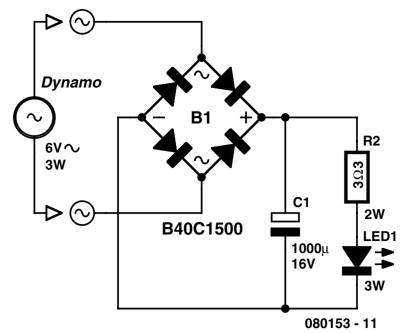


Figure 3. The first experimental circuit for using a 3 W LED in a bicycle light.

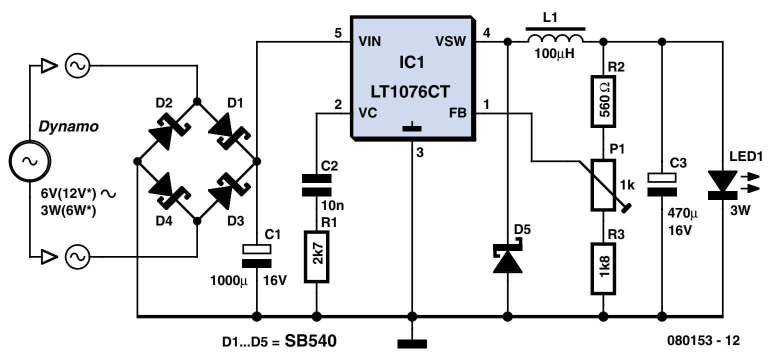


Figure 4. This final circuit for the bicycle light gets the maximum possible illumination from the 3 W LED.

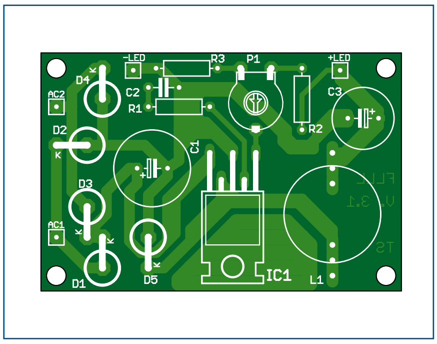


Figure 5. Eagle design files for the printed circuit board are available for download.

COMPONENTS LIST

Resistors
R1 = 2kΩ7
R2 = 560Ω
R3 = 1kΩ8
P1 = 1kΩ preset, miniature, horizontal mounting

Capacitors
C1 = 1000µF 35V, radial, lead pitch 5mm
C2 = 10nF
C3 = 470µF 16V, radial, lead pitch 5mm

Semiconductors
D1-D5 = SB540 (Schottky)*
LED1 = 3W power LED, white*

Miscellaneous
L1 = 100µH 1A (e.g. Reichelt L-PISR 100µ)*
Optics for power LED (20°- type)*
PCB # 080153-1 (artwork download on www.elektor.com)

* see text

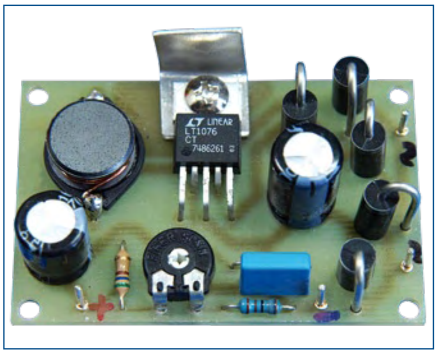


Figure 6. Very compact prototype of the switching regulator.

LED with as little power loss as possible, with a corresponding increase in current to 700 mA.

At such low voltages an ordinary step-down converter will operate at an efficiency of around 80 %. Rectifying the AC voltage from the dynamo using a bridge consisting of Schottky diodes will cost a voltage drop of twice 0.4 V, giving an additional power loss of 0.4 W at 0.5 A. Allowing 0.1 W for the rear LED light leaves us with just 2.5 W; 80 % of that is 2 W. Compared to the circuit in **Figure 3** we have gained a meagre 0.4 W.

So, theoretically at least, things are not looking good. However, according to [1] hub dynamos can develop up to 12 V. At 0.5 A that corresponds to a power of 6 W.

This is more than enough: working backwards from the 3 W required for the LED, we divide by 80 % to obtain an input power to the switching regulator of 3.6 W. At 0.5 A this means a voltage of 7.2 V. Adding on the 0.8 V dropped by a Schottky rectifier bridge, and we need 8 V at the output of the dynamo, which is well within its capabilities.

The switching regulator gives us a further advantage: it protects the LED from excessive current and, above a certain dynamo speed, ensures that the light output provided is constant.

Figure 7. The LED (mounted on its carrier board) and lens are bolted to a piece of aluminium angle to make the lighting module.

Act II: The circuit

Figure 4 shows a type LT1076 step-down converter [3]. The device requires a minimal number of external components and draws only 8.5 mA to power its internal circuitry. It operates at 100 kHz, can start up from an input voltage of 3.5 V and can deliver up to 2 A.

D1 to D4 form the bridge rectifier, and D5 is the flyback diode. At 5 A the SB540 is somewhat overspecified for this application; at 0.5 A the diode only drops 0.33 V. Good 1 A Schottky diodes such as the SB140 can be substituted for D1 to D5, with a resulting drop in overall efficiency of around 2 %.

The RC network comprising R1 and C2 connected to pin 2 of IC1 provides frequency compensation. The regulator compares the voltage on pin 1 with its internal reference (2.21 V), and so the adjustable voltage divider comprising R2, P1 and R3 allows the output voltage to be adjusted from 2.7 V to 4 V.

L1 is a fixed 100 µH inductor designed for operation at 100 kHz and 1 A. A low ohmic resistance increases overall efficiency. However, the component is not particularly critical, and even a 100 µH toroidal suppression choke will give an efficiency of over 75 %.

Act III: Construction and test

The printed circuit board (**Figure 5**) makes construction straightforward. The layout design was done using Eagle, and the design files and a PDF of the layout are available for download from http://www.elektor.com. If IC1 is to be mounted flat against the board its pins must be bent accurately. A small heatsink made from a piece of aluminium angle (**Figure 6**) is adequate. IC1 dissipates a maximum of 0.5 W, so it is also possible to solder the M3 fixing nut to the copper pad on the reverse side of the board.

The coil suggested in the parts list is a low-cost SMD component to which two lengths of wire need to be carefully soldered. The printed circuit board also has pads for other package varieties.

After populating the board and checking over the soldering, the circuit can

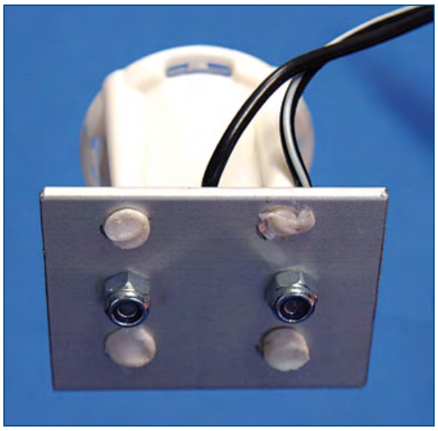


Figure 8. The module from behind: the four plastic lugs of the lens are melted slightly to secure them and the LED is isolated using plastic washers and fixed using M3 locknuts.

be connected to a bench supply or mains adaptor capable of delivering 9 V to 12 V at 0.5 A or more. The output is loaded using a 4 W 4.7 Ω resistor. It should be possible to adjust the output voltage over the range given above and IC1 should become gently warm to the touch. With 10 V at the input and 3.75 V across the 4.7 Ω resistor the overall efficiency of the circuit should be about 75 %: 4 W in and 3 W out.

Before turning the circuit off, adjust P1 to obtain the minimum output voltage so that when the LED is connected it is not immediately overloaded when the circuit is switched back on.

Before wiring up the power LED it, and the printed circuit board on which it is mounted, should be bolted to a length of aluminium angle (not forgetting a dash of thermally conductive paste). It is best if the lens is also fixed to the aluminium angle. This makes a compact lamp module (see **Figure 7** and **Figure 8**) which has the advantage of not immediately damaging your retina if you look directly into it. The module can be built into the old bicycle lamp enclosure with the filament bulb and suppressor removed. **Figure 9** shows the author's prototype where, with a judicious bit of filing, he managed to attach the module to the inside of the original lens in the lamp. The electronics can be mounted in a separate plastic enclosure.

Never look directly into a power LED when it is on!

Finale: Adjustment

As explained in the text box, the voltage across the power LED needs to be adjusted so that the correct current (approximately 0.7 A) flows through it. For maximum LED lifetime (over 20,000 hours) it is essential that this value is not exceeded. With adequate cooling, however, some devices can be run at up to 1 A.

The adjustment is straightforward. If we try to measure the current directly by putting a meter in series with the LED the resistance of the meter will significantly affect accuracy, and so instead we connect the LED module directly to the output and measure the input current. Starting at the bottom of the adjustment range (P1 set to the far left position) we gradually adjust it until the input current is 0.4 A at 10 V, for a total input power of 4 W. Since the overall efficiency of the circuit is approximately 75 %, this means that the power delivered to the LED is approximately 3 watts. If a 12 V input, for example from a mains adaptor, is used the corresponding input current is 0.33 A. The forward voltage of the LED falls with increasing temperature, and so the current though it will rise. P1 will therefore need to be adjusted several times until, after perhaps five minutes, thermal equilibrium is reached. The adjustment is then complete.

Warning: never look directly into the LED. The LED also gets hot!

Encore!

At low road speeds a hub dynamo delivers a low frequency AC voltage. At 5 km/h the LED blinks, becoming steady as the speed rises to 10 km/h. The circuit has not been tested with rim or other types of dynamo.
With a bit more pedalling effort (at speeds of over 30 km/h) the voltage from the dynamo, without suppressor diode, can reach 12 V. This will not cause any problems for the LED, which is protected by the circuit; however, if an ordinary 6 V 0.6 W filament bulb is used in the rear light it will soon be destroyed. It is therefore recommended to use an off the shelf LED-based rear light as well.

The attitude of the governments of some European countries towards our efforts to equip our bicycles with bright and reliable lamps is hardly what one might call 'enlightened': in the author's home country the law specifies the use of filament bulbs in bicycle lights, notwithstanding the fact that a brightly-shining home-made light is a definite improvement on an off-the-shelf regulation-compliant light, and much better again than an ordinary light with a blown filament!

(080153)

Links and References

[1] Hub dynamo laboratory test:
www.vintagebicyclepress.com/VBQgenerator.pdf

[2] P6KE7.5CA data sheet:
www.fairchildsemi.com/ds/P6%2FP6KE7V5CA.pdf

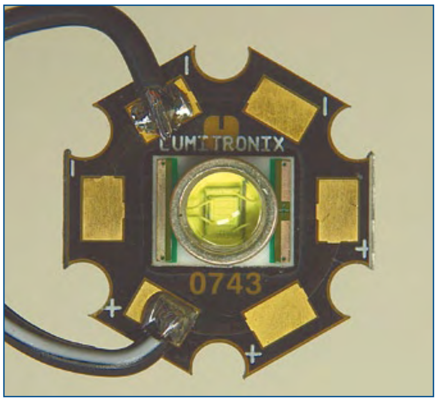
[3] LT1076 data sheet:
www.linear.com/pc/downloadDocument.do?navId=H0,C1,C1003,C1042,C1033,P1007,D2659

Light show

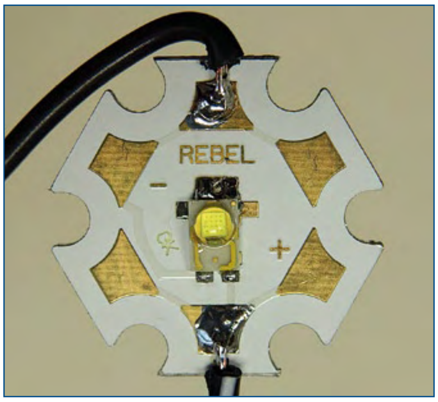
The power LED is the most important component in this circuit. The photographs show sample devices from three manufacturers, all offering efficiencies of between 90 lm/W and 110 lm/W, around the same as a good fluorescent light. Cheaper, but decidedly inferior, 3 W LEDs are also available on the market, but purchasing these is a false economy. It is also best to avoid the 'warm white' variants, which have lower efficiency. The devices shown come mounted on a small printed circuit board which includes an aluminium slug that simplifies extracting heat. When run at 3 W some 2 W is dissipated as heat and a power LED not equipped with cooling will have rather a short life.

There are good reasons for operating LEDs at a constant current rather than at a constant voltage. A typical differential resistance for an LED of the kind used in this project might be as low as 0.2 Ω, which means that a voltage step of 20 mV gives rise to a current step of 0.1 A. Now, 20 mV is not a large quantity, and the sharp temperature dependence of the LED's forward voltage means that a temperature change of 10 °C could easily lead to a current change of more than 0.1 A.

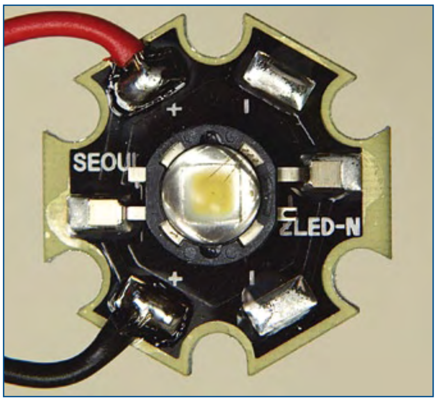
Unfortunately most switching regulator ICs are designed for constant voltage rather than constant current operation. The internal reference voltage of the IC used here is 2.21 V, which is too large to allow the construction of a simple current feedback loop using a series sense resistor: at 0.75 A the power dissipated in the sense resistor would be in the region of 1.6 W. We therefore must resort to controlling the current via the output voltage of the regulator, adjusted via P1 to suit the particular LED used. This is sufficiently accurate if the differential resistance is around 0.2 Ω.



This 3 W power LED from Cree is also an attractive piece of electronics in its own right.

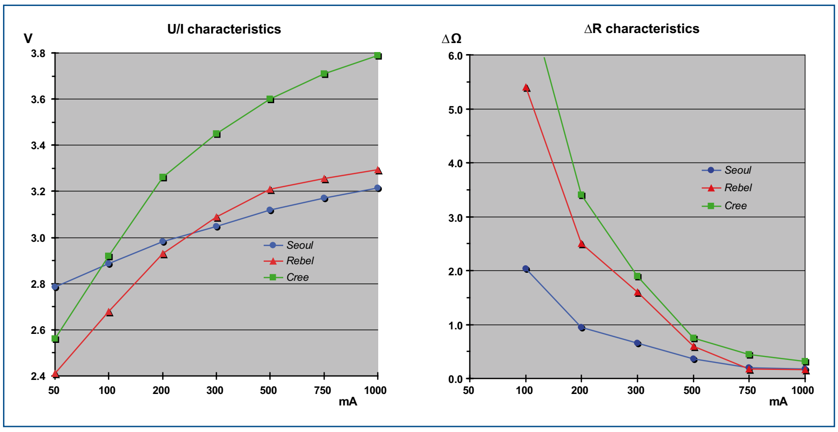


The Luxeon Rebel is particularly small and is mounted on a ceramic substrate.



The Seoul Z-LED is encapsulated not in hard plastic but in a silicone resin which offers long-term resistance to dulling.

In order to examine the differences between the various makes of LED, we made some measurements on a sample of each. The resulting characteristic curves are shown here. It is clear that the forward voltages are very different from one another and that the differential resistance of the LED is very low at currents of around 0.75 A. The consequences of this are as follows.



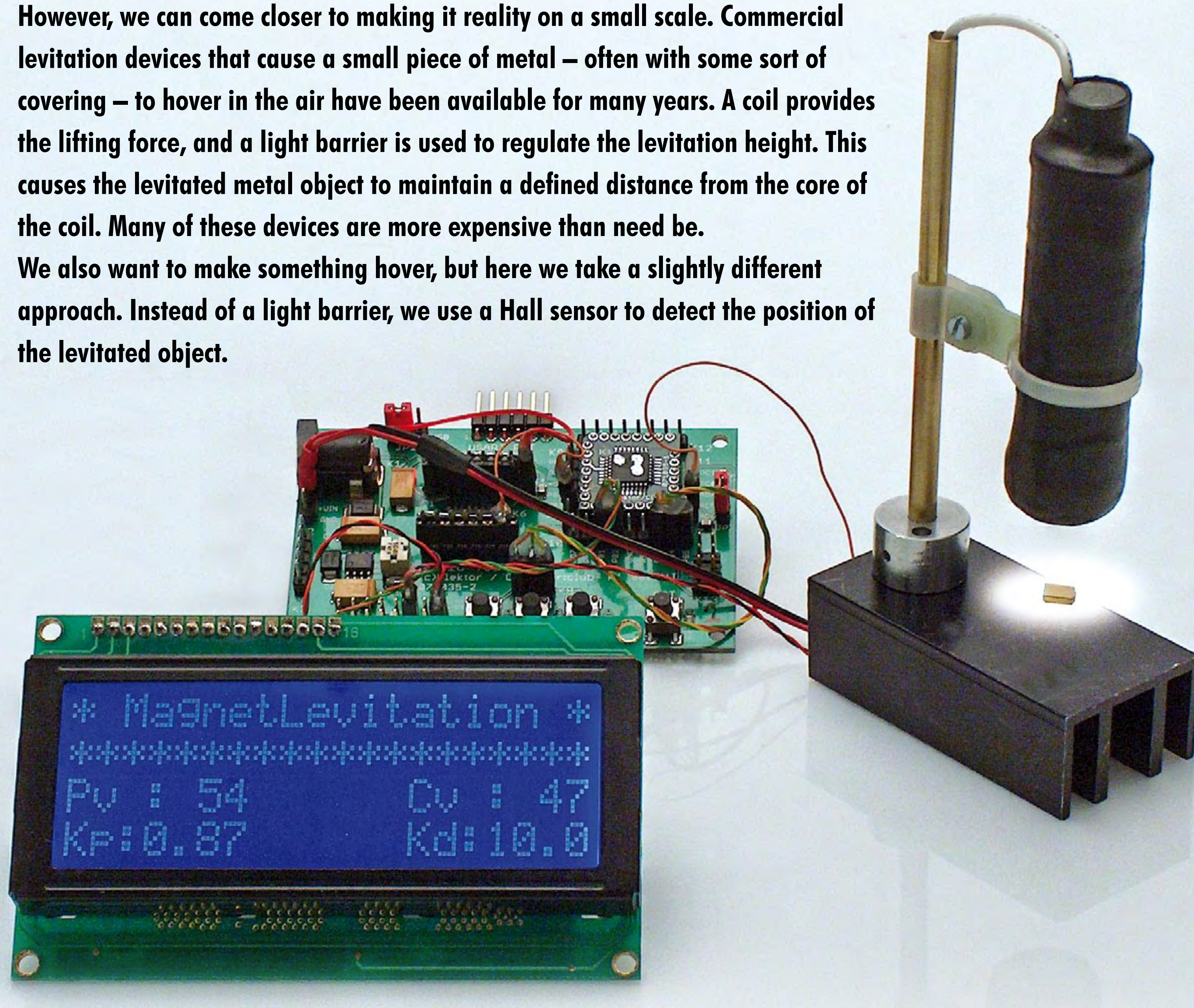
LED characteristic curves: voltage (left) and differential resistance (right) at various currents.

Light as Air

Using the ATM18 to control a magnet levitation device

Udo Jürß and Wolfgang Rudolph

Overcoming gravity is an age-old dream, which we can't expect to see fulfilled anytime soon. However, we can come closer to making it reality on a small scale. Commercial levitation devices that cause a small piece of metal – often with some sort of covering – to hover in the air have been available for many years. A coil provides the lifting force, and a light barrier is used to regulate the levitation height. This causes the levitated metal object to maintain a defined distance from the core of the coil. Many of these devices are more expensive than need be.
We also want to make something hover, but here we take a slightly different approach. Instead of a light barrier, we use a Hall sensor to detect the position of the levitated object.



With the usual levitation devices, which have already been described in DIY articles in past issues of *Elektor*, the beam of a light barrier is more or less obstructed by the 'floating' object. The amount of light received by the sensor of the light barrier is used to control the amount of current flowing through the coil. The mechanical and electronic construction of the device is designed to maintain the levitated metal object in the prescribed position. Distance control using a Hall sensor is based on a completely different principle.

Magnetic field sensor

A Hall sensor is a semiconductor device that generates a voltage proportional to the strength of the surrounding magnetic field. The voltage produced by the actual sensor element is very small (in the millivolt region), so a sophisticated bridge amplifier is also necessary. We use a Micronas HAL815 integrated magnetic sensor housed in a low-profile TO-92UT package in our levitation controller, so this is already taken care of. The amplifier, temperature compensation and a filter are incorporated in the IC (**Figure 1**). All of the parameters can be programmed by superimposing digital signals on the supply voltage (with pulses that increase the voltage from 5 V to 8 V). For instance, the measuring range can be adjusted from ±30 mT to ±150 mT. Programming is not necessary in this case, because the device is factory-configured for the ±30 mT range – which is exactly right for this application. With a supply voltage of 5 V, the output voltage is 2.5 V with no magnetic field present. The output voltage varies by plus or minus 2.5 V depending on the direction and strength of the magnetic field, for a total range of approximately 0 to 5 V. Only one direction is needed in this application, so only the range between 2.5 V and 5 V is used.

The ATM18 project on Computer:club²

aTM18 was developed jointly by Elektor and Computer:club² (*www.cczwei.de*) with contributions from Udo Jürss, the main developer of *www.microdrones.de*.

Each month, the latest developments and applications of the ATM18 system are presented by Wolfgang Rudolph of CC²-TV in a TV broadcast on the German NRW-TV network. The levitation controller with the ATM18-AVR board described in this article can be seen in ***instalment 12*** of CC²-tv, initially broadcast on 26 June.

CC²-TV is also broadcast as a Livestream on the Internet at *www.nrw.tv/home/cc2*.

CC²-TV Podcasts are available from *www.cczwei.de* and — a few days later — from sevenload.de

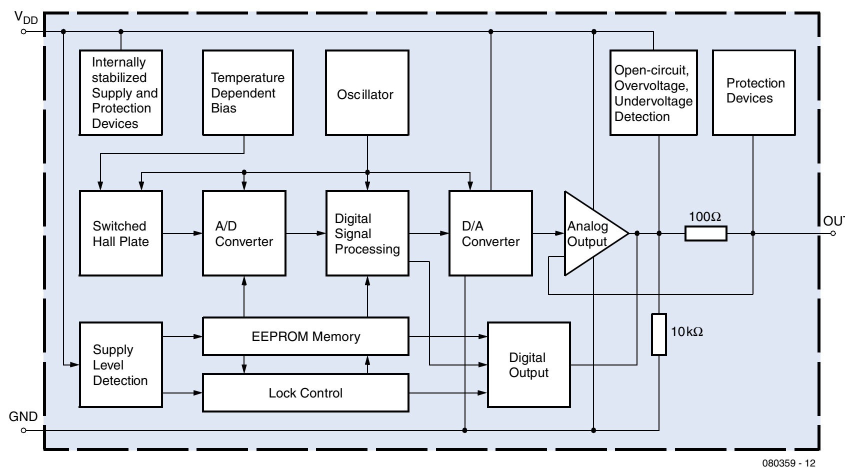


Figure 1. Block diagram of the sensor.

Hall effect

The American physicist Edwin Herbert Hall discovered this effect, which was later named after him, during his doctoral work in 1879. The Hall effect is based on the Lorenz force. Moving charges are deflected in a magnetic field, and this produces a potential difference perpendicular to the direction of current flow.

Hall sensors are made from small, thin sheets of semiconductor material with a low charge carrier density in order to achieve high electron velocity. This results in a relatively high output voltage. If a current flows through the sensor and it is placed in a magnetic field with the field lines perpendicular to the surface of the semiconductor, the sensor voltage changes. The output voltage of the sensor is proportional to the product of the current and the magnetic field strength. As the value of the current is known, the magnetic field strength can be determined from the measured voltage. These sensors are usually integrated in a package with a signal amplifier. The thermal sensitivity of the sensor is also compensated in such devices.

Controller

If we bring a magnet close to the Hall sensor with the magnetic field lines perpendicular to the surface of the sensor, the output voltage of the sensor varies in proportion to the magnetic field strength. This makes it possible to determine the distance between the sensor and a magnet with a known field strength. With this information, a controller can adjust the current in the coil to keep the magnet 'floating' in the air. The current is adjusted around 1000 times per second. This continual adjustment requires certain rules. PID controllers (proportional, integral and differential – see the inset) are used in electronic systems for this purpose.
In our case the 'I' component is not necessary, so we can use a PD controller. However, it is not implemented as an analogue circuit with opamps for this ATM18 project, but instead with software in the form of a controller program. Every minute departure of the levitated magnet from its intended position, every air movement, every change in temperature, every vibration, and many other things can directly affect the levitated behaviour.
If the magnet moves a bit closer to the solenoid coil, the current in the coil must be reduced immediately. If the

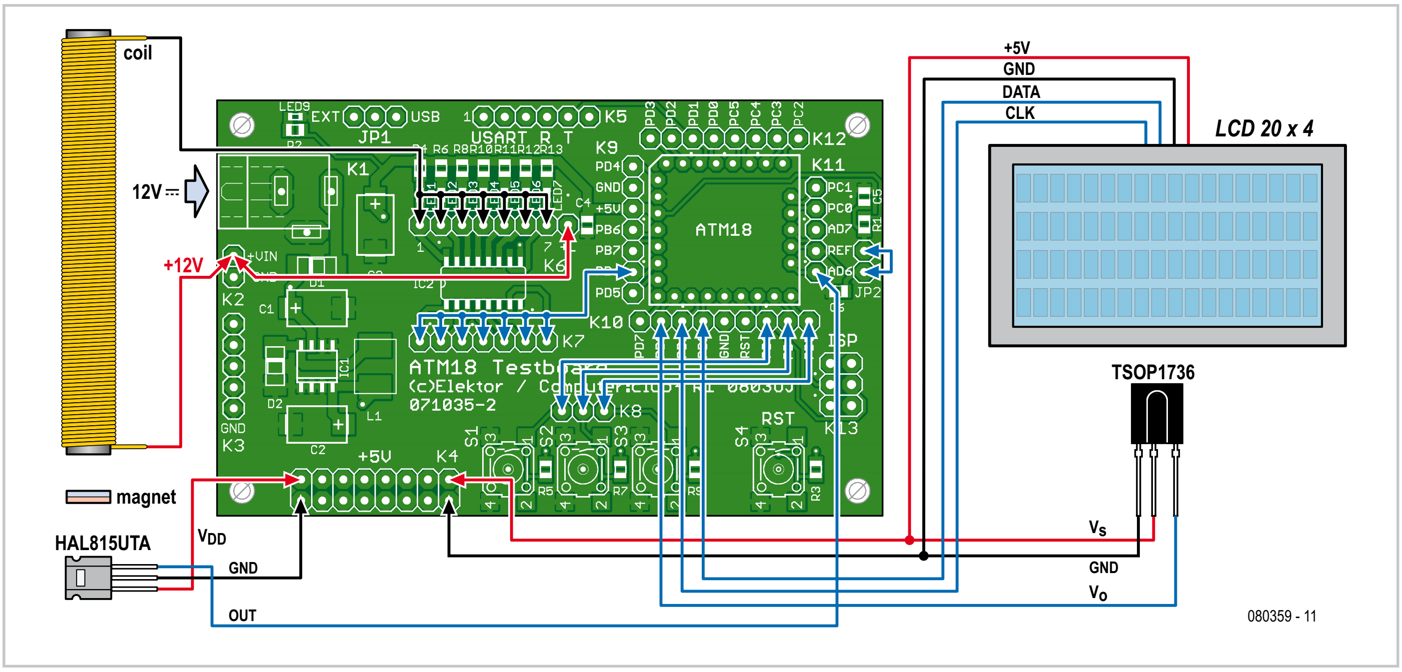


Figure 2. Schematic diagram of the experimental circuit

magnet moves even a small distance away from the coil, the current must be increased immediately. As the coil is connected to the PWM (pulse-width modulated) output of the microcontroller via a UL2003, this is done by changing the duty cycle. The pulses are integrated in the ferrite core and coil to yield an average current level.

Figure 2 shows the structure of our prototype. The Hall sensor is connected to ADC6. The PWM output on PD6 drives one or more inputs of the ULN2003 power stage. The coil is connected between the open-collector outputs and +12 V. It is important to connect pin 8 to K6 so the internal protection diodes in the ULN2003 can limit the inductive spikes from the coil. Pushbutton switches S1–S3 are used to configure the control parameters. This lets you raise or lower the levitation position of the magnet by up to 10 mm. Alternatively, you can use an RC5 infrared remote control unit to operate the device via an IR receiver connected to the circuit. The parameters are constantly shown on the LCD display.

General requirements

Making a magnet hover in the air is not a trivial task. If it comes too close to the coil, it will immediately be pulled all the way to the coil, and the controller can't do anything to stop it. This means that the coil must be mounted at a sufficient height. On the other hand, the magnetic field of the fully energised coil must be strong enough to lift the magnet from its lowest position. This means that you have to wind the right coil on the right core and use a magnet that is as small and light as possible, but also strong. And you have to adjust the device for a suitable levitated distance.

Another difficulty is that the output voltage of the sensor is not proportional to the distance between the coil and the magnet. Nonlinear controlled systems can lead to stability problems. On top of this, the magnetic field of the lifting coil also affects the sensor. The severe requirements imposed by the controlled system make the job of the controller more difficult. Here a bit of help in the form of damping can't hurt. It arises in a rather unobvious manner due to the aluminium heat sink, under which the sensor is mounted. Every motion of the magnet creates an eddy current in the aluminium, and this produces an opposing magnetic field. In this way, magnet oscillations are damped by eddy-current losses.

Magnet and coil

The magnet must be very light and very strong. A neodymium magnet with a mass of less than 0.3 g is quite suitable. We used a type Q-CDM50-G from www.supermagnete.de (mass 0.23 g) in our various prototypes. Another potential source of small, strong magnets is cannibalised CD drives. A preliminary test with the solenoid coil will tell you whether a particular magnet is suitable. With an applied voltage of 12 V, the coil should be able to lift the magnet from a height of at least 3 cm, but 4 cm or more is better.

A ferrite rod such as is commonly found in medium-wave radios is used for the coil. It should have a diameter of 10 mm and a length of 80 to 100 mm. Don't try to rush things when constructing the coil. As you can see from **Figure 3**, you start by sliding a length of heat-shrink tubing over the ferrite rod (**a**) and shrinking it in place (**b**). You can also use electrician's tape instead. After this, you can start winding the coil (**c**). It consists of four layers of 400 turns each, wound with 0.2-mm enamelled copper wire. You can wind the coil entirely by hand, or you can use an electric drill running at a very low speed (**d**). After you finish winding the coil, secure both ends with heat-shrink tubing (**e**), making sure to feed out the free ends for the leads (**f**). Finally, you can fit another length of heat-shrink tubing over the entire coil to protect it (**g**).

If you want to avoid counting turns and would rather wind the coil 'helter-skelter', you can wind the ferrite rod over a length of 50 mm with 0.2-mm copper wire until the winding reaches a diameter of 18 mm. The coil will then have a resistance of 40 to 50 Ω, so the

current will not exceed 300 mA with a 12-V supply voltage (this only holds true for DC current). When the coil is driven by the PWM output of the processor, amplified by the ULN2003, the current is pulsating DC instead of pure DC. The average value of the current is thus less, and the coil characteristic is similar to that with AC operation, with the result that a distinctly lower current flows through the coil.
This completes the coil. After you have carefully protected the leads and the ends of the coil with electrician's tape, you can simply use the alligator clips of a 'third hand' (soldering aid) to hold the coil for initial testing. This makes it easy to adjust the height to the proper value (**Figure 4**).

Practical aspects

Our prototype (see the photo at the head of the article) was built around an aluminium heat sink with the sensor mounted underneath. A brass rod was fitted to the heat sink, and the wiring that conducts the current to the coil was routed along this rod in a suitable manner. A plastic bracket was fitted to the rod, and the coil was clamped to the bracket. The details are shown in **Figures 5a–d**.

After the coil has been secured, you can connect everything to the prototyping board and start your levitation tests. Two ready-made sample programs are available on the Elektor website for downloading. One of then was written in Code Vision, and the other in BASCOM.

The best approach is to start with the C program, since it shows all the par-

PID controllers

Our objective here is to use an electromagnet to attract a permanent magnet exactly enough to levitate it at a particular height. As the magnet levitation system is an unstable, nonlinear controlled system, it must be stabilised as well as regulated. We use a PD controller for this purpose. The task of a closed-loop controller is to continually and independently control a physical quantity in order to maintain a specified setpoint value – in our case the magnet position – and eliminate the effects of disturbances. For this purpose, the controller constantly compares the actual value (the position of the magnet) with the setpoint value (the desired position of the magnet). The control error determined in this manner is used to generate the control output, which acts to minimise the control error when the control loop is in balance. However, it takes a certain amount of time for a system of this sort to respond and for the control output to take effect, and for this reason it must overreact at first and then underreact immediately afterward in order to avoid overcompensation that would cause control failure. This requires the control output to have a damping effect, depending on the system characteristics. The behaviour of the controller is described by differential equations.

The magnitude of the P component varies in proportion to the control error (difference between the actual value and the setpoint value). This only affects the proportional gain factor.

The D branch of a controller is a differentiator that must always act together with the P component (or the I component). The D component arises from variations in the control error over time and is multiplied by the integral action time. It does not depend on the control error, but instead on the rate of change. A large integral action time cause a large change in the control output and often causes instability in the control loop.

An integral component is used when the control error must reduced to zero (or as close to zero as possible). It is not used here because the levitation device always works with a control error and only the control gain is adjusted. The slope of the control curve decreases as the distance from the sensor increases, which is offset by increased gain. This compensates for the nonlinear characteristic of the controlled system.

Listing

Example BASCOM PD controller

```
' Atm18 PD regulator
' S1 At Pb3 = Up
' S2 At Pb4 = Down

$regfile = „m88def.dat"
$crystal = 16000000

Dim N As Byte
Dim X As Integer
Dim Y As Single
Dim Z As Single
Dim Xold As Single
Dim Xp As Single
Dim Xi As Single
Dim Xd As Single
Dim P As Single
Dim I As Single
Dim D As Single

Config Adc = Single , Presca-
   ler = 32 , Reference = Off
   ' AD-Wandler starten
Start Adc
Config Timer0 = Pwm , Presca-
   le = 1 , Compare A Pwm =
    Clear Down , Compare B Pwm = Clear Down

P = 0.1
D = 60

Do
 If Pinb.3 = 0 Then P = P + 0.0002
 If Pinb.4 = 0 Then P = P - 0.0002
 X = 0
 For N = 1 To 8
     X = X + Getadc(6)
 Next X
 X = X / 8

 If X < 512 Then X = 512
 Xp = X - 512
 Xp = Xp * P

 Xd = X - Xold
 Xold = X
 Xd = Xd * D

 Y = Xp + Xd
 Y = Y / 2
 If Y > 255 Then Y = 255
 If Y < 0 Then Y = 0

 Pwm0a = Int(y)
Loop
```

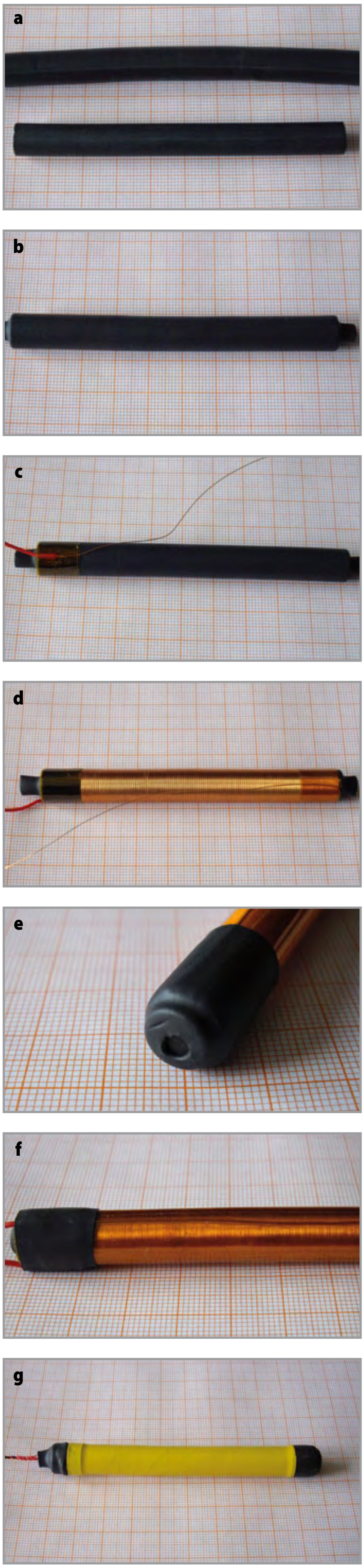


Figure 3. Coil construction stages: ferrite rod with heat-shrink tubing (a) shrunk onto the ferrite rod (b); start of coil winding (c); fully wound coil (d); coil ends covered with heat-shrink tubing (e) and with the leads fed out (f); finished coil covered with heat-shrink tubing (g).

ameters on the display. Right after you switch on the supply voltage or reset the circuit, no current flows through the coil because the proportional factor of the controller is zero. Place the magnet above the sensor, orient it to obtain a maximum reading for the displayed Pv value, and press button S1. This should cause the current to increase. You can also see this from the increasing brightness of the LEDs on the outputs. If nothing happens, the magnet is probably the wrong way round. Turn it over and repeat the experiment.

The longer you press S1, the more the coil current will increase. Suddenly the magnet will start to rise and then remain suspended in a stable position. You can press S1 to make it rise even higher. If you press S1 and S2 at the same time, it will drop gradually. At some point, you will doubtless overdo the levitation height and the magnet will fly up to the ferrite rod with a bang. Now you know the maximum levitation height. You can probably increase the levitation height slightly by carefully adjusting the position of the solenoid coil. The coil should be just high enough that it can still lift the magnet from the surface of the heat sink.. S1 adjusts the proportional factor of the controller, which effectively means the control gain. You can also use S3 to alter the proportion of the differential component, which is important for stability. However, in most cases the default value is suitable.

If the magnet refuses to lift, the direction of the magnetic fields may be to blame. Try reversing the polarity of the coil. You can also use a voltmeter to check the output voltage of the sensor. It should be close to 2.5 V with no magnet present, and the value with the magnet lying above the sensor should be more than 4 V. Some other possibilities are that the magnet is too weak or too heavy. However, this should have already been sorted out by the initial test without the controller.

MLC in C

The C program for the magnet levitation controller (MLC) is very large and can only be described here in general terms.

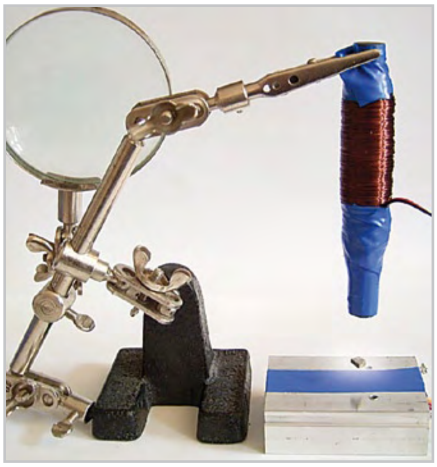


Figure 4. A simple experimental setup.

Hall sensor data acquisition and timing generator

The A/D converter is used to acquire the Hall sensor data and as a timing generator. Eight sensor readings are acquired in an interrupt routine within 1 millisecond. After this the 'adc_ready' flag is set. The main program loop uses this flag for synchronisation. The function 'adc_get_average()' calculates the average of the eight sensor readings, which forms the current actual value for the PD controller. This averaging suppresses noise on the measured signal.

Controller

The PD controller is recalculated 1000 times each second. Due to this constant time interval, the control algorithm does not have to calculate the time, which saves processing time. The average sensor value is first calculated in the function 'mlc_update'. The P component is calculated from this actual value. The D component is calculated as the difference between the previous and current actual values. The control output (the pulse width of the PWM signal) is formed by adding the two components.

Actuator

Here the actuator for the controlled system is the electromagnet in the form of a ferrite-core coil. A PWM signal with a pulse rate of 32 kHz drives the power stage (ULN2003). The coil is switched to ground. Thanks to the high PWM frequency and the large inductance of the coil, the coil current is strongly filtered (integrated). This yields a constant magnetic field with a low ripple component.

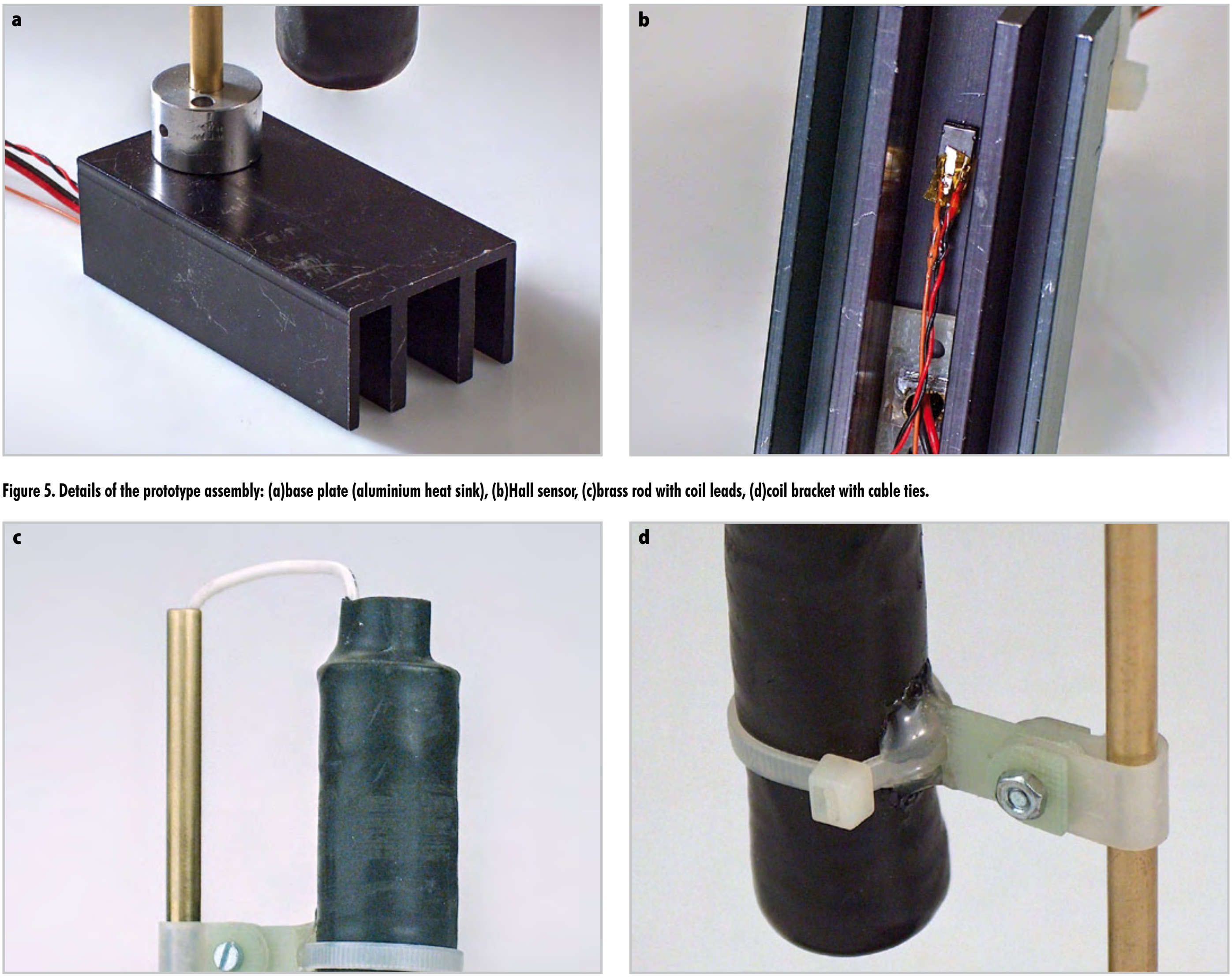


Figure 5. Details of the prototype assembly: (a)base plate (aluminium heat sink), (b)Hall sensor, (c)brass rod with coil leads, (d)coil bracket with cable ties.

Display output
To avoid reducing the control frequency as a result of time-consuming display outputs, the outputs are divided into many individual jobs. The function 'mlc_write_lcd()' uses a state machine to perform a single display output in each control cycle.

Control process
After the individual modules have been initialised, the same process is executed repeatedly in an endless loop:

1. Update the control loop:
   mlc_update(); // Update magnet levitation control
2. LC display output:
   mlc_write_lcd(); // Do a single LCD operation
3. Scan control parameter buttons:
   mlc_scan_buttons(); // Check the Kp and Kd pushbuttons
4. Synchronise with A/D converter:
   while (!adc_ready) // Synchronise the control loop
5. Start the next control cycle at step 1

RC5 control
With an IR receiver connected, you can use an RC5 infrared remote control unit to operate the device remotely. Button 1 increases the P value, while button 4 decreases it. Button 3 increases the D value, while button 6 decreases it. In addition, button 0 acts an emergency stop and causes the P value to be set to 0.

BASCOM example

The Basic program (see listing) has intentionally been kept simple, so it does not include the LCD and remote control functions. Only the P factor (and thus the effective levitation height) can be adjusted using the S1 and S2 buttons. When the program is started, P is assigned the value 0.1 to provide a certain amount of gain so you can place the magnet exactly above the sensor by positioning it to obtain maximum coil current.

The controller performs its calculations with real numbers (single precision). Here again the actual value is obtained by averaging eight individual readings. The controller can only use the range between 512 and 1023. The lower the magnet position, the higher the measured value. The measured value is multiplied by the P factor to yield the setting for the PWM value. The system would also work without a D component, but the motion is damped if this component is added. If the magnet rises quickly, the controller anticipates an imminent overshoot and reduces the current accordingly.

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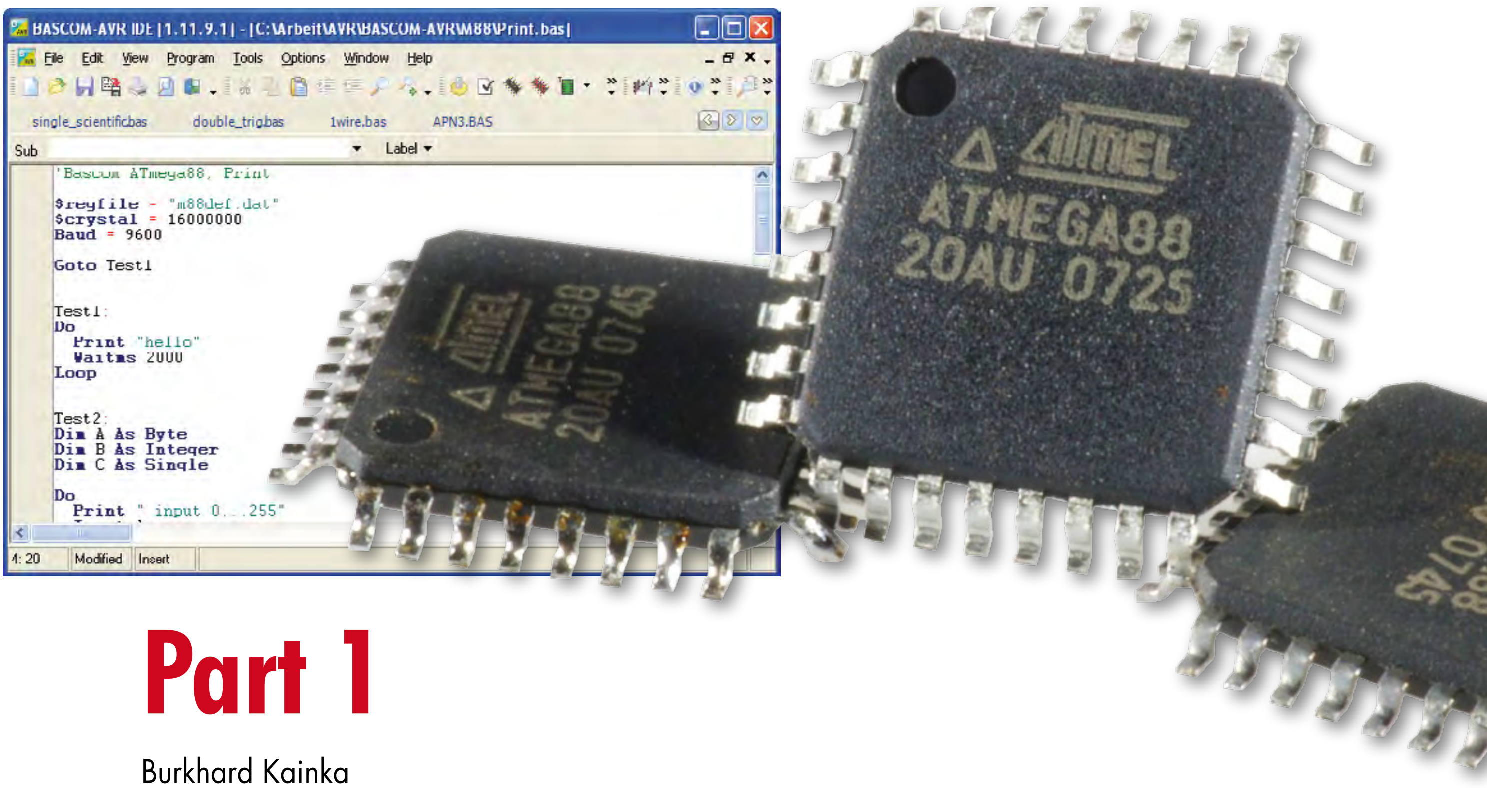
Assembly note

A parts kit with a ferrite rod, HAL815 and magnet is available from www.elektor.com.

BASCOM AVR Course

Programming the ATmega controller



Part 1

Burkhard Kainka

The AVR series of microcontrollers from Atmel are very popular. Many projects already featured in Elektor have an ATmega beating away at their heart. In this mini course we turn the spotlight onto software development for these controllers. BASCOM is an ideal programming language for the newcomer; it has a steep learning curve ensuring that your path to success (and a working prototype) is reassuringly short.

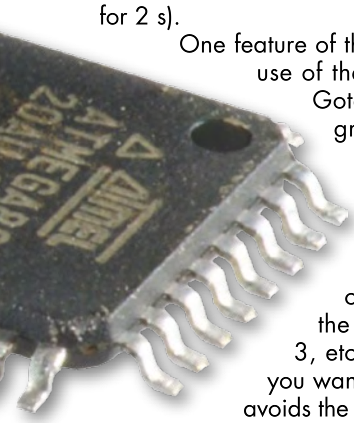
The ATmega controller and BASCOM together make a strong team! Whatever application you have in mind, controllers from the ATmega range are sure to have the majority of the necessary peripheral hardware already integrated on-board: ports, timer, A/D converter, PWM output, and UART are all standard together with a choice of RAM, ROM and EEPROM size. BASCOM is one of the easier languages to use and makes interfacing to peripherals using LCDs, RC5 and I²C a simple task requiring very few instructions. There is a good range of development hardware for this microcontroller family. The STK500 from Atmel or the Elektor CC² ATM18 AVR board [1] are both suitable platforms for this course. Alternatively there is no reason why you should not experiment with your own homebrew design built on a piece of perfboard. It also makes little difference whether you choose a Mega8, Mega88 or even the larger Mega16 or Mega32. They all basically have the same core; the main differences are in the number of port pins and the amount of internal memory space. In this first instalment of the course we look at the controller's UART and A/D converter.

The serial interface

All of the ATmega series have a built-in serial interface (UART) using pins RXD (PD0) and TXD (PD1). The signals are TTL compatible so it is necessary to add an RS232 interface buffer such as the MAX232 to implement a true

RS232 interface. These buffers are already implemented on the Atmel STK500 development system. A suitable serial to USB Adapter can be connected directly to the Elektor ATM18 AVR board for serial communication [2]. The PC will need to be running a terminal emulator program before serial communication from the ATmega can be viewed on the screen. The serial interface is covered here first because the software routine is very simple and can be easily modified if required.

Listing 1 shows all the elements necessary for all of the BASCOM programs. The first line $regfile = "m88def.dat" indicates which controller the code will be running on; in this case it is the ATmega88. The line can be omitted and the controller type specified using the Options/Compiler/Chip menu but this method will generate an error if a different AVR system is used. It is far better to declare the controller type clearly in the program header with any program that you write. It also has priority and overwrites any setting defined in the Options menu.
It is also important to specify the crystal frequency ($crystal = 16000000 for 16 MHz). It influences both the division ratio necessary to provide the requested communications baud rate clock (Baud = 9600) and also the timebase used to count milliseconds in the 'wait' statements (Waitms 2000 for 2 s).



One feature of the test program given here is the use of the unconditional jump instruction Goto Test1. It is normally good programming practice to avoid using Goto statements because they interrupt the program structure. In this instance we have included several programming examples in the same source code so it is only necessary to alter the first Goto Test1 to Goto Test2 or 3, etc. (depending on which example you want to run) and then recompile. This avoids the need to compile individual source files for each example and reduces the number of files generated in the compilation process. Additional test programs can simply be added to the code and run using an appropriate Goto statement.
The small program example used for Test1 forms an endless loop between the Do and Loop statements. The program outputs a 'hello' message every two seconds. A terminal emulator program like HyperTerminal is needed to receive the message.

Calculating

The program in **Listing 2** is used to calculate the area (C) of a circle where 'A' is the given radius:

$C = A^2 * 3.1415$

'A' must be an integer variable, which is dimensioned as a byte and input via the serial interface. The value of 'A' (in the range 0 to 255) is first multiplied by itself. The resultant intermediate value 'B' can be up to a word long (0 to 65535). The result 'C' is a real value and is dimensioned as single which requires four bytes to store its value.
Anyone familiar with other dialects of BASIC may be wondering why the calculation has not been written as C = 3.1415 *A *A or Print 3.1415*A*A.
The reason is that BASCOM only allows one calculation per expression so it is necessary to break down complex

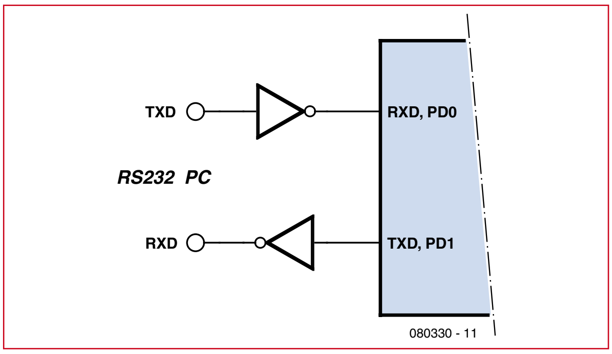


Figure 1.
The serial interface.

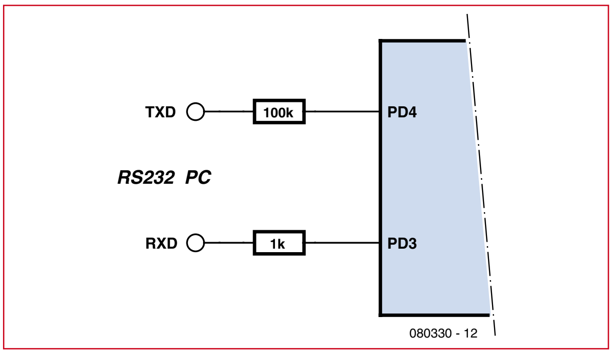


Figure 2.
The simplest serial interface without an inverter.

calculations into series of single steps to avoid violating this rule.

Procedures

The A/D converter in the ATmega has a 10-bit resolution. **Listing 3** shows an example of how the converter is initialised:

Config Adc = Single , Prescaler = 64 , Reference = Off.

The converter clock frequency is defined here as 1/64 of the processor clock, i.e. 250 kHz with a processor clock of

Listing 1

Print 'hello'

```
,Bascom ATmega88, Print
$regfile = „m88def.dat"
$crystal = 16000000
Baud = 9600

Goto Test1

Test1:
Do
  Print „hello"
  Waitms 2000
Loop

Test2:
…
Test3:
…
End
```

Listing 2

Calculating in BASCOM

```
Dim A As Byte
Dim B As Word
Dim C As Single

Do
  Print " input 0...255"
  Input A
  B = A * A
  C = B * 3.1415
  'not allowed: C = 3.1415 * A * A
  Print C
Loop
```

Listing 3

Using a procedure

```
Declare Sub Voltage
Dim N As Byte
Config Adc = Single , Presca-
   ler = 64 , Reference = Off
Start Adc

Do
  N = 0 : Voltage
  Print "ADC(0) = " ; U ; " V" "
  N = 1 : Voltage
  Print "ADC(1) = " ; U ; " V" "
  Print
  Waitms 500
Loop

Sub Voltage
  D = Getadc(n)
  D = D * 5
  U = D / 1023
End Sub
```

Listing 4

Using the Software UART

```
Baud = 9600
'Open "comd.3:9600,8,n,1" For Output As #2
Open "comd.3:9600,8,n,1,INVER
   TED" For Output As #2
Config Adc = Single , Presca-
   ler = 64 , Reference = Off

Do
  N = 0 : Voltage
  Print #2 , "ADC(0) = " ; U ; " V" "
  N = 1 : Voltage
  Print #2 , "ADC(1) = " ; U ; " V" "
  Print #2 ,
  Waitms 500
Loop
```

16 MHz. The internal reference voltage is not used but is derived externally and applied to pin AREF. In most cases the 5 V stabilised supply voltage can be used.
A procedure is used to input the ADC measurement and convert it to a voltage reading. It is only worthwhile using a procedure if it can be reused by different parts of the main program body. In this example two voltage measurements are displayed. The new procedure is called Sub Voltage. Before the procedure can be called it must first be declared: Declare Sub Voltage.

The program fragment shown here does not conform to good software writing practice. In Visual Basic it is usual to pass the channel parameter 'N' when the procedure is called: Voltage(N). Alternatively a function could be written and then called using: U = Voltage(N). In the example here we are using only global variables so that D, N and U are accessible from all parts of the program including other procedures. All of the accepted software guidelines indicate that this is not good programming practice but in this instance it simplifies the job for the compiler and controller. Experience has shown that even large programs occupying 100% of the flash memory of a Mega32 and using a large number of global variables are completely stable in operation and run without problem. Passing variables to procedures can sometimes generate errors which are quite difficult to trace.

The software serial interface

One of the many highlights of the BASCOM compiler is its software serial interface. Say you are already using the hardware serial interface with the RXD and TXD pins and you require another COM interface? Alternatively it could be that you do not have any RS232 interface inverter chip (e.g. a MAX232) on your board but still need to provide a connection for an RS232 cable. In both cases BASCOM has a solution to the problem. Any available port pins can be defined in software as serial interface pins for the software serial interface.
The example **Listing 4** uses PD3 as a serial output. Communication speed is set to 9600 Baud and the interface number 2. To output a simple message you can use Print #2, 'hello' for example.
Using the INVERTED parameter allows the interface to be built without the need for a MAX232 interface inverter. BASCOM inverts the signal so that inactive level is a logic Low. The PC interface RXD signal can then be connected directly. The signal levels are not truly RS232 but it provides a useable interface solution and can, for example, be used to interface a USB to serial adapter to the Elektor ATM18 AVR board without the need for a MAX232.

(080330-I)

References

[1] ATM18 AVR Board, *Elektor* April 2008.

[2] USB <-> RS-232 Cable, *Elektor* July/August 2008.

Downloads and further information

The programming examples and more information for this course can be downloaded from the project page at www.elektor.com.
We also welcome your feedback in the Elektor Forum.

Projection over Hundre

Laser projector with servos

Gert Baars

We've already covered a laser projector in an earlier instalment of this series. This time however, we use a different projection mechanism. With a few servos, a laser module from eBay, a microcontroller and a little dexterity we can make a laser projector which, depending on the laser, can be seen from several hundreds of metres.

Laser projectors are often used for light effects at, for example, places of entertainment. These generally use powerful laser beams which generate striking light patterns. These types of laser projectors are not cheap however and even the individual parts such as laser modules and fast servos are not really that attractive either, considering their price. The alternative then, naturally, is to make your own.

Laser diodes and modules

Through eBay and the like, laser pointers and modules are frequently on offer for less than 10 pounds. These are typically red lasers with a power of less than 5 mW. This is more than enough to project something indoors during the day and outdoors at night up to a distance of about 100 metres. More powerful lasers, such as green lasers rated at 30 mW, can be used outdoors during the day over hundreds of meters and at night over several kilometres. Using this type of laser is not recommended, in principle, because of safety considerations.

You can also use a single laser diode. But you will need a so-called collimator to obtain a parallel light beam.

Controller

The heart of the control system (see **Figure 1**) is an ATmega88 controller. Although it would be possible to drive the servos with a purely analogue system, from a music source for example, using a microcontroller offers additional possibilities such as the projection of text.

Analogue signals are required to drive the servos. We generate these with two PWM DACs (X-Servo and Y-Servo). The 78 kHz PWM frequency is strongly suppressed with a four-stage RC-filter. The two ADC inputs (X-in and Y-in) allow for analogue control, for use as a XYZ-plotter and an X-T oscilloscope. The Z-input (with internal pull-up) is used to turn the laser on and off. An RS232 interface is added so that an LCD and keyboard interface are not required.
The HyperTerminal program that is part of any standard Windows installation can be used to communicate with the projector. The correct port settings are 9600 baud, 8 bits, 1 stop bit, no parity and no flow control.

The schematic for the laser controller shows that the laser is driven with a constant current. R_i defines the laser current and the quiescent current can be set with P1. This is sometimes better because laser diodes start to work at a certain threshold current but only produce optimal light when operating at a certain temperature. By setting the idle current just under the threshold current the light output is increased when used as a projector.
On pin 6 of the controller there is also an output called 'TTL optional'. This is because some laser modules are supplied with a control PCB which has a

ds of Metres

ALWAYS BE VERY CAREFUL WHEN WORKING WITH LASER TYPES III-A AND III-B AND GREEN DPSS LASERS. LOOKING INTO THE BEAM CAN PERMANENTLY DAMAGE YOUR RETINA!

separate modulation input that can be driven directly.

Laser modules, such as the ones used in laser pointers, often have a photo diode which is used to control the laser current. These common modules are usually intended for 3 V battery operation. If you measure the current of the module at 3 V you can use this to determine what the value for Ri should be. In this case it is better if Ri is selected to be slightly smaller.

The servos

Making your own servos that are reasonably fast is not all that difficult. Servos targeted for the model-building world are not an option because they are too slow and inaccurate for this application. The servos for the laser projector can easily be made from a small DC motor that is often found in older CD/DVD drives. We refer here to the motor that opens and closes the tray, but sometimes a CD/DVD drive contains multiple motors of the same type.

To turn the DC motor into a servo an angle sensor is required. This angle sensor measures the rotation of the motor shaft. The result of this measurement is used to correct the position of the motor shaft. In a standard servo the angle sensor is generally a potentiometer which is connected to the motor shaft. This, however, creates a lot of friction and is not very accurate. The servos for the laser projector use a combination of a magnet and a Hall-effect sensor as the angle sensor. The magnet is an especially powerful Neodymium miniature magnet which measures only 2×2×2 mm.

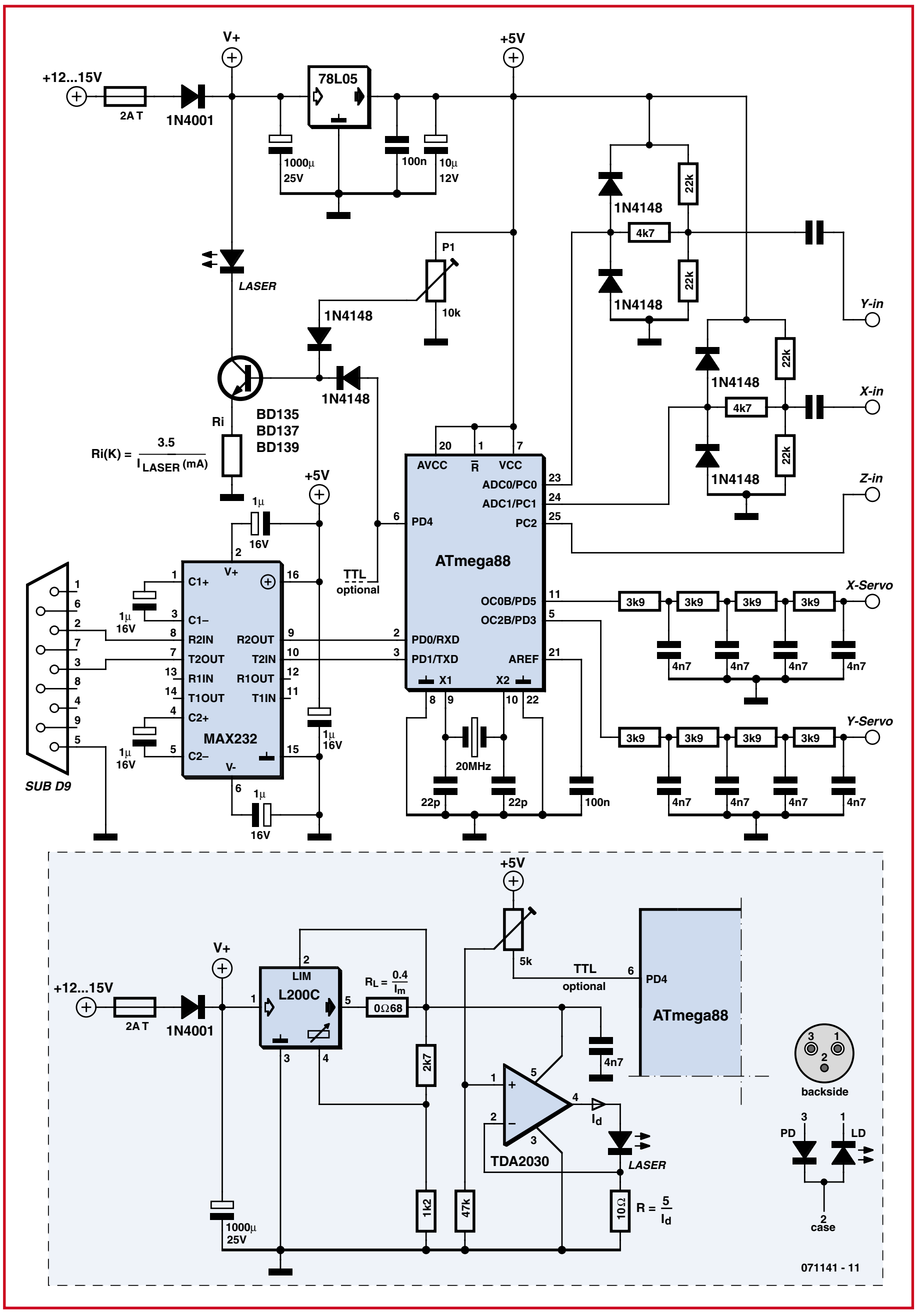


Figure 1. The schematic for the laser controller. The optional driver circuit can be used for larger lasers.

There are several possibilities for attaching the little magnet to the spindle. Here we used the clamp from a plastic terminal strip as the coupling (see Figure 2). These have an internal diameter of 2.2 mm while the motor shaft has a diameter of 2 mm. Not really ideal, but the clamp can be fixed in place with the screw and the little magnet is easily glued to it. When gluing the magnet you need to make sure that the north- or south-pole of the magnet does not face the shaft but is perpendicular to it. It is as if the side of the magnet is glued and not the end. Whether the North or South pole faces to the left or right does not matter. It is merely a case of reversing the motor wires to make everything right again. Finding the poles is not that hard. These are the sides where the magnet is most powerful. When two magnets grab each other the joined surfaces are always the poles. The mirror that deflects the laser beam can be attached with instant glue.

When the motor shaft rotates from its neutral position, the polarity of the magnetic field in front of the sensor rotates as well. This is necessary for the proper operation of the servo. Naturally, the construction of the clamp with the magnet and the mirror contribute to the inertia of the motor. However, tests showed that this contribution was smaller than the inertia of the rotor itself and this contribution can therefore be ignored.

It is best if the mirrors are so-called first surface (or front surface) mirrors. These do not have glass in front of the reflective surface, which avoids additional refraction and means that the angle of incidence is always equal to the angle of reflection. This ensures that the laser beam remains nice and focussed after reflection. First surface mirrors can often be found in older (laser) printers/scanners/bar code readers and can be cut to size reasonably easily using a glass cutter. The mirrors in the laser projector are cut with dimensions of about 6×8 mm. When gluing the mirrors you have to make sure which side has the reflecting layer. The rear side (the side with the glass) is obviously the side that is to be glued.

Once the glue has set properly the servo can be assembled. The motor has to be mounted on a piece of circuit board, preferably using the original

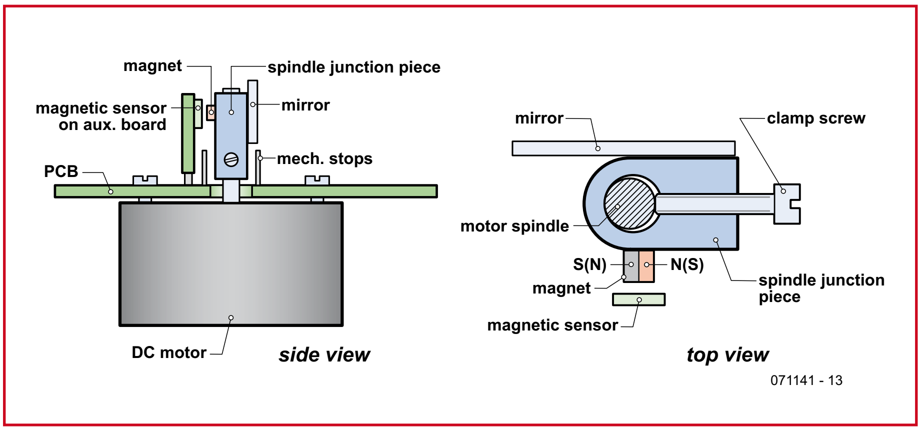


Figure 2. This figure shows how the mirror is attached to the servo shaft and how the angle sensor is constructed.

mounting screws. Make sure that the screws do not protrude too far into the motor so that they touch the rotor. The shaft coupling, complete with magnet and mirror, can now be attached to the shaft. After this, the Hall effect sensor has to be mounted in front of the little magnet. The Hall sensor used in the prototype was in an SMD package and therefore a small piece of circuit board was used as the mounting support for the sensor. The same sensor is also available in a SIP package, which makes things somewhat easier.

When positioning the sensor you have to take into account the desired mirror position, which will usually be 45 degrees for a 90° reflection. The centre of the sensor package has to be exactly opposite the magnet at a distance of about 1-2 mm. This is precision work, but is not hard to do.

To ensure that the magnet cannot turn too far away from the sensor, two end-stops are fitted that prevent this from happening. The end stops are easily

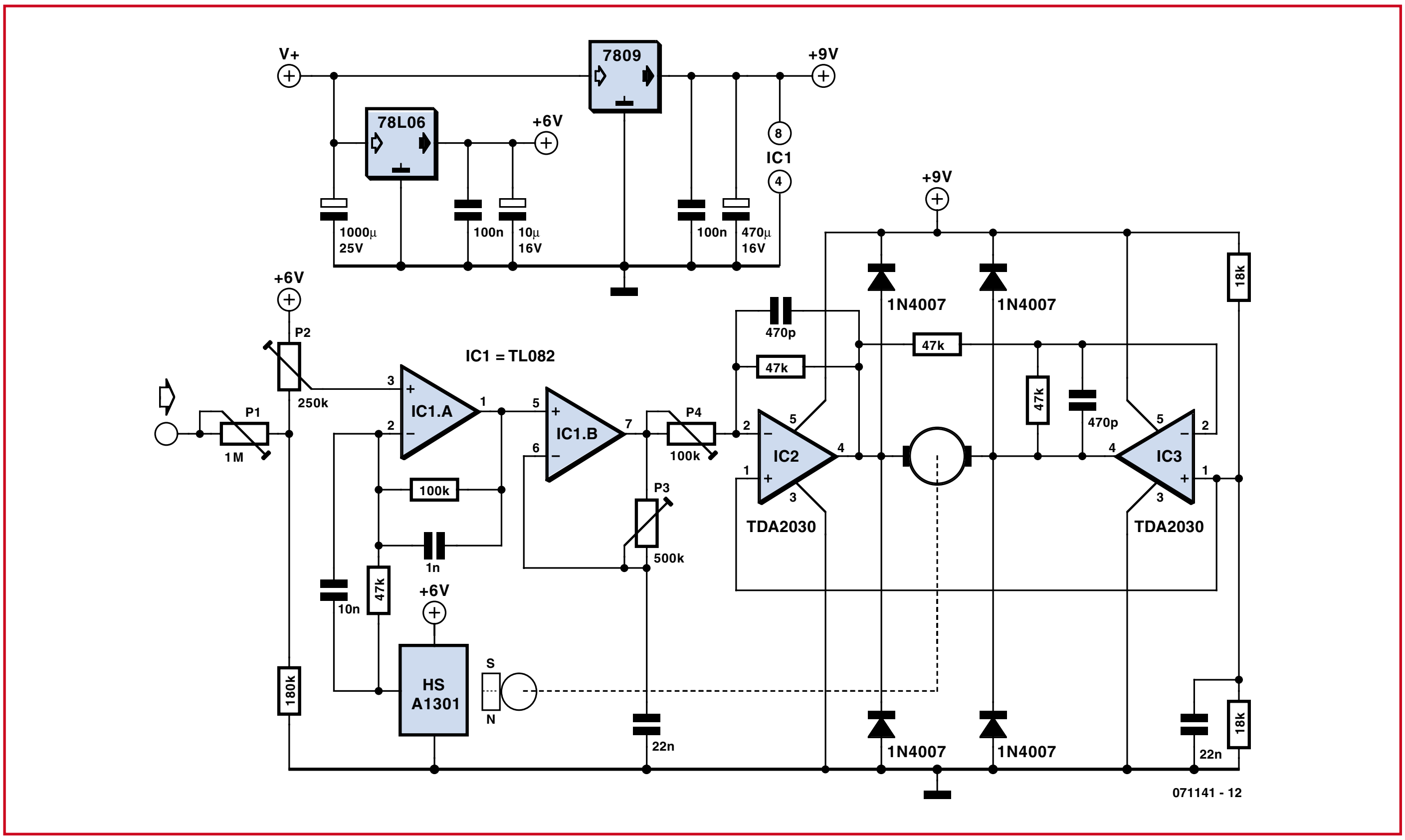


Figure 3. Each servo motor is controlled by this circuit. The input is therefore connected to the X-servo and Y-servo outputs of the main schematic (Figure 1).

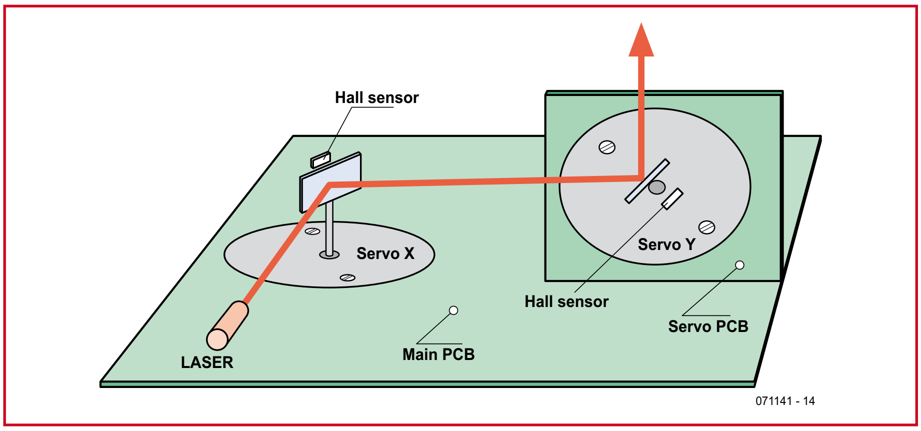


Figure 4. To enable control in both the x- as well as the y-direction the servos can be positioned like this.

mounted and are in the form of two pieces of wire, cut from a resistor lead, for example. These can be soldered onto the motor PCB to the left and right of the screw for the shaft coupling. This completes the servo.

Servo control

The electronics for the servo drive can be kept quite simple (see **Figure 3**). P1 is used to set the input signal sensitivity and determines the maximum projection format. P2 sets a DC-offset, which is used to move the projection image a little, for example. IC1a amplifies the difference between the signal from the magnet sensor and the input signal. When this difference is positive, the motor turns in the opposite direction compared to when this signal is negative. In this way a closed loop is created which is necessary for controlling the servo. IC1b is a proportional-differential (PD) amplifier. This is indispensable to correct the phase of the feedback loop.
IC2 and IC3 are connected as a bridged amplifier for driving the motor. These ICs, type TDA2030, are intended as an audio amplifier but are functionally just big difference amplifiers that can deliver about 3 A. More than enough for this type of motor. Four diodes prevent the inductive flyback voltage of the motor from damaging the IC.
The power supply voltage for these ICs is provided by a 7809 regulator. With a 9-V power supply, IC2 and IC3 can drive the motor with plus and minus 6 volts. In the prototype IC2, IC3 and the 7809 were all mounted without insulation on a common heatsink.
The current consumption of the servos depends on the amount of drive. This is typically not more than 100-200 mA each. The average power consumption of the entire projector including a 5 mW red laser module is about 300 mA. Batteries will therefore not last very long, but powering from a mains adapter or a small lead-acid battery for ‘in-the-field operation’ are good options.

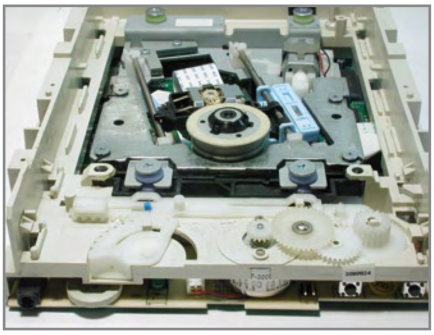
Adjusting the servos

When a servo is connect to the drive PCB for the first time, all the potentiometers have to be set to their centre positions. When the power supply is connected, and all is well, the motor now turns such that the magnet is exactly opposite the sensor. If the magnet turns away from the sensor then the motor wires need to be swapped around.

Using HyperTerminal we can send commands via the serial port to the projector. There are two commands for adjusting the step response of the servos: AX and AY (adjust X/Y). After issuing an AY command the step response of the Y-servo is projected. The potentiometers for the PD controller and motor driver now need to be adjusted so that the projection is a nice, clean pulse waveform without showing any oscillation artefacts. The same is true for the X-servo after issuing the AX command. Repeat the adjustment of both servos once more. Measured with an oscilloscope (at the sensor output), the step response time of the prototype was about 2-4 ms, depending on the step size. The –3 dB sine response is about 150 Hz.

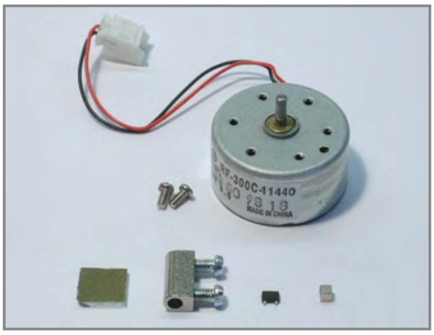
In operation

Once the servos are working and are adjusted properly, the projector itself can be tried. The serial port of the projector is connected to the serial port of a PC/laptop. Start HyperTerminal and enter the COM-port settings. A connection can now be established with the ATmega88. You can now enter commands using the keyboard. With the LC command (list commands) the list of available commands is displayed on the screen. Each command consists of two (capital) letters. If there are no parameters this is then immediately followed by pressing the enter key. Commands with parameters are

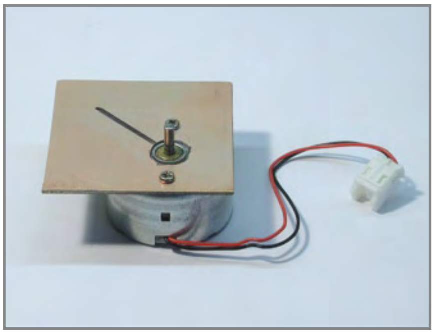


An opened CD-drive. The little DC-motor under consideration sits at the front in the middle.

The little DC-motor as removed from the CD-drive (keep the little mounting screws).

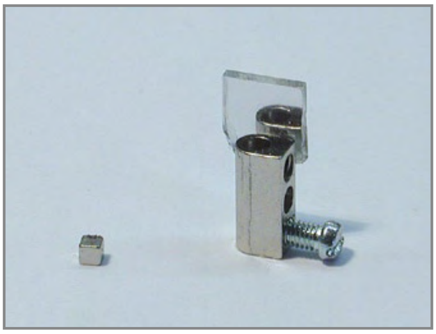


All parts of the servos together: mirror, shaft coupling, magnet sensor and the little magnet.



The little motor mounted on a piece of printed circuit board with the 45-degree line where the magnet sensor has to come.

The mirror, the shaft coupling and the little magnet, ready to be glued together.



The mirror glued to the shaft coupling; the magnet is next.

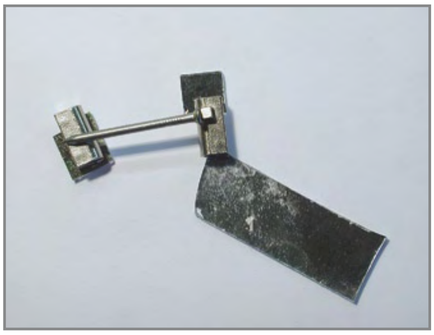
entered by typing the command, followed by a space, then a parameter, then another space, etc. Parameters are a number, usually 0-9. There is no checking of the input and therefore there are no error messages either!
Using the command MS (mode set), one of four modes can be selected. If the projector is used on an occasion where music is played, it can be nice to show the music as an oscilloscope image on the wall. In this case the sound output from a CD-player, or from a microphone with pre-amplifier, is connected to the Y-input of the controller. After issuing the command MS 3, the projector operates as a projection oscilloscope. The command SS (save settings) can now be used to save everything. If the projector is now switched back on, after having been switched off, it will continue to operate with these same settings and can therefore operate 'stand-alone'.
If the projector is to be used as a non-stop text display this can be accomplished as follows: the text is entered with the TX command. The text size and scroll speed are set with TS. The entered text is now projected as a running text display. If the text is displayed in mirror image or upside down then this can be corrected with the RE command. Once all is correct, the SS command can be used to store everything (including the entered text).
To project text, the MS 1 or MS 2 command need to be issued. In mode 1 the text scrolls letter by letter and in mode 2 word by word. With the latter there is the possibility that a word is too long when the letter size is too large. No error detection for this situation is programmed in, users will have to look out for this themselves.
An important adjustment is the timing. The software assumes predictable response times of the servos. These are stored as two parameters. Using the TM command with 2 parameters these can be altered and saved with SS. In the TM command the first parameter is a fixed time and the second causes a delay proportional to the size of the projection. The default is: TM 3 4. The projector works well with the default settings, but experimenting with the settings gives you a better feeling for the workings of the projector. For example, TM 1 4 distorts the projection and with TM 4 4 is slower than necessary. Fine adjustment is possible however and can gain some speed which means that texts with larger scroll widths can be used. These would otherwise be delayed too much which results in a flickering image. This is however only a problem with large letters and a scroll width of more than about 5 characters.
Should this experimenting with the settings result in some problems with the display, the LD command (load defaults) can be used to set everything back to the initial state. Don't forget to store this 'reset' with the SS command.

Positioning

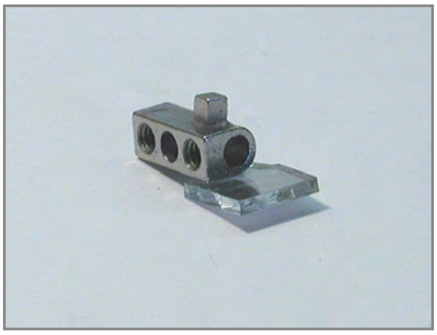
Figure 4 and the photos show how the servos can be positioned. It is advisable that the position of at least one servo and also that of the laser is made to be mechanically adjustable. It is important that no laser light misses the mirrors. With a little bit of adjustment of the laser position (height and direction) all of the correct settings are usually easily found.
Note that with laser modules the housing is often the + connection. A little piece of heatshrink sleeving is then required for insulation.

Lasers with larger powers

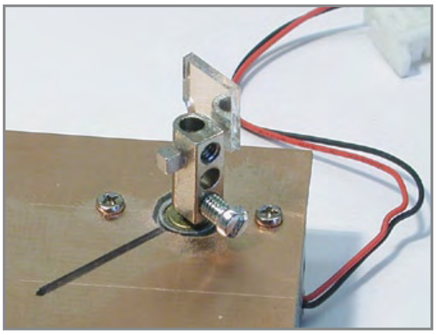
As mentioned before, working with red lasers can be considered safe for pow-



A small nail holds the magnet in place for gluing.

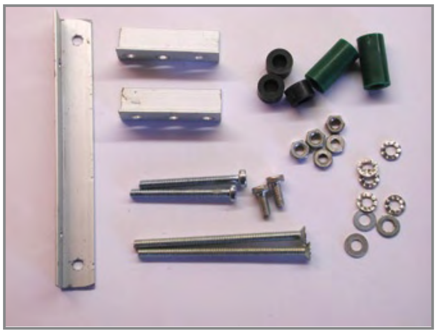


The shaft coupling with mirror and magnet, all glued together.

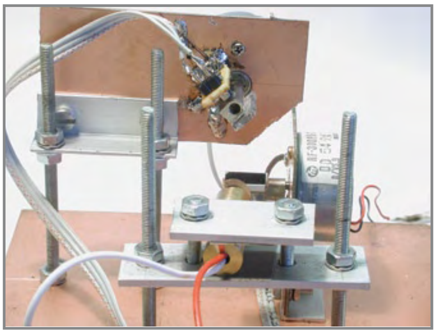


The complete shaft coupling, mounted on the motor shaft. Now the Hall-sensor.

The complete servo including the magnet sensor which is held in the correct place with a small PCB.



We make the mechanical construction with M3 hardware and aluminium angle profile.

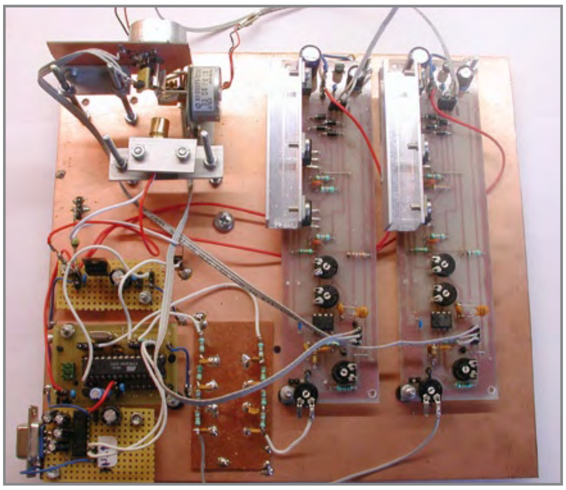


The two mounted servos with the laser module in the foreground.

ers up to a few milliwatts (still, *never* look into the beam). The advantage of a green laser compared to a red one is that the eye is much more sensitive to green light, so that the projection appears much brighter. Green lasers are usually DPSS (Diode Pumped Solid State) types, where the beam of an 808 nm infrared laser diode drives a pair of crystals. These crystals convert the 808 nm beam in two steps to 532 nm (green). The efficiency of this is much smaller than 100% so that, in principle, a big infrared laser diode is required. To illustrate this: a 5 mW red laser diode requires a drive of about 40 mA, a 5 mW green DPSS module needs typically 200 mA.

If you must work with more power, then for a few tens of Euro you can purchase a green laser pointer rated at, for example, 30 mW. These will have to be dismantled, which usually involves sawing to gain access to the driver PCB.

The driver PCB often delivers too little current and/or is too slow. Driving the diode directly with a current source is often the best solution for optimum speed and light output. When the driver PCB is removed, after determining which are the connections to the laser diode, it is best if the laser diode and photo diode are connected in anti-parallel. This is just a case of soldering two pins to each other (usually pin 1 and pin 3, pin 2 is the housing). This is because a laser diode typically has a reverse blocking voltage of no more than 2 V and the photo diode prevents this from being exceeded. Laser diodes are also sensitive to static discharge, so take the necessary precautions.
In the circuit of **Figure 1** there is an additional circuit for driving a bigger laser diode with a constant current and to modulate it. The assumption here is for a current of 500 mA for a 30 mW DPSS module obtained from a laser pointer.
The TDA2030 is configured as a current source which can be modulated with TTL signals and the L200 is added as regulator with current limiter. This is additional safety to protect the expensive laser module from currents greater than about 550 mA. The potentiometer sets the quiescent current which is just below the threshold at which the module starts to 'laser' This serves to slightly increase the average temperature (for optimal light output).
The resistor R is used to set the current through the laser diode and R_L is for the current limit. If the nominal current needs to be 500 mA, for example, it is safe to calculate R_L for 550 mA (500 + 10%).



The complete laser projector: the two servo driver PCBs are on the right, the servos are at back left and the controller and RS232 interface are in front on the left.

Program fuse settings

BOOTSZ = 11

BODLEVEL = 100

CKSEL = 0111

SUT = 11

(brownout VCC = 4,3 V,
ext. full swing XTal)

Applications

There are of course a number of interesting applications for a laser projector. It is, for example, possible to use it for chatting. Two people and two tables with a computer on each can be positioned against opposite walls. The chatters can then see the text of the other person behind/above their monitor on the wall. Using the wall of a larger building it is possible to chat in a group, provided each participant has their own projector, of course.

Another application is the projection of advertising messages in a shop window, for example. This can be done from the inside because the text can be projected mirror-reversed. The text can then be read normally from the outside.

Many other applications can be conceived of, but we leave those up to you.

(071141-I)

E-blocks: Accelerated Design

E-blocks + Flowcode + TINA

John Dobson (Matrix Multimedia)

In this article we take a look at some of the latest techniques you can use to accelerate the design process, in this case of a switch-mode power supply.

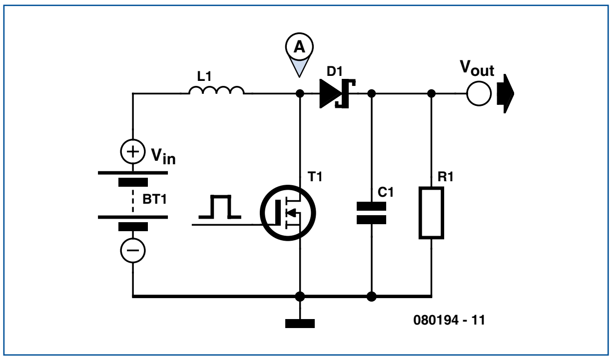


Figure 1. Principle of a step-up ('boost') voltage converter (redrawn from Microchip application note).

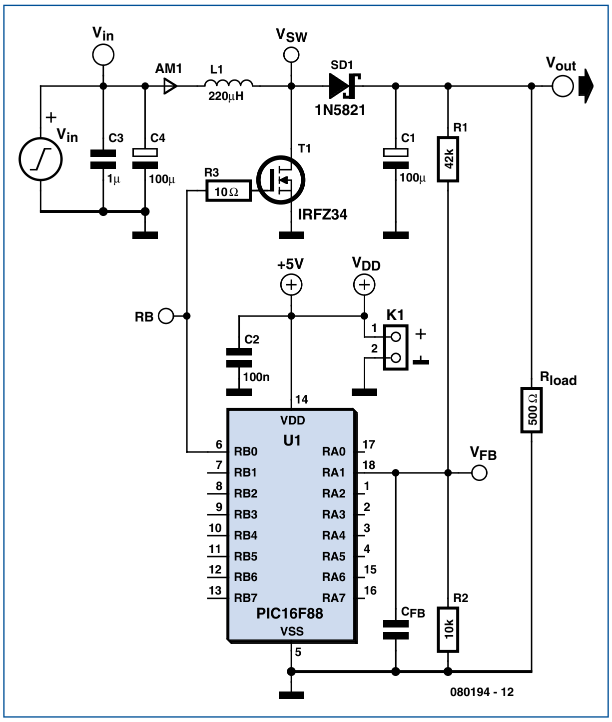


Figure 2. Basic circuit of a switch-mode step-up voltage converter (note: schematic for use in TINA, redrawn in Elektor style).

Switched mode power supplies (SMPSUs) are traditionally viewed as a bit of a black art. And with good reason – the mathematics behind the design process is complex, prototyping — often with custom wound inductors — is awkward, and the custom SMPS regulation chips used in the design itself are expensive. However this does not need to be the case: most modern circuits now contain a microcontroller with extra capacity that can be used to control the power supply, and design tools have advanced to a point where virtual prototyping is now possible. Sure, the mathematics is still there – but the use of simulation tools, with a little trial and error, means that if you make a wrong turn, getting back on track is not so difficult. At least that is what we are hoping — we have to assume we're complete novices here!

The circuit

We are looking at the possibility of generating a 12 to 15 VDC voltage rail from a 5 VDC supply. This is for an instrument that requires ±12 V rails. As the application is only for driving a few opamps we only need a few tens of milliamps — if that. Having sniffed around the Internet we came across a Microchip Application Note that describes the use of the elementary circuit in Figure 1.

This is a fairly traditional 'boost converter'. We intend to power the circuit with a 5 V supply — shown as V_{in}. FET T1 is periodically switched on by a pulsed control input — more about this later. At the point where the FET is switched on, a relatively large current is drawn through inductor L1, and the energy stored in the inductor increases. All of this current will be supplied via the 5 V supply — Schottky diode D1 will ensure that no current flows from the second half of the circuit because V_{out} is greater than V_{in}. At the point where the FET turns off, the energy stored in the inductor is released. In this release there will be a voltage surge across the inductor which will result in a larger voltage at point A than the supply voltage. At this time in the cycle diode D1 will start conducting and charge will be pumped across it into C1. As long as the discharge current through the load,

R1, is not too large then the result of this circuit is that the output voltage is larger than the input voltage.
So this is a great little circuit that can be implemented relatively cheaply, and will — in theory — do the job we need. Providing that the load is precisely known — and does not change — and a switching waveform of an appropriate frequency and period can be supplied, we are home and dry. Of course these conditions rarely apply — loads vary depending on the actions of the rest of the circuit, components have tolerances and in practice a closed loop system incorporating some method of regulation is going to be needed. A more practical circuit is shown in Figure 2.

This is essentially the same circuit with some additions. As the currents drawn by L1 can be large, a couple of capacitors have been placed across the supply rail for decoupling. The load resistor here is 500 ohms. This will give us around 30 mA as the model load — more than enough for our needs. The FET switching control is governed by a PIC microcontroller output pin. The pulse waveform on this line will determine the charge and discharge of L1. To complete the feedback loop, the circuit output voltage is fed into the PICmicro analogue input pin A1 via a potential divider made up of R1 and R2. The RC network formed by R2 and C_{FB} provides a little smoothing on the feedback signal. The value of C_{FB} can be established empirically.

Software development

The firmware to make the PIC supply the control pulses was developed using Flowcode, the software suite with E-

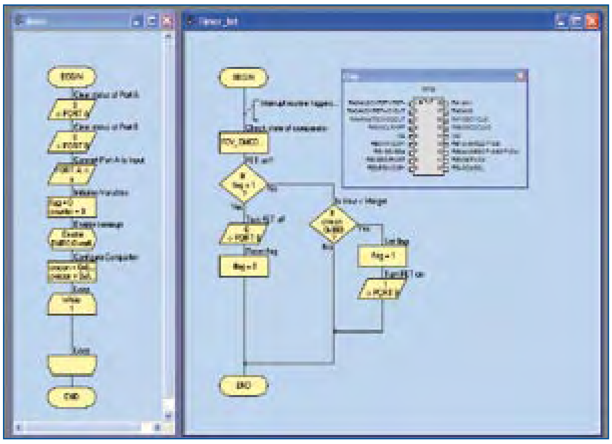


Figure 3.
A section of the Flowcode program written for the PIC-controlled SMPSU.

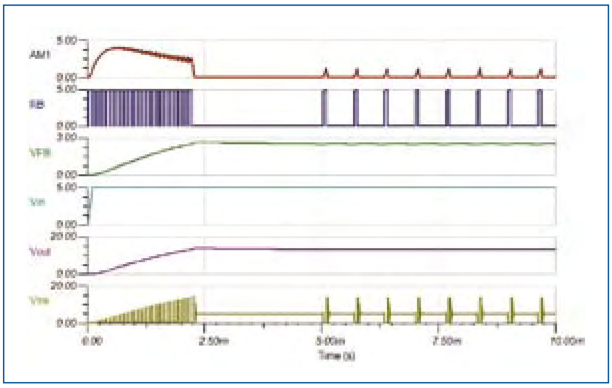
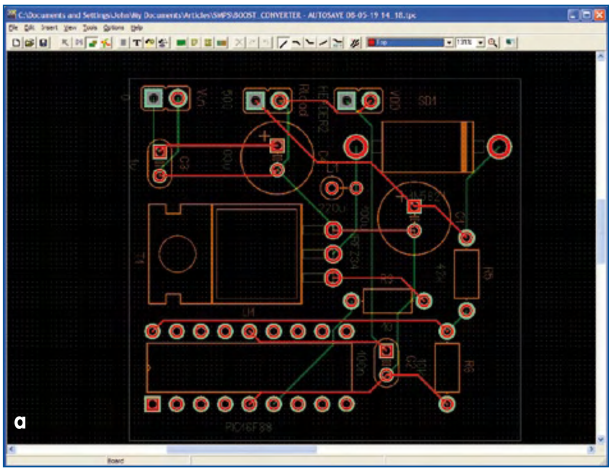


Figure 4.
TINA at work showing the response of a virtual circuit running Flowcode-generated ASM code and combining a PIC with analogue components. Now start optimizing without soldering!



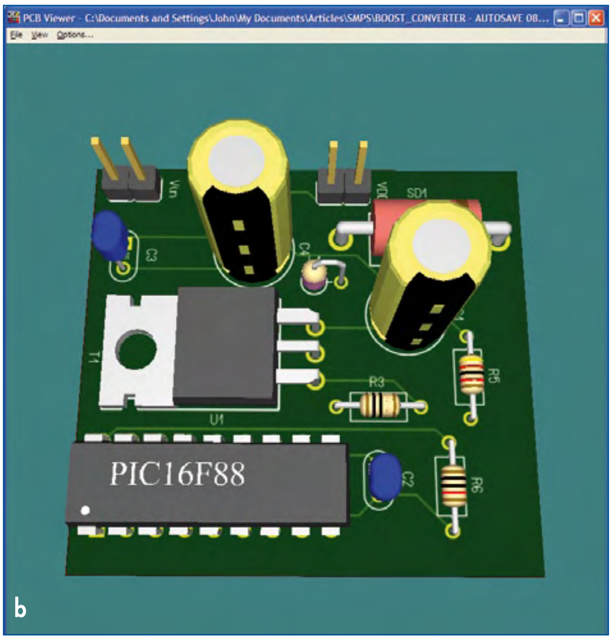


Figure 5. TINA also routes the PCB tracks (5a) and generates a 3-D rendering of the board (5b).

blocks. The program is relatively simple and can be seen in Figure 3. Referring to this and the schematic, here is a description of how the program works. The .fcf file proper sits in archive file 080194.-11.zip on the Elektor website for those that want to study the details.

In the MAIN loop the program sets up the relevant pins as inputs and outputs and sets system variables. An interrupt icon is used to trigger an interrupt at around 10 kHz, equivalent to 100 µs. Then there is a 'C' icon with the contents:

```
cmcon = 0x02;   //set comparator register to compare
                with internal Vref

cvrcon = 0xAC;  //set internal Vref to Vcc/2
```

A comparator, rather than an A/D, is used because it operates much faster by comparison (the PIC16F88 supports both internal comparators and A/Ds) The last icon in the MAIN flowchart is a While loop which just keeps the program running — all the control is carried out by the timer interrupt routine.

The interrupt routine first reads the internal comparator which compares the feedback at point V_{FB} (on RA1) with the internal voltage reference. If the voltage is lower than a preset threshold (in this case 80_{hex} which corresponds to about 2.5 volts at pin RA1) then a flag is set and the FET is turned on by pin B0 for one interrupt cycle – around 100 µs. When the FET is on, current flows through the inductor and when the FET is turned off, the back-EMF produced increases the voltage at point V_{sw} so current flows through the diode. If the voltage at RA1 is above the threshold then the FET is not turned on.

From Hungary comes TINA

Now for the clever bit – the schematic shown in Figure 2 can be entered into in a software package called 'TINA' from DesignSoft [2]. TINA supports a relatively new kind of simulation where you can simulate high-speed analogue circuitry at the same time as simulating your microcontroller running the code you have designed. The process here is simple: design your software using Flowcode, assemble the Flowcode program to ASM code, alter the characteristics of the PIC inside TINA so that the microcontroller is associated with the relevant ASM file and then simulate the circuit. You can see the results of the simulation in Figure 4.

The first trace shows the current drawn at point AM1 through the inductor, the second trace shows the state of RB0, the third trace shows the feedback voltage, the fourth shows the input voltage V_{in}, the fifth trace shows the output voltage, and the last trace shows the voltage at the junction of the FET drain and the inductor. Whilst there is some ripple on the output the voltage is a pretty steady 14 V. The big surprise for me here was the amount of current taken in the first few milliseconds and the size of the subsequent bursts which are more than an amp!

Getting practical (again)

So having got the simulation working we used an E-blocks Multiprogrammer and a Prototype Board to put the circuit together. The system seems to work well with around 13.5 V at 30 mA. If you try to lower the load resistor and draw more current then all sorts of strange things happen as the 7805 regulator we are using starts its impression of a toaster and cuts out at regular intervals resetting the PIC. As an added bonus here it makes a noise like a rat being strangled — stand clear!

The PCB design and 3-D rendering generated using TINA are shown in Figure 5. The exercise once again proves that both Flowcode and E-blocks are far more 'open' products than is often assumed, and right up the street of anyone starting out in microcontrollers, whether PIC as demonstrated here or AVR.

(080194-I)

Web Links

[1] www.elektor.com/080194 (Free downloads)

[2] www.tina.com

E-blocks

E-blocks is a modular system designed to learn microcontroller programming at various levels. The current product range comprises about 70 modules and ancillaries for PIC, AVR and ARM platforms. E-blocks systems employ the 'Flowcode' graphics programming software tool. E-blocks are available from the Elektor SHOP, see www.elektor.com/e-blocks.

Ultrasonic Sound Detector

track down high frequencies

Ton Giesberts

Using the circuit described here you can quickly and simply check whether harmful sounds with a high frequency are being produced somewhere nearby, especially important at locations where the so-called ultrasonic teen-deterrents against loitering youths are installed. Ten LEDs indicate the sound pressure of signals with frequencies between 16 and 40 kHz.

These days, to harass loitering youths into leaving, an 'ultrasonic' sound system is often used (such as the Mosquito). Such a system generates, in the vicinity of a popular gathering place, a sound with frequencies between 17 and 20 kHz. This sound appears to be very irritating to youths, with the result that they soon move on. Older people appear to be unable to hear these frequencies and are therefore not bothered by them.

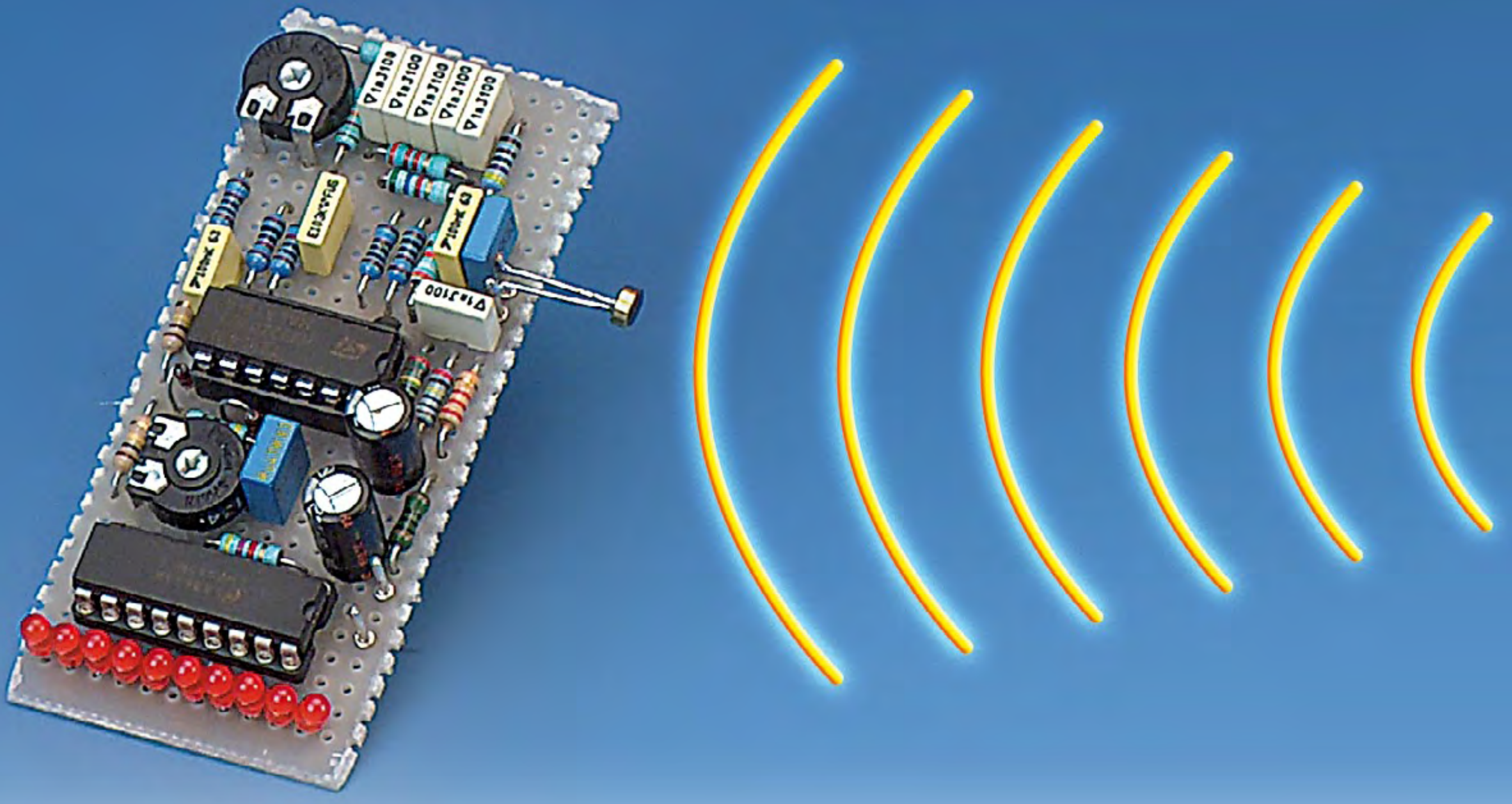
The term 'ultrasonic' is actually not quite correct. Ultrasonic sound is normally used to describe the range of frequencies that are above the range of human hearing, that is, above 20 kHz. Because the frequencies used are below 20 kHz, they are not only audible to loitering youths (insofar as they don't have any hearing damage), but they are even better heard by babies, small children and pets. The sound pressure is not all that high, according to data provided by the manufacturer. But if the ultrasonic deterrent is nevertheless considered to be annoying, it is very likely to be even more irritating to babies and small children (and that is not taking into account the potential hearing damage by prolonged exposure).

Babies and pets cannot say what is wrong (with the exception of parrots perhaps). So if you are walking through the city with a baby there is the chance that the child is exposed to these types of sound without the parents realising.
So that you can quickly get an indication whether harmful sounds with a high frequency are being produced somewhere, we designed an indicator that can detect these signals and measures their intensity. Ten LEDs show the sound pressure of sound in the frequency range from 16 to 40 kHz. Lower frequencies are suppressed by a fifth-order, high-pass, Butterworth filter so that the indicator will not react to speech and other everyday sounds. When designing the measuring range for the indicator the decision was made for maximum deflection at a sound pressure of 90 dB. If you are exposed to 90 dB for more than an hour then there is the risk of permanent hearing damage. Whether you can also suffer hearing damage from frequencies you cannot hear any more, wear of the auditory ossicles for example, has not been researched yet.

Schematic

The circuit shown in **Figure 1** may look quite involved, but it is really not that bad. The circuit comprises a microphone amplifier, a fifth-order high-pass filter, an active rectifier, a buffer stage and finally the display driver with ten LEDs. For driving these LEDs we used the old, trusty LM3915 in dot-mode (we deliberately did not choose bar-mode because of the current consumption). This IC is configured for its simplest application with REF ADJ connected to ground. In this configuration the input signal has to be 1.28 V_{DC} (typically) for 'full deflection'.
Working backwards from this value and the sensitivity of the electret-microphone that is used, we can calculate the required gain. For the microphone we chose a type that can be obtained from Farnell (the Kingstate type KEEG1542TBL-A). This choice was mainly determined by the frequency response curve shown in the datasheet (which can be downloaded courtesy Farnell). This shows a slight increase towards 20 kHz, which leads us to conclude that it will still be usable at frequencies a little over 20 kHz. While there may be a lot of ripple in the curve above 20 kHz this is not a problem since we're only looking for an indicative measure of sound pressure. At 90 dB the microphone module will give an output of about 8 mV. When we take into account that the rectifier contains a peak detector (makes a difference of $\sqrt{2}$ in the gain) and that the sensitivity of the microphone can vary by up to ±3 dB, we therefore need a circuit with a minimum gain in the region of 80 to 160.

The input contains a gain stage (IC1A) which amplifies 40 times. This also cuts off the lowest frequencies at the same time (C1 and C4). C3 and C5 compensate a little for the slight drop of frequency response above 20 kHz. For the opamps the ST type TS924IN quad rail-



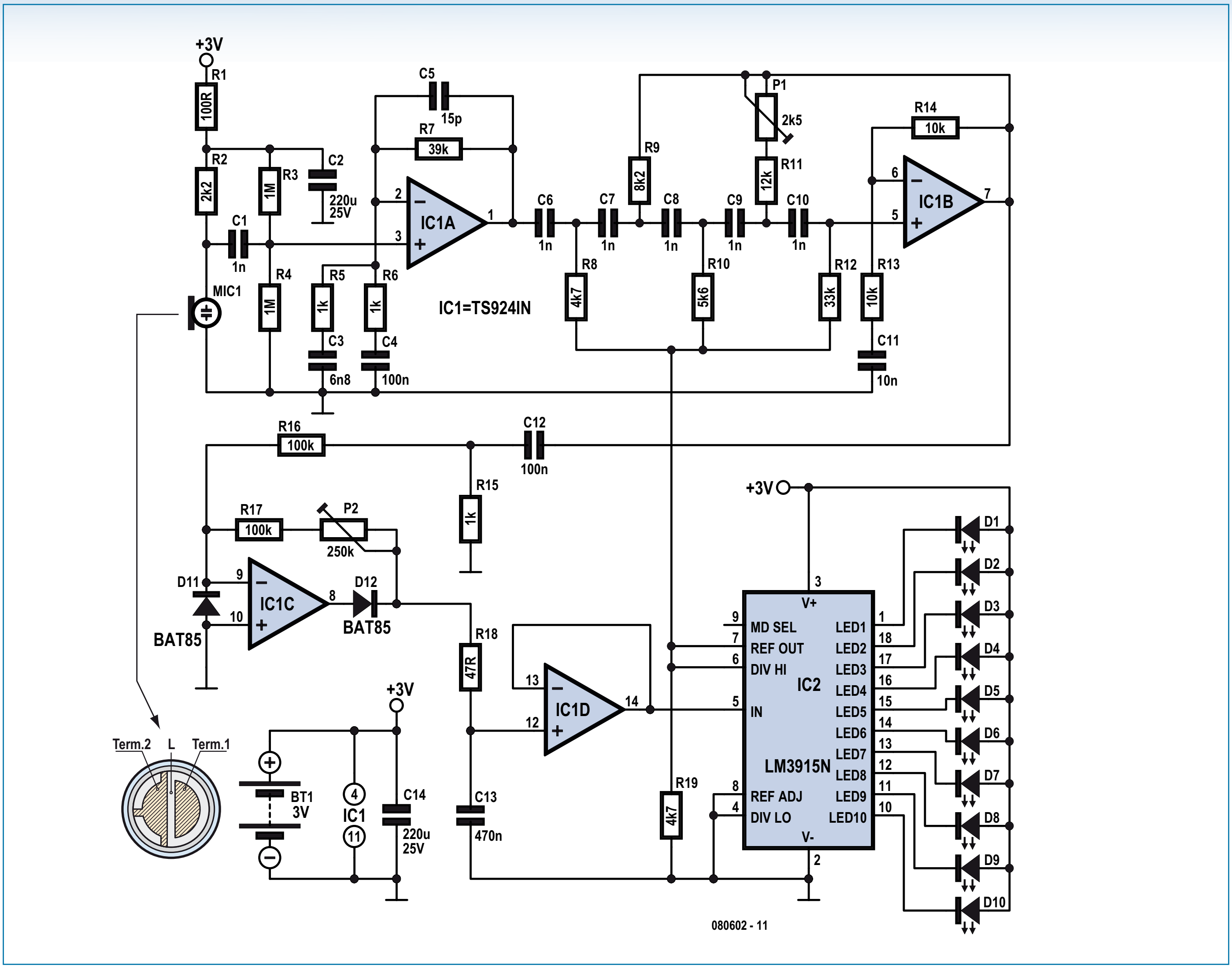


Figure 1. With this circuit you can very easily track down high-frequency audio signals.

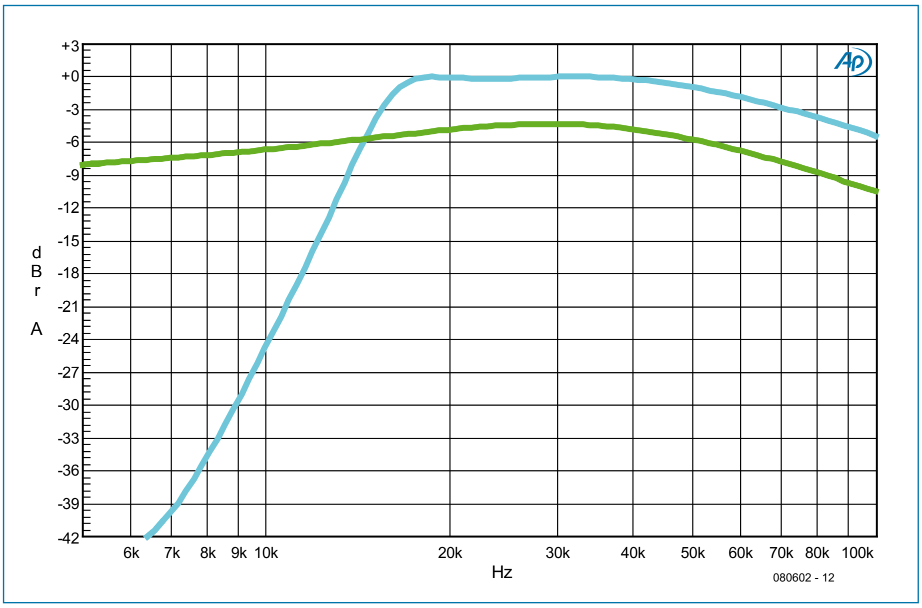


Figure 2. The frequency characteristic of the input amplifier on its own (green) and the input amplifier followed by the high-pass filter (blue).

to-rail device was selected, which can deliver no less than 80 mA. This opamp has a relatively large GBW (gain-bandwidth product) of 4 MHz, so that the bandwidth of the input amplifier at a gain of 40 is still 100 kHz (C5 is only for RF decoupling), more than enough for this application. This is followed by a steep filter built around IC1B that passes only frequencies above 16 kHz (–3 dB). The measurement curves (**Figure 2**) show the amplitude response of the input amplifier on its own and that of the input amplifier followed by the filter. For the proper operation of the fifth-order filter a buffer is not enough, but the opamp needs to have a gain of 2 (this can be seen clearly in the measurement curves). This is a fortunate circumstance since the other stages now don't need to have as much gain.

The filter contains an adjustable component to allow for the compensation of component tolerances. P1 can be used to make the curve as straight as possible. If you do not have the means to measure this then you can use the nominal value of 870 Ω for P1 instead. It is still recommended to measure and select C6 through C10 for equal values. The rectifier around IC1C is a standard implementation, where the usual diode between the output of the opamp (pin 8) and the inverting input (pin 9) is not necessary because the output cannot go negative. To ensure correct operation, the rectifier is AC-coupled (R15/C12) to the output of the filter. D11 protects the input of the opamp from excessive negative input voltages.

The output voltage of the rectifier (cathode of D12) charges capacitor C13 to the peak value via R18. The purpose of R18 is to limit the maximum charging current. With the values as shown, C13 is charged relatively quickly, the RC time-constant is only 22 µs. The total amplification of the circuit can be adjusted over a wide range with P2 so that other (less sensitive microphones) can be used as well. The discharge time of C13 varies somewhat with the setting of P2, but that is not important here.

The fourth opamp (IC1D) is used as a buffer to drive the LM3915.

Although the resolution of the LM3915 is 30 dB (10 × 3 dB) but because of the simple design of the rectifier the voltage across C13 is not exactly proportional to the input signal. The bottom LED D1 lights up at –21 dB compared to the voltage required to turn on the topmost LED (D10).

The current consumption of the whole circuit is between 11 and 15 mA, good for six days of continuous use. The circuit appears to work down to nearly 2 V, so that instead of alkaline batteries rechargeable batteries could be used as well. This is much more environmentally friendly.

If you like to experiment, you could try to make a small parabolic reflector so that you can pinpoint the source of the ultrasonic sound. The microphone needs to be mounted at the focal point of the reflector. Perhaps even a small horn is already enough...

(080602-I)

Hexadoku

Puzzle with an electronics touch

After the colossal — but reportedly not too difficult — AlphaSudoku puzzle in the Summer Circuits edition we cheerfully continue with a regular Hexadoku. As before, do participate! All correct entries received enter a prize draw for an E-blocks Starter Kit Professional and three Elektor Shop vouchers.

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.

SOLVE HEXADOKU AND WIN!

Correct solutions received enter a prize draw for an

E-blocks Starter Kit Professional

worth **£248.55**

and three **Elektor SHOP Vouchers** worth £35.00 each.

We believe these prizes should encourage all our readers to participate!

The competition is not open to employees of Elektor International Media, its business partners and/or associated publishing houses.

PARTICIPATE!

Please send your solution (the numbers in the grey boxes) by email to:

editor@elektor.com - Subject: hexadoku 9-2008 (please copy exactly).

Include with your solution: **full name and street address.**

Alternatively, by fax or post to: **Elektor Hexadoku**
Regus Brentford - 1000 Great West Road - Brentford TW8 9HH
United Kingdom - Fax (+44) 208 2614447

The closing date is **1 October 2008.**

PRIZE WINNERS

The solution of the June 2008 puzzle is: **0EA75**.

The **E-blocks Starter Kit Professional** goes to: John Hall (UK).

An **Elektor SHOP voucher worth £35.00** goes to: Francois Herbert (NZ); Antonescu Alexandru-Florian (RO); Sven Skjenneberg (N).

Congratulations everybody!

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

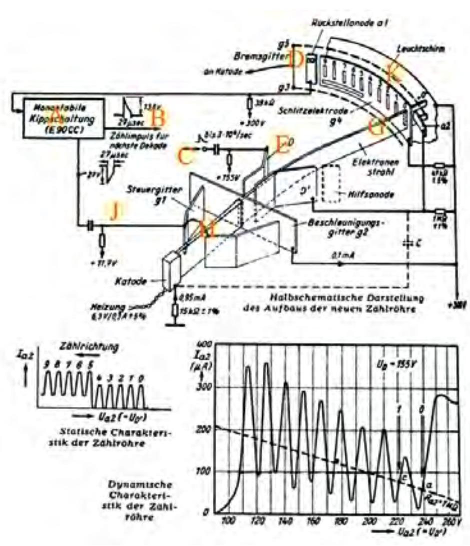
(c) PZZL.com

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

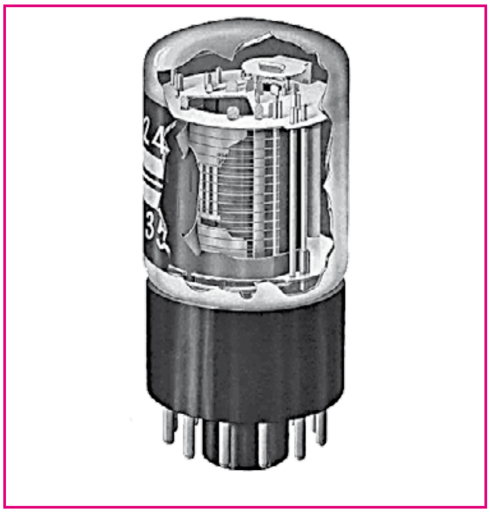
E1T decade scaler tube (ca. 1954)

Rui Figueiredo

A previous instalment of Retronics discussing the 'Dekatron' decimal counter valve [1] having aroused my attention through feedback published in Elektor's Mailbox section, I thought I'd alert the Editor to another counter tube, the Philips E1T. A good amount of information on the actual use of the device being available on the Internet (see web links), I decided to concentrate on the scientific environment at the time when the E1T was 'prima donna'.



A monostable: reset to zero (blanking); carry bit generator
B next decade driver
C pulse count driver
D overflow detector
E deflection plates
G ribbon type electron beam
H electron beam gun
J blanking pulse (reset to zero)
K slotted electrode (self-centering) and phosphor screen



First produced at around 1954, the E1T combines a display, a scratch memory and a counter in one device. Even for those not familiar with electron tubes, the diagram (reproduced from radiomuseum.org) gives an idea about the operation of the E1T and how it fits in a counter cascade arrangement. The E1T may be likened to a small cathode ray tube (CRT) in which the count/display readout (0 through 9) jumps from digit to digit under the control of deflection plates (E) with internal feedback maintaining the position until a new pulse occurs (see dynamic characteristics). The 10^{th} pulse causes the beam to collide with reset anode a1 (D). The resulting negative pulse is processed by an E90CC dual triode connected as a monostable generating two pulses (or 'flags' if you like): a carry bit to drive the next decade, and a cutoff level to reset the E1T to zero. The system, devised almost 60 years ago, is the precursor of 'overflow-with-carry' in a microprocessor!

The use of the E1T seems restricted to Philips' own scientific division as well as high-end professional instruments and equipment including radar, nuclear and x-ray (XRD, XRF). In the latter application (without computers or calculators!) Bragg's law ($n\lambda = 2d \sin \theta$) was traditionally relied on to count pulses. To cope with the tremendous 'intensity' variations expressed as the number of pulses and their amplitude, two techniques became established after some time. The first was counting all pulses coming from the detector (a Geiger or Flow counter), the second, applying the pulses to a pulse level detector set to 'threshold' or 'window' mode. A linear amplifier supplying output pulse levels between (almost) 0 V and 100 V_{pk} was usually inserted between the counter output and the pulse analyser.

The E1T's maximum 'speed' of about 30 kHz was a limiting factor, as well as the 27 µs necessary to reset the decades to zero (minimum safe width for non-selected tubes). This required the use of a prescaler if, say, three E1Ts were intended to constitute a counter readout.

Usually, the prescaler was a pure 8-bit counter using E90CC triodes with neon lamps as bit readers. Thus any value on the three E1T decades has to be multiplied by the prescaler-selected factor and added to the binary counter for better accuracy.

The E1T was designed conceptually at around 1946 by Adriaan van Overbeek of the famous Philips NatLab (PhysLab), based on earlier research by Jan Jonker. Later, another NatLab worker, Kees Van der Velden (now C. Keith Vandervelden) further perfected the device under supervision of the legendary Klaas Rodenhuis of Philips TubeLabs.

Probably due to cost, the E1T was not mass-produced like other Philips tubes. Yet it's not rare and Rodenhuis once said that the 10,000 or so devices around had been ordered from Philips TubeLabs' sample department (!). He also confirmed that 'E' was for 6.3 V heater, 'T' for 'tellerbuis' (counter tube) and '1' for the first device in the series. See, you could count on Philips for consistency in type designations!

(080365-I)

This month's free Retronics download is the E1T datasheet.

Reference

[1] The 'Dekatron' decimal counter valve, Elektor March 2008.

Web Links

www.radiomuseum.org/tubes/tube_e1t.html

www.dos4ever.com/trochotron/TROCH.html

www.dos4ever.com/E1T/E1T.html

www.tube-tester.com/sites/nixie/different/e1t-tubes/e1t.htm

www.lks.physik.uni-erlangen.de/diffraction/iinter_bragg.html

http://www-outreach.phy.cam.ac.uk/camphy/xraydiffraction/xraydiffraction7_1.htm

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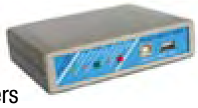

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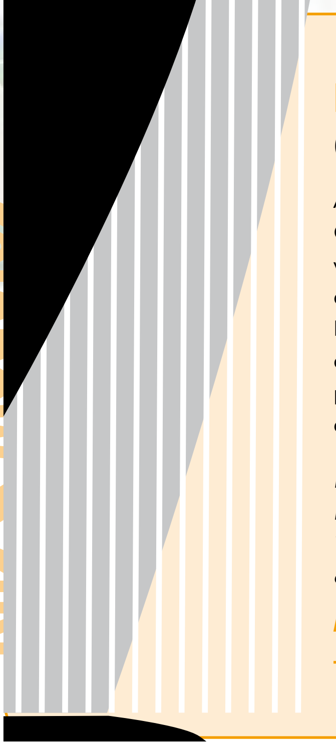

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(May & April 2008)

A low-cost home automation server based on a Freescale Coldfire 32-bit microcontroller. The project has been designed with open source in mind and doubles as a powerful Coldfire development system using free CodeWarrior software from Freescale. DigiButler activates electrical appliances in and around the home, accepting on/off commands from a WAP phone, through an Ethernet network or via a webpage at an allocated IP address and with full access security.

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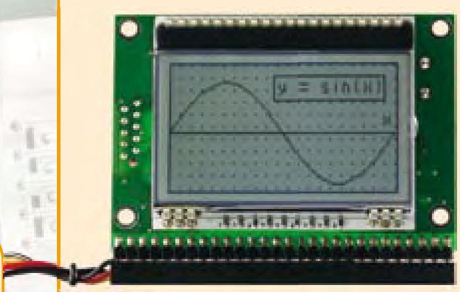

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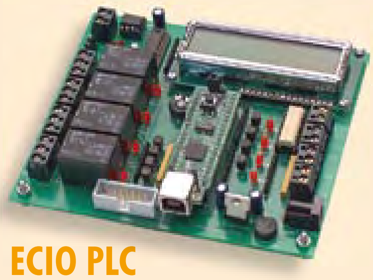

ECIO PLC

(March 2008)

An ECIO acts as the brains of this PLC board that has relays, opto-isolators CAN (!) connectivity and an LCD. All this I/O capacity together with Flowcode allows the board to act as a versatile, powerful PLC for quite complex control and automation projects. The LCD module is used to display ASCII characters to the user as a means of troubleshooting during the software development stage or for monitoring the system.

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234 pages • ISBN 978-0-905705-72-9
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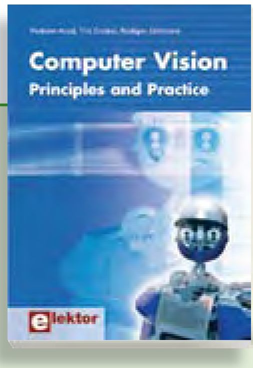

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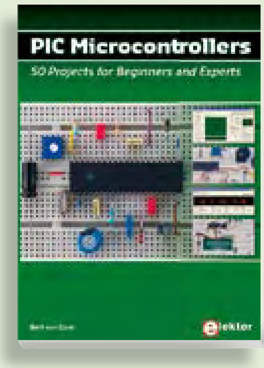

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5.0, 6.0, VBA, .NET, 2005

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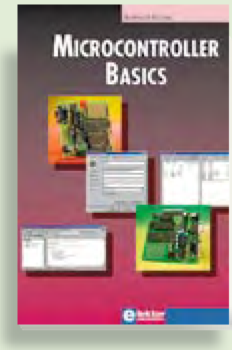

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Elektor SMD Reflow Oven

SMDs (surface mount devices) are increasingly used in today's circuit design, but mounting these parts is not easy without industrial tools. However Elektor again comes up with the goods by presenting its very own SMD Reflow Oven. In this specially designed and manufactured oven, the temperature is accurately preset and controlled to maintain a certain curve that's optimised for baking SMDs onto a circuit board using different brands of solder paste. The oven is available commercially from the Elektor SHOP.

DMX512 Dimmer with MSP430

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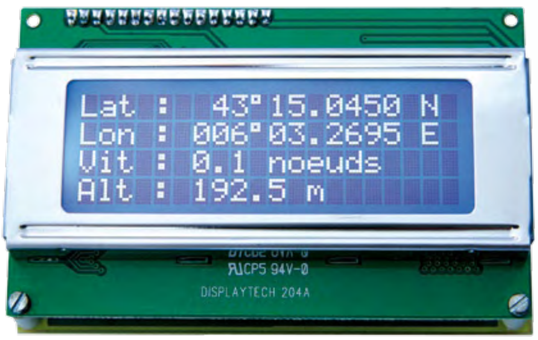
Some salient features of the circuit:

- DMX input and output;
- 6 dimmable power output channels;
- Status LEDs and suppressor coils on each output;
- Switch for addressing and a 'copy' option.



Multifunctional GPS receiver

Motorists all over the world have embraced GPS technology for their navigation systems. Due to their small size, GPS receiver modules can be used for other purposes, too, like helping a robot to find its way about. In this article we not only explain how to enable a PC to talk to a GPS system, but also how such a system can be integrated into a robot.

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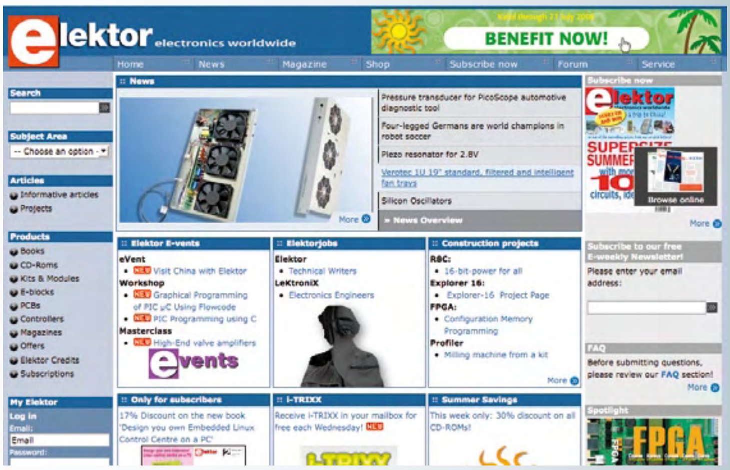

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