

November 2009

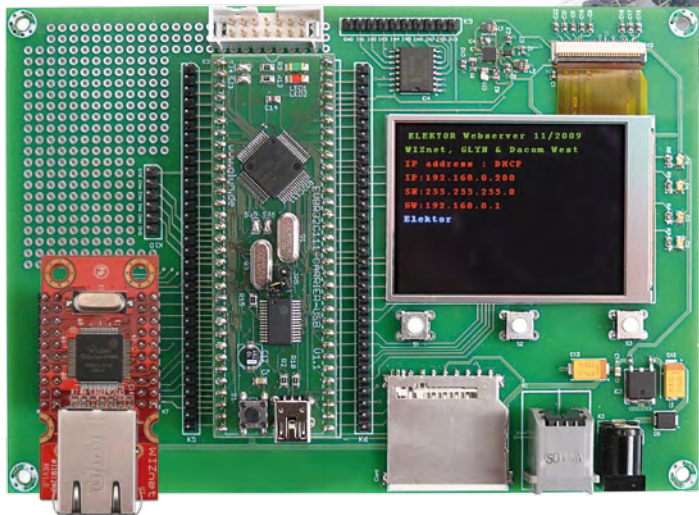
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# Elektor

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## ELECTRONIC COMPONENT ORDERING

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## R32C WEB SERVER

Networking module for HTTP, e-Mail, FTP and much more

**LIGHT THERAPY BOX** Blue LEDs combat winter blues

**SOLDER STATION 'PLUS'** With integrated DVM



R48

11

# BitScope

## Analog + Digital

### Digital Storage Oscilloscope

- ✓ Dual Channel Digital Scope with industry standard probes or POD connected analog inputs. Fully electrically isolated from PC.

### Mixed Signal Waveform Analyzer

- ✓ Capture and display analog and logic signals together with sophisticated cross-triggers for precise waveform timing measurement.

### Instant Replay Signal Generator

- ✓ Built-in synchronized waveform generator. Synthesize arbitrary waveforms or replay captured analog or logic signals instantly.

### Multi-band Spectrum Analyzer

- ✓ Display analog waveforms and their spectra simultaneously in real-time. Baseband or RF signals with variable bandwidth control.

### Integrated Waveform Data Recorder

- ✓ Record to disk anything BitScope can capture. Allows off-line replay and waveform analysis. Export captured waveforms and logic signals.

### Multi-platform & user programmable

- ✓ Supports Windows, Linux and Mac OSX. USB and Ethernet models with user programming libraries, drivers and customizable software.

## Mixed Signal Oscilloscopes



## FULL METAL JACKET

BitScope is built tough to last a lifetime.

Enclosed in a new low profile solid extruded aluminium case BitScope 325 can handle the harshest working environments.

Its full metal jacket and electrically isolated design means that unlike cheap plastic alternatives it is also highly noise immune for the most sensitive mixed signal measurement applications.

On the road or in the lab, BitScope is the ideal choice!



Logic/Timing Analyzer Probes



Industry Standard Scope Probes



Software Included

### BitScope Software and Libraries

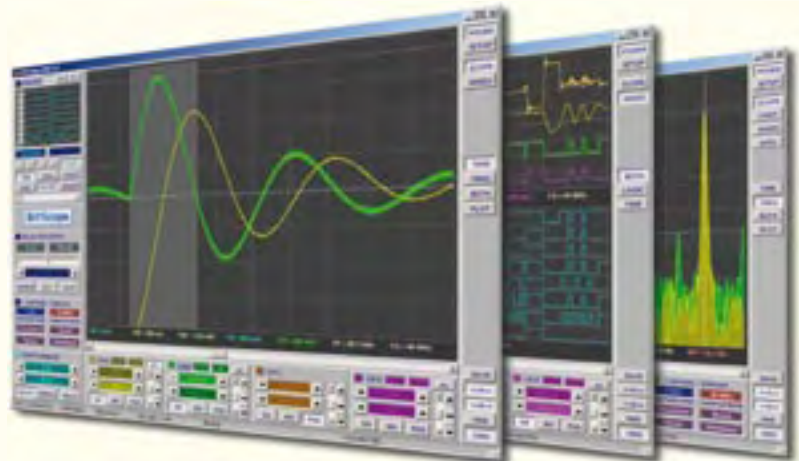
BitScope 325 includes DSO, an intuitive test and measurement software application for your PC.

The integrated test instruments include a digital storage oscilloscope, spectrum analyzer, logic state and mixed signal timing analyzer and an arbitrary waveform generator in one package.

DSO is fast, with display rates up to 50Hz and deep, with capture up to 512kS per frame.

Also included is a built-in data recorder to share captured signals with colleagues or customers via data export and real-time offline analysis.

If you also need programmability, BitScope 325 comes with the BitLib application programming library for custom software applications or full integration with existing third party tools.



**Windows, Linux or Mac  
Ethernet or USB**

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# DEVELOPMENT TOOL JUST THE WAY YOU LIKE IT

Everything you've always wanted from a development tool  
Experience the ease of creating your own electronic devices!



## Complete PIC development solution

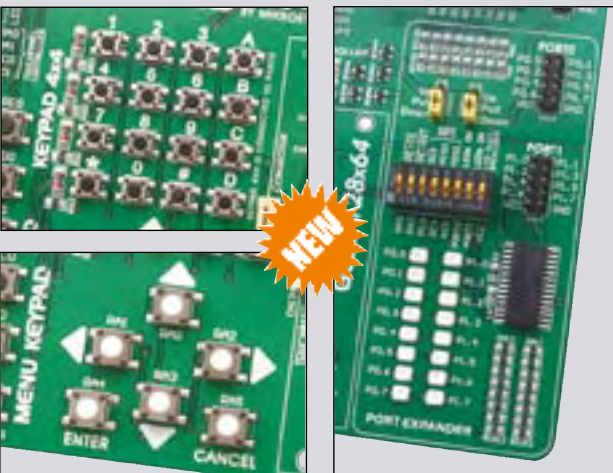
Speed up your prototype development with the EasyPIC6 Development System. The EasyPIC6 comes packed with examples that makes your PIC development fast and easy.

## Save time & money!

Get extra value for your money with this first-class tool for PIC development solutions. Get into the PIC world faster and easier than ever before with the EasyPIC6 Development System.

## Designed to suit your needs

Your development time can be considerably reduced, resulting in an early prototype design and fast time-to-market for your end product.



Thanks to many new features, you can start creating your own devices immediately. **EasyPIC6** supports **8-, 14-, 18-, 20-, 28- and 40- pin PIC** microcontrollers. The **mikroICD** (Hardware In-circuit Debugger) enables very efficient step by step debugging. Examples in **C, BASIC** and **Pascal** are provided with the board.

**Hardware In-Circuit Debugger** for step by step debugging at hardware level

**Port Expander** provides easy I/O expansion (2 additional ports) using serial interface

**Full-featured and user-friendly** development board for PIC microcontrollers



We deliver our products across the globe and our satisfied customers are the best proof of our first-rate service. The company is an official consultant on PIC microcontrollers and a Third Party Partner of Microchip Technology. We are also an official consultant and Third Party Partner of Cypress Semiconductors since 2002 and official consultants to Philips Electronics. All our products are RoHS compliant.

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## Refresh — not just the readout

Those of you with an eye for detail will not have failed to notice that Elektor looks, well, different this month. After an analytical look at the existing page layout we decided to go for a less cluttered design without hairlines, slightly thicker lines, solid bars, shadows around boxes — to mention just a few styling elements. A new type font and an even tidier cover should give the magazine a fresh lease of life.

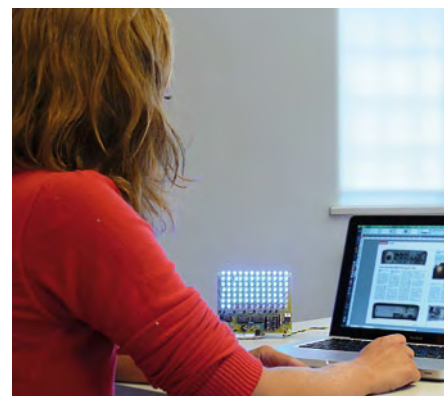
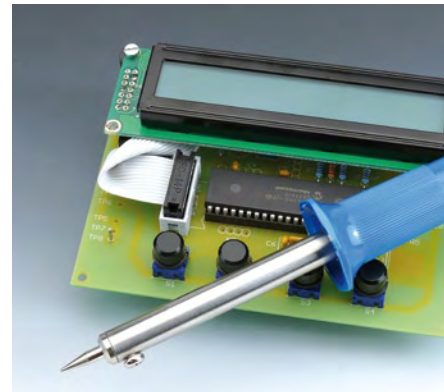
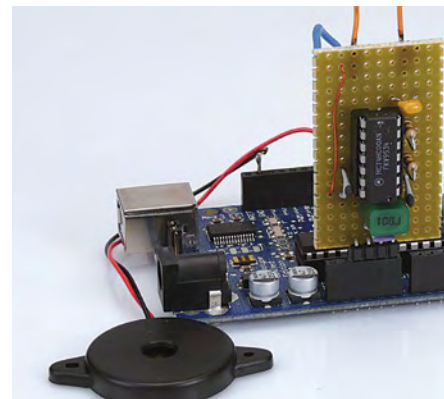
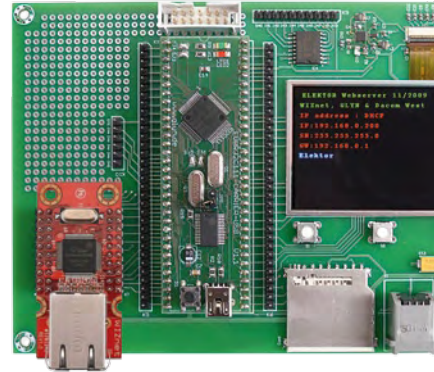
Your initial response might be “don’t bother, I read all your stuff anyway”. That’s highly appreciated, but there are more changes afoot at Elektor than just cosmetic touches to the monthly printed product. At a deeper level, we would like the magazine to remain up to date in terms of technology while keeping up the quality level our customers have come to appreciate over so many years.

Quite some time and effort was spent recently on the above issues and a number of conclusions reached. Here’s a quick summary of the main goals we hope to achieve: 1) Elektor should provide clearer pointers into the subject matter covered (see the five main areas we’ve defined in the text bar above the logo); 2) members of the editorial team should increasingly speak out on their personal fortes, interests and preferences (they already do in Editorial Board meetings); 3) the Elektor Lab has a central role in respect of the technical quality of the articles and consequently gets a central position in the magazine (‘E-Labs Inside’ section a.k.a the blue pages); 4) new online activities (to be launched later this year) should better serve the various communities out there; 5) all these changes should be transparent from, as well as underscored by, the magazine pages, hence the restyling as of this, your very own November 2009 issue. Will you change along?

Wisse Hettinga  
Elektor International Editor in Chief



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This tiny oscillator circuit, when coupled with the software running on the Arduino microcontroller board, has a huge range of potential applications, allowing proximity-based control of any other circuit or system.



## 38 Solder Station 'Plus'

Twenty pounds or so would probably buy you a simple soldering station but it would not give you the same satisfaction as one that you built yourself and besides it would not have the energy control or DVM features of this design with its in-built microcontroller.



## 48 Light Therapy Box

During the winter many people suffer from Seasonal Affective Disorder (SAD), which is commonly known as the Winter Blues. With the help of blue light these symptoms can be reduced. The blue-light generator described here has a built-in timer and is perfect for this task.

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Blue LEDs fight SAD a.k.a. the Winter Blues.

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# 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.



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# Elektor Personal Organizer 2010

NEW!

➔ Complete with a free pen and SMD-tool

The Elektor Personal Organizer 2010 makes planning your appointments a real pleasure, and you always have ready access to have handy information that everyone who works with electronics needs to know.

In addition to the usual features such as an appointments calendar, address book and notes pages, this organizer has around 40 pages packed with useful information for you as an electronics specialist, both professionally and in your leisure time. For example, there is an extensive collection of formulas and tables for calculating current and voltage, component descriptions, physical constants, connector pin assignments, and much more.

#### The Elektor Personal Organizer 2010 at a glance:

- 2010 calendar (two pages per week)
- Appointments calendar (with corner perforations) in six languages
- 40 pages of technical information on electronics
- Seven sections, separated by tab sheets
- Alphabetic address and telephone book
- Handy monthly planner
- Lined pages for your notes
- Five credit-card pockets and a pocket for business cards
- Push-button closure
- Six-ring binder mechanism (diameter 25 mm)
- Luxurious grey imitation-leather binding

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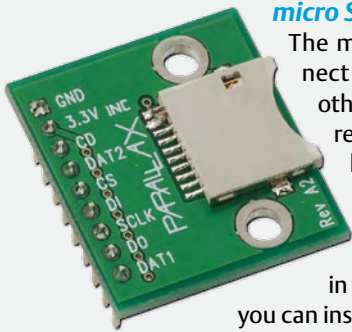
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Errors and omissions excluded.

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## New products galore from Parallax



### micro SD-Card Adapter

The micro-SD Card Adapter (32312) allows you to easily connect a micro-SD Flash Memory Card to your Propeller chip or other microcontroller. This adapter contains the components required for an SPI interface between the host microcontroller and a micro-SD memory card.

The micro-SD Card Adapter includes a card detect switch which allows you to detect when a memory card is physically present in the socket. It also includes mounting holes so you can install it in your application. Price: \$14.99.

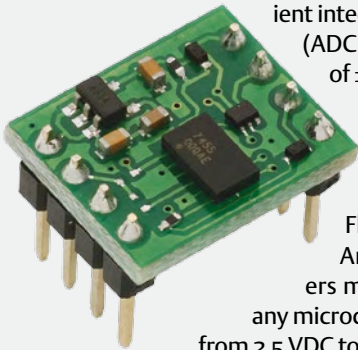
### 433 MHz RF Transceiver Module

The Parallax RF Transceiver (27982) is a very easy to use and low cost module capable of sending serial data wirelessly between microcontrollers or to a PC. The low power consumption makes this module ideal for use in battery powered applications. This module sends and receives data by AM or CPCA modulation, thus offering a higher average output power which extends its range. This module is equipped with an RSSI feature that can be utilised to improve power efficiency by waking up circuitry only when an external signal is detected. Price: \$39.99.



### MMA7455 3-Axis Accelerometer Module

The Freescale Semiconductor MMA7455L 3-Axis Digital Output Accelerometer (28526) is a low power, micro machined sensor capable of measuring acceleration along its X, Y, and Z axes. It offers several convenient integrated features including an analogue to digital converter (ADC), digital low-pass filter, and selectable sensitivity ranges of  $\pm 2g$ ,  $\pm 4g$ , or  $\pm 8g$ . This device can be easily configured to detect quick motion pulses as single taps, double taps, and 0g (free fall) conditions on any or all axes and provides configurable interrupt pins (INT1 and INT2) for each type of event.



Flexibility and compatibility are designed into this module. An on-board voltage regulator and I/O voltage level-shifters make this module especially easy to connect to virtually any microcontroller. It operates over a wide range of supply voltages from 2.5 VDC to 5.5 VDC and communicates via Serial Peripheral Interface (SPI) or Inter-Integrated Circuit (I2C) bus. Price: \$34.99.

### 7.2V Motor, Bracket and Wheel Kit

High quality 7.2 Volt DC motors feature durable construction, and 100% all-metal gears that stand up boldly to rough terrain and abuse. The motors' top speed of  $\sim 310$  RPM equates to a speed of approximately 6.6 feet/second (2.0 m/s) which is perfect for most medium- to small-size robotic projects.

The included machined aluminium hubs solidly engage the 4 7/8 inch (12.4 cm) diameter wheels. The tread is moulded directly onto the wheel and offers excellent traction on most common surfaces. Price: \$79.99.



[www.parallax.com](http://www.parallax.com)

(090750-I)

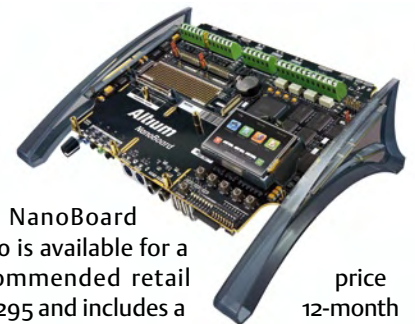
## Altium NanoBoard 3000 FPGA dev kit for £295

Altium has launched a new addition to its NanoBoard family of FPGA-based development boards. The NanoBoard 3000 is a programmable design environment, supplied complete with hardware, software, ready-to-use, royalty-free IP and a dedicated Altium Designer Soft Design license. Designers have everything they need to explore FPGAs 'out of the box'. They are no longer forced to search the web for drivers, peripherals or other software, and then have the hard work of integrating all these elements to make them work together.

Using the NanoBoard 3000, electronics designers can construct sophisticated 'soft' processor-based systems inside FPGAs without any prior FPGA expertise. Engineers do not need any specialist VHDL or Verilog skills.

Instead, they can use their existing board layout and systems design skills to construct, test and implement FPGA-based embedded systems. The IP libraries and intuitive graphical editors that are central to Altium Designer mean they can simply add processors, memory controllers, peripheral blocks and software stacks. They have everything they need to create next-generation, FPGA-hosted embedded systems with off-the-shelf components without having to write HDL or low level driver code.

Altium includes a range of reference designs and tutorials to get engineers designing immediately. More IP will be added in the future. The first NanoBoard 3000 features a Xilinx Spartan 3AN FPGA. Two more NanoBoards, featuring Altera and Lattice FPGAs, are planned. In all three NanoBoard options, the FPGA is fixed.



The NanoBoard 3000 is available for a recommended retail price of £295 and includes a 12-month subscription to an Altium Designer Soft Design License which also includes all software updates released by Altium during the 12-month subscription period. Designers can purchase a NanoBoard 3000 from Farnell UK.

<http://uk.farnell.com/altium>

(090750-II)



## The Next evolutionary leap in microphone technology



Laser-accurate technology revolutionises the very concept of the microphone, trading mechanical parts movement for the patented and incredibly precise measurement by a laser of the movement of particulates suspended in air. Proof-of-concept was demonstrated by Laser-Accurate inventor and digital audio pioneer David Schwartz at AES show floor in New York, on September 21, 2009.

There have been several key milestones in the evolution of the microphone, from the development of the basic transducer in the 19th century, to the introduction of the condenser microphone

in the 1920s, followed by FET microphones in the 1960s and the more recent multichannel microphones used for surround audio applications. The next step in this evolutionary procession was introduced at the 127th Audio Engineering Society Show, Oct. 9-12, 2009, at the Javits Center in New York City. Laser-Accurate® technology, from Schwartz Engineering & Design (SED), is claimed to represent a revolution in microphone technology: instead of the conventional diaphragm whose resonance creates electrical impulses against a coil or a back plate, Laser-Accurate technology uses a laminar stream of air in a chamber in which microscopic particles are suspended. When excited by changes in air pressure, the movement of these particles is detected by a laser beam that continuously passes through the chamber aimed at a photoelectric cell opposite the laser source.

Conventional microphone design has numerous inherent idiosyncrasies: the speed with which a traditional diaphragm can react is innately limited by its physical size and shape, and the variety of those mechanical elements inevitably adds tonal colouration — distortion — to the sound it's recording. In the design of Laser-Accurate, the diaphragm or plate is replaced with microscopic particles dispersed in a gas-filled chamber in which the laminar flow of the gas is constant. Detection of the displacement of the airstream and particles by a laser and optical receiver creates a completely non-intrusive method by which to measure the movement of air. This arrangement means no significant mass stands between the source of the sound and the transduction of it to a recording media.

(090750-V)

## Long life, low cost sealed sleeve bearing DC fans

Orion Fans, a division of Knight Electronics, has developed a new family of sealed sleeve bearing DC fans. The Challenger Series fans feature a unique patented sealed sleeve bearing system that has an exceptionally long life expectancy of more than 50,000 hours at 25°C (L10). MTBF is in excess of 200,000 hours. The new sealed sleeve fan technology retains lubricant by using metal foils that serve as a guard to redirect and recycle the lubricant. The fans were developed



in response to a continuing demand for fans with a wider temperature range and longer life than sleeve bearing fans, but at a lower cost in comparison to traditional ball bearing fans.

The Challenger Series sealed sleeve fans are offered in seven sizes ranging from 40 × 10 mm to 120 × 38 mm, and are available in 12 VDC and 24 VDC versions. Airflow ranges from 6.7 to 105 CFM.

The fans feature a brushless DC, auto restart, polarity-protected motor with a UL94V-0 plastic frame and impeller. The sealed sleeve fans are RoHS compliant.

The sealed sleeve Challenger Series fans are available from stock at Allied Electronics in North America and RS Components in Europe.

www.orionfans.com

(090750-IV)

## New ESR analyser Atlas ESR<sup>+</sup>

Measuring ESR is a fantastic way of finding faulty electrolytic capacitors, and even for tracing PCB short-circuits.

A new addition to the Peak range has now been released which offers even more than the well established ESR60. The new instrument, the Atlas ESR<sup>+</sup> (Model ESR70) adds several features that many hobbyists, tech-



nicians and engineers will find invaluable. The most notable new feature is the inclusion of 'Audible Alerts'. Every measurement of ESR will be shown on the display as usual of course, but the unit will also produce a variety of tones depending on the value of ESR. The ESR measurement range has also been enhanced, now doubled, measuring from 0 to 40 ohms with a resolution as low as 0.01 ohms. This remarkably fine resolution is great for assessing large capacitors and even allows you to use the Atlas ESR<sup>+</sup> for tracing short-circuits and finding the precise area of a PCB that has that invisible wisp of solder.

The original Peak Atlas ESR (ESR60) unit will continue to be manufactured by Peak and is available at a new special price of £75 inc VAT, while the new Peak Atlas ESR<sup>+</sup> (ESR70) is available for £89 inc. VAT. Peak charge just £2 for delivery in the UK.

If you're an existing user of the original Atlas ESR (ESR60), you can send it to Peak for a hardware and software upgrade to the ESR70 features for £55 inc. VAT. Customers with an ESR60 unit less than 3 months old can upgrade for just the difference in price between the two units.

www.peakelec.co.uk

(090750-IX)

## IAR: development package for ARM Cortex-Mo, -M1, -M3 cores

IAR Systems now supplies their Embedded Workbench for Cortex-M. Believed to be one of the world's first integrated development environment designed specifically for ARM Cortex-Mo, Cortex-M1, and Cortex-M3 based cores, IAR Embedded Workbench for Cortex-M provides a comprehensive set of tools in a single package. Based on the latest full license edition of IAR Embedded Workbench for ARM 5.40, this limited license edition is competitively priced and helps keep the costs of equipping development engineers with industry respected toolsets to a minimum. It is perfect for developers just entering the ARM Cortex market.



The package includes an editor, project management tools, a highly optimizing C and C++ compiler, and a C-SPY simulator. Other tools include hardware debugging functions, support for RTOS-aware debugging on hardware, run-time libraries, relocating assembler, linker and librarian tools.

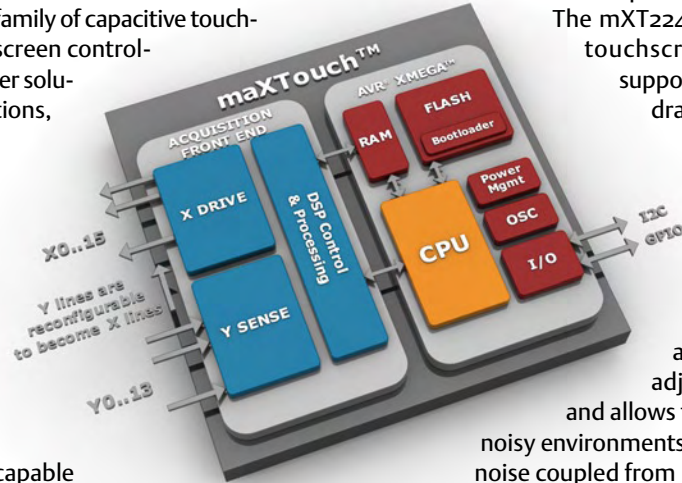
IAR Embedded Workbench for Cortex-M provides extensive support for a wide range of hardware debug systems and RTOSes and generates very compact and efficient code. Ready-made device configuration files, flash loaders and example projects are also included. The compiler can check against the rules of MISRA C (MISRA C:2004) software development standard as established by the Motor Industry Software Reliability Association. An evaluation edition of IAR PowerPac RTOS, file system, USB stack and a TCP/IP stack bundles in included within the package. IAR RTOS plugins are available from IAR Systems and other leading RTOS vendors.

www.iar.com

(090750-VI)

## Atmel maXTouch™: superior human interface touchscreen solution

Atmel® Corporation announced the production release of its new maXTouch™ family of capacitive touchscreen controller solutions,



capable of supporting an unlimited number of unique simultaneous touches with a video-quality screen refresh rate of 250 Hz. Atmel's new maXTouch technology platform supports the development of touchscreens surpassing 10 inches with full zoom, rotate, handwriting and shape recognition functionality.

The first device in the family, the mXT224, has 224 nodes that allow it to accurately report the positions of unlimited, simultaneous touches and it can completely redraw the screen every 4/1000th of a second (4 ms). The mXT224's large number of nodes and fast performance makes it the world's first touchscreen solution suitable for advanced touch screen

functionality, such as rejection of unintended touches, stretch/pinch and rotate gestures, handwriting and shape recognition such as face detection on mobile phones, mobile Internet devices (MID) and netbook screens surpassing 10 inches.

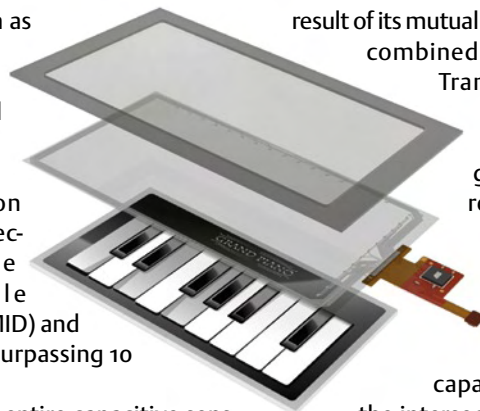
By integrating the entire capacitive sensing circuitry on-chip, these maXTouch products provide a fully integrated single-chip solution without the need for external components to support the capacitive sensing, minimizing the cost and PCB footprint requirements. Multiple mXT224

touchscreen solutions can be used to provide smaller interspatial distances between touches on larger screens. Products utilizing the advanced mXT224 touchscreen solution are currently progressing in design at several leading handset, netbook and other consumer product OEMs.

The mXT224 is the first capacitive touchscreen solution able to support the use of a stylus for drawing or signature capture and character recognition, thanks to its 80:1 signal-to-noise ratio (S/NR) and extremely fast refresh rate. A high S/NR is critical for the accurate reporting of adjacent or weak signals, and allows for precise reporting in

noisy environments such as products with noise coupled from radio transceivers, LCD displays and battery chargers. Solutions without a suitably high S/NR consume more power and decrease their response time with extra filtering and processing in an attempt to extract a weak signal from a high noise environment. In contrast, the nearest competing off-the-shelf touchscreen solution has half as many nodes as the mXT224, a screen refresh rate of only 83 Hz (66% slower) and an S/NR of only 25:1 (66% less). In addition to offering the best SNR rates in the market, maXTouch offers advanced noise suppression algorithms to provide end products with the ultimate immunity against coupled noise issues.

The unlimited number of touches possible with Atmel's maXTouch technology is the result of its mutual capacitive sensor design,



combined with Atmel's Charge-Transfer method of signal acquisition. Unlike self capacitance technologies that sense individual rows or columns leaving ambiguity in reported multi-touch positions, mutual capacitance sensors create a matrix of independent capacitive sensing nodes at

the intersections of these rows and columns. Using Atmel's maXTouch technology, each of these nodes are independently scanned within the matrix accurately sensing the position of an unlimited number of touches and delivering smooth movement in any location of the screen.

The processing efficiency provided by the XMEGA™ microcontroller CPU allows the chip to ignore unintentional activity such as facial touch when on a call with a mobile phone. This capability, combined with the ability to collect the charge image in near theoretical times, allows the maXTouch products to demonstrate extraordinary performance. The mXT224 integrates Atmel's single-cycle RISC AVR core with 32 registers and two on-chip DSP engines that process the X and Y positions on the touchscreen. An event system and peripheral DMA controller off-load all inter-peripheral communications and data transfer operations from the CPU, freeing it up for post-processing of the sensor image. This architecture enables the simultaneous processing of 224 nodes at 250 Hz, while consuming less than 5 mW. Additional maXTouch touchscreen solutions will be introduced in the Q4 2009 and Q1 2010.

[www.atmel.com/maXTouch](http://www.atmel.com/maXTouch)

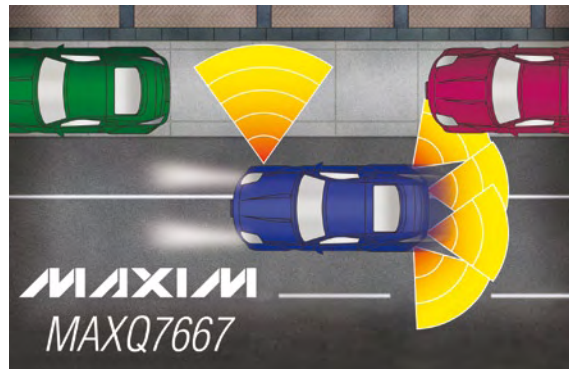
(090750-VII)

## Automotive SoC enables precision ultrasonic sensing

Maxim's newest MAXQ mixed-signal microcontroller provides a compact SoC for accurate ultrasonic distance measurements, and adds intelligence to cost-sensitive sensor-conditioning applications.

The MAXQ7667 SoC is a mixed-signal microcontroller for ultrasonic sensor applications. A highly integrated DAS (data-acquisition system), this SoC provides a cost-effective solution for applications that must measure weak signals over long distances or identify multiple targets. Its integrated functions, moreover, allow designers to add intelligence to cost-sensitive sensor-conditioning applications. The MAXQ7667 is optimized for automotive-sensor systems such as EPA (electronic parking assist) and PDC (park-distance control); it is also well suited for industrial processing, automation, and handheld applications requiring position measurement.

This 7mm x 7mm device integrates the main functional blocks required to accurately measure position, including burst control (pulse transmission), analog echo reception, digital signal processing, and a



microcontroller. This advanced integration reduces system cost and increases sensor-mounting options.

The MAXQ7667 features a programmable burst-frequency generator to compensate for transducer tolerances, adjust frequency with temperature, and perform diagnostics. Programmable burst and duty cycles can optimize power to match environmental conditions. The echo receive path includes a variable gain amplifier, a 16-bit sigma-delta ADC, a digital bandpass filter to eliminate OOB (out-of-band noise), and a digital demodulator with lowpass filtering to create an echo envelope.

The MAXQ7667 is available in a space-saving 48-pin LQFP package, and is fully supported over the -40 degrees Celsius to +125 degrees Celsius automotive temperature range.

An evaluation kit is available to speed designs. This kit includes an evaluation board and a PC-based IDE (integrated development environment), which provides a debugger, assembler/linker, time-limited version of the IAR C-compiler, and simulator.

[www.maxim-ic.com/MAXQ](http://www.maxim-ic.com/MAXQ)

(090750-XI)

## LED street lights in Portuguese cities

The implementation of efficient, attractive LED street lighting in Portugal has gathered pace over the summer as EnergiaViva has completed installations of the new UrbanLED street light in ten towns and cities. Installation

work in a further 20 Portuguese municipalities is expected to have been completed this fall.

The UrbanLED luminaires were introduced in April 2009, when they were installed on a street in the Portuguese town of Pombal. The solution, which uses LUXEON Rebel power LEDs from Philips Lumileds, provide an attractive combination of power efficiency, CRI, uniform light distribution and low maintenance and repair costs.

These qualities have seen it quickly gain favor with other municipalities in Portugal. During the summer, UrbanLED street lights have been installed on streets in the towns of Alcochete, Moita, Barreiro, Arraiolos, Pombal, Santa Maria de Feira Vale de Cambra, Estarreja, Coimbra and Torres Vedras.

The installations have been carried out by EnergiaViva and the installations are as



popular with residents as with municipality officials. The white light from the UrbanLED transforms areas that were previously a dark yellowish colour from the high-pressure sodium lamps that they replace.

The accelerating roll-out of LED street lighting means that high-pressure sodium lamps could begin to be eliminated from Portuguese streets.

The installation progress in Portugal is the result of a unique consortium of companies in the energy, lighting and construction industries. Exporlux and its development division BlueSpan, which is responsible for the luminaire design, and Rosas Constructores SA have joined forces and as EnergiaViva, deliver a complete solid state street lighting solution to municipalities.

[www.philipslumileds.com](http://www.philipslumileds.com)

(090750-X)

## From 8 to 32 bit: PSoCs with 8051 and ARM cores

By Jens Nickel (Elektor Germany Editorial)

The chip manufacturer Cypress Semiconductor is introducing two new variants to their PSoC (Programmable System on Chip) family of devices. The new PSoC3 architecture is based on an 8051 compatible core while the PSoC5 includes a 32-bit ARM Cortex-M3 processor. Since the original version using this architectural concept was introduced six years ago the company has shipped 500 million units but this new generation of devices with its improved capabilities promises to open up even more areas of application. In a time of credit crunch and recession it seems as though the embedded controller market is one area of growth in US manufacturing.

Just like the earlier version of this chip architecture (now renamed PSoC1) the new system-on-chip variants contain digital building blocks which are configured via software (just like a CPLD) to produce timers, counters PWM generator and a whole lot more. Uniquely the PSoC1 and the two new PSoC chips have the capability to configure analogue circuits also so that ADCs (with 20-bit resolution), DACs, mixers, PGAs (Programmable Gain Amplifiers), opamps and much more can all be implemented on-chip. The chip architecture is popular with designers because it often results in a true single-chip solution which reduces time spent in development and produces a finished chip which occupies much less space on the PCB compared with other solutions.



entiator; the user can select the amount of feedback and much more besides. At the press of a button the tool generates a set of APIs which allows the running software access to the functional hardware blocks. For controller software development there is a CA51 Compiler from Keil and a GNU GCC-ARM Compiler included in the IDE. The 'PSoC Creator' combines and expands on the functionality of the earlier 'PSoC Designer' and 'PSoC Express' tools which were developed for use with earlier PSoC1. PSoC Creator is a completely new development and not compatible with these older tools.

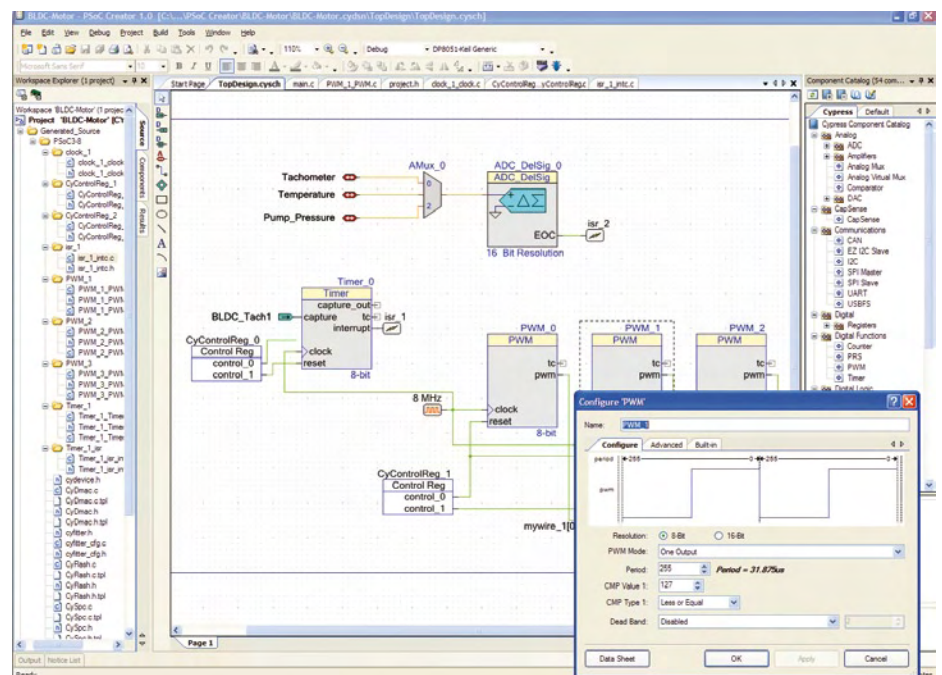
### Faster, Better, Bigger, More

The introduction of these new variants to the PSoC family was spurred by the custom-

er's request for more processing power. The earlier PSoC devices are based around an M8C core and many have been put to good use in the design of computer keyboards and USB mice. Processing power is sufficient for jobs such as motor control and sensor interfacing e.g. the 'CapSense' capacitive proximity detector input sensor developed by Cypress to replace unreliable mechanical switches and sliders. More advanced applications such as audio/video processing, multimedia (now in the automotive sector) and high speed communication processing all demand significantly more processing power. The need for speed is ever present. Cypress estimates that the potential market for its 8 to 32-bit embedded controllers could be in the region of \$15 billion. Com-

### From Drag & Drop to finished circuit

Programming and configuring the new PSoC-Chips is accomplished using the 'PSoC Creator' Integrated Design Environment (IDE). This powerful tool is free to download from Cypress semiconductor. The PSoC Creator environment allows the connectivity of the functional blocks in the chip to be defined using a 'drag and drop' graphical interface placing the blocks on a 'design canvas'. The IDE is supplied with a library of dozens of pre-configured analogue and digital peripherals and the user can also develop new blocks and add them to a library as necessary. The user interface allows the functional block connections to be configured down to opamp level and 'parameterized' to make optimum use of the on-chip resources. An integrator for example could be reconfigured as a differ-



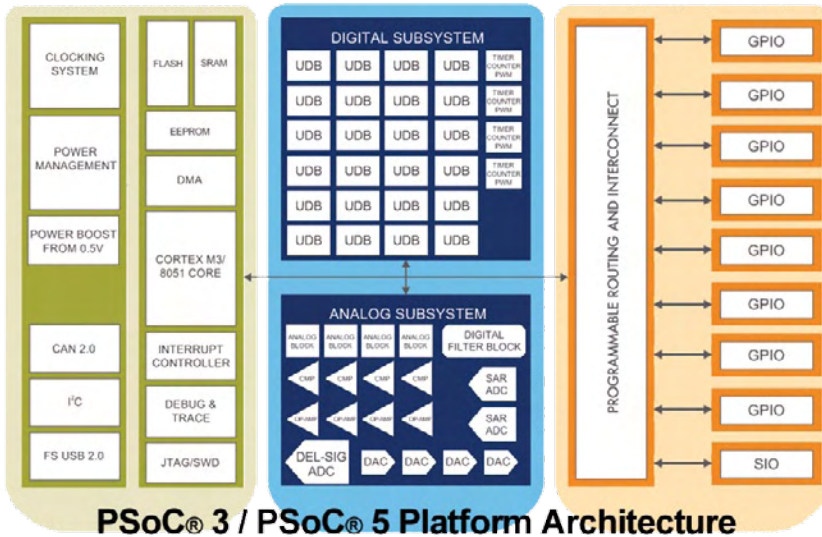
peting manufacturers offering FPGAs and other similar programmable devices will also take some share of this market.

The new PSoC variants bring with them impressive processing power: The 8-bit 8051 processor achieves 33 MIPS while the 32-bit ARM Cortex-M3 can hit 100 MIPS and its DMA interface achieves fast memory access. In addition the number of programmable gates has risen from 1,000 on the original PSoC1 up to 20,000 on the PSoC3. Filter functions are now realised digitally rather than as analogue blocks. This should increase available bandwidth; the original

chips also provide support for full-Speed USB, I2C, SPI, UART, CAN and LIN interfaces. The PSoC5 is also fitted with a JTAG debug interface.

**Starter kits from \$49 US**

First samples of the PSoC3 chip should be available from November 2009 and it is anticipated that samples of the PSoC5 will be available by the beginning of 2010. Production is due to commence in the first quarter and second half of 2010 respectively. The chips will be available in a variety of package outlines offering different levels of integration (memory size and GPIO count).



**PSoC® 3 / PSoC® 5 Platform Architecture**

was good for signals up to 150 KHz before it ran out of steam. Prominent at the top of the data sheet are the power saving features of the design: firstly the supply voltage range is quoted as 5.5 V to 0.5 V (!) while 'hibernate' mode of the PSoC3 consumes just 200 nA which should be good news to designers of small mobile equipment, wireless sensors and other ultra low power applications.

A significant advantage of the family is the pin and API compatibility between the 8 and 32-bit architectures. This means that a designer can start system design with a PSoC3 and if later on more processing power is required the existing design can migrate up to the PSoC5 platform without problems. A good feature to simplify circuit layout is the free allocation of any GPIO pin to any signal in the functional blocks. The

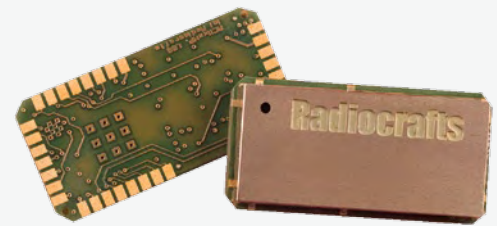
The unit price is expected to be in the range between 1 and \$10 US. Two evaluation kits are available: the PSoC 3 FirstTouch™ Starterkit retails at \$49 US and includes a PSoC3, evaluation board and on-board acceleration sensor, thermistor and 'proximity detector' (we took a closer look at the starter kit in last month's edition of Elektor).

A more comprehensive kit costing \$249 US is well appointed and contains both a PSoC1 and a PSoC3 processor board. This will give developers a hands-on opportunity to compare the two PSoC systems. The Cypress semiconductor website is the place to go for data sheets, application notes and also to download the 'PSoC Creator' software package, just follow the link below.

[www.cypress.com/psoc](http://www.cypress.com/psoc) (090775-1)

**Low cost high power RF module for 868 MHz ISM**

Radiocrafts AS have expanded their RC232 product line family with a completely new high power module, the RC1180HP-RC232. The module is pin compatible



with the existing RC11xx-series, and enables extended range using the same low-cost design philosophy applicable for the whole RC11xx product family.

The RC1180HP-RC232 (868 MHz) module is certified for operation up to 500 mW under the European radio regulations for license-free use. When used with quarter-wave antennas a line-of-sight range of over 3 km can be achieved.

The compact RC1180HP-RC232 module, measuring only 12.7 × 25.4 × 3.3 mm, sets a new standard of integrating high power technology into a complete RF modem in one single tiny package, replacing tens of components compared to a discrete design. No external components are required, except an antenna. The modules are delivered on tape and reel for efficient volume production.

The module is a complete RF system solution running on the existing industry proven RC232™ protocol, with an easy-to-use UART interface for both configuration and communication. The embedded RC232™ protocol provides a point-to-multipoint solution with individual addressing or broadcast, and CRC check for signal integrity. The module can also be used as a wireless RS232 / RS485 cable replacement. Modules and Demo Kits are available now.

[www.radiocrafts.com](http://www.radiocrafts.com) (090750-NN)

# Where (in the World) Can You Get It?

## Ordering electronic components



By Thijs Beckers (Elektor Netherlands Editorial)

As far as electronic components are concerned, going out to do a bit of shopping is a thing of the past. Now you can order almost everything on the Internet. Email, plain English and a credit card go a long way. You just have to wait a little while for the courier service, and then you have what you want. Despite retail having gone e-tail, a visit to your local electronics shop can have its advantages. Here we present an overview of electronic component suppliers.

As opposed to five years ago, or even a bit longer, nowadays almost every electronic parts retailer or distributor has an Internet presence. In fact, the situation has completely reversed: in many cases there's only a webshop, so you unlike the glory days of London's Edgware Road you can't just pop in and pick up your components, or have them handed to you over the counter.

How does this affect the availability of electronic components? And what about service and prices?

### Can you get anything you want?

There are now countless webshops on the Internet. Of course, most of them are aimed at consumers, but the situation in the

electronic components business is somewhat different. As this involves individual components instead of finished products, it is much more common for a company (OEM) to order these components (in bulk) with a view to making an end product, which is then ordered by an end user.

There are a number of large companies, such as Farnell, Mouser, DigiKey and RS Components, which can supply nearly all commonly used electronic components. If you are a commercial customer, they offer a good range of products and (in most cases) a good search engine. However, it is often difficult (or more difficult) for private persons to place orders with these companies, since they are used to handling orders for large quantities. In addition, you can often find components at lower prices elsewhere, such as in much smaller webshops that specialise in particular components. Naturally, this requires a certain amount of searching, but as a private person you can usually find the time for this — at much lower cost than, say, a 50-mile ride, or a bus ticket to the nearest city (and finding the shop closed).

Most large wholesalers and distributors only take orders from commercial customers. If you don't fall in this category, you can ask your acquaintances whether they know someone with a small business registration who would be kind enough to place an order for you. Here you have to bear in mind that prices on sites of this sort typically do not include sales taxes, which you have to pay as well.

### Other sources

In addition to webshops, you can find electronic components on auction sites and sites that sell second-hand goods. The best known example is [www.ebay.com](http://www.ebay.com), but if you ask your favourite search engine to look for auction sites you will find many more. On the eBay site, it's usually worthwhile to look for shops (eBay stores) that specialise in electronic components.

### Service

If you take the traditional approach of visiting your local (or nearest) electronics shop, you can usually expect to receive suitable assistance from the sales staff. Their knowledge (with regard to more than just components) can come in handy when you are looking for a particular solution, so don't be afraid to ask for help.

When you search for components on the Internet, you are fully on your own. You have to personally pick the right component package (now then, what should it be: TQFP, LQFP, or something else?). You may be able to obtain useful information from forums oriented toward electronics, such as a number of the .alt and .sci Yahoo newsgroup clusters. Some sites provide component data sheets, which can be very helpful. They can be very useful when you're making a PCB layout or looking for a component with suitable specifications.

## Tips!

- Many manufacturers let you order free samples. In this case, you can obtain a few components either free of charge or by paying the shipping charges only.
- In quite a few cases, you can also order directly from the manufacturer. This may not be the least costly approach, but it is certainly the most direct.
- Data sheet sites such as [www.alldatasheet.com](http://www.alldatasheet.com), [www.datasheetarchive.com](http://www.datasheetarchive.com), and [www.datasheetcatalog.com](http://www.datasheetcatalog.com) are especially useful.
- Exercise caution with orders direct from China and other far Asian countries, since they are a source of many fake items.

## Group purchasing

Some components are only available in large quantities. As a private person, you often need only a small quantity or just one, so it's unreasonable and not affordable to buy 100 or more at once.

A group purchase often provides a remedy in such situations. Someone takes the initiative to organise the purchase of a particular component (or even a complete product) from a wholesaler at a reduced price. If enough people can be found to participate in the group purchase, the initiator orders the components or products and forwards them to the other members of the group after they are received.

These purchases are usually organised via a website in order to find enough participants. Group purchases of specific items, such as engines for model aeroplanes, are often organised on hobby sites.

As you are dealing here with an individual who organises the purchase, rather than a webshop, it's a good idea to first make sure that the person concerned is trustworthy, such as by looking for previous group purchases organised by this person. Of course, there's always a certain risk, but if you find many positive comments and few if any negative comments, you generally don't have to worry.

## NOS and NIB

A noteworthy phenomenon is companies that sell what are called 'NOS components'. 'NOS' stands for 'new old stock', which means components that are unused (and thus new) but which are no longer in production and have been in stock for a while, perhaps tucked away in the back of a warehouse ('old stock'). In particular, there is a surge in demand for valves that were once produced by companies that no longer exist. 'NIB' (new in box) is also sometimes taken to refer to the above type of component.

This can even go so far that a company buys a full fabrication system — the complete production line with all the original machinery — in order to produce and sell 'old-fashioned' components. For example, Russian Sovtek valves are made using former Telefunken machinery.

Company	Internet address	Notes
<b>International/ global</b>		
Antique Electronic Supply	<a href="http://www.tubesandmore.com">www.tubesandmore.com</a>	valves
ACAL Technology	<a href="http://www.acaltechnology.com">www.acaltechnology.com</a>	distributor, semiconductors, RF, emech, interconnect, passive
Allied Electronics	<a href="http://www.alliedelec.com">www.alliedelec.com</a>	broadband supplier
Conrad Electronic	<a href="http://www1.uk.conrad.com">www1.uk.conrad.com</a>	broadband supplier
DERF Electronics Corp.	<a href="http://www.derf.com">www.derf.com</a>	distributor
Digi-key	<a href="http://www.digikey.com">www.digikey.com</a>	broadband supplier
Distrelec	<a href="http://www.distrelec.com">www.distrelec.com</a>	broadband supplier
Eldata	<a href="http://www.eldatacomponents.com">www.eldatacomponents.com</a>	broadband supplier
Farnell	<a href="http://www.farnell.com">www.farnell.com</a>	broadband supplier, distributor
Futurlec	<a href="http://www.futurlec.com">www.futurlec.com</a>	broadband supplier, distributor
Glyn	<a href="http://www.glyn.com">www.glyn.com</a>	embedded, Japanese products
Huijzer	<a href="http://www.huijzer.com">www.huijzer.com</a>	Elektor components (trade only)
Ledsee	<a href="http://www.ledsee.com">www.ledsee.com</a>	LEDs
Monacor	<a href="http://www.monacor.com">www.monacor.com</a>	audio parts
Mouser	<a href="http://www.mouser.com">www.mouser.com</a>	broadband supplier
Nedis	<a href="http://www.nedis.com">www.nedis.com</a>	broadband supplier (trade only)
RF Parts Company	<a href="http://www.rfparts.com">www.rfparts.com</a>	RF components
RS Components	<a href="http://www.rs-components.com">www.rs-components.com</a>	broadband supplier, distributor
Sparkfun	<a href="http://www.sparkfun.com">www.sparkfun.com</a>	microcontroller kits
Würth Elektronik	<a href="http://www.we-online.com">www.we-online.com</a>	inductors, transformers
<b>National (mostly UK based)</b>		
2001 Electronic Components	<a href="http://www.2k1.co.uk/">www.2k1.co.uk/</a>	broadband supplier
Anglia Components	<a href="http://www.anglia.com/">http://www.anglia.com/</a>	distributor of approx. 40 brands
Arcol	<a href="http://www.arcol.co.uk">www.arcol.co.uk</a>	resistors
Arrow	<a href="http://www.arrowuk.com">www.arrowuk.com</a>	broadband supplier, trade only
Avnet Abacus	<a href="http://www.abacus.co.uk">www.abacus.co.uk</a>	interconnect, passives, emech, power supplies, batteries
Bardwells (N.R.)	<a href="http://www.bardwells.co.uk">www.bardwells.co.uk</a>	family business, famous shop, wide range of parts
BEC Distribution	<a href="http://www.bec.co.uk">www.bec.co.uk</a>	TOKO distributor, RF parts
Bitsbox	<a href="http://www.bitsbox.co.uk">www.bitsbox.co.uk</a>	UK P&P £1.50 flat rate
Bowood Electronics	<a href="http://www.bowood-electronics.co.uk">www.bowood-electronics.co.uk</a>	broadband supplier, kits



Buy electronic components	<a href="http://www.buy-electronic-components.co.uk">www.buy-electronic-components.co.uk</a>	
Chelmer Valves	<a href="http://www.chelmervalve.co.uk">www.chelmervalve.co.uk</a>	valves, huge range and stock. Also components
Cliff Electronic Components	<a href="http://www.cliffuk.co.uk">www.cliffuk.co.uk</a>	components for the music industry. Also USA, Australia, Taiwan
Component Forum	<a href="http://www.componentforum.co.uk">www.componentforum.co.uk</a>	obsolete and surplus stock, buy & sell
CPC Farnell	<a href="http://cpc.farnell.com">http://cpc.farnell.com</a>	electrical parts, mainly industrial. Also consumer electronics
Cricklewood Electronics	<a href="http://www.cricklewoodelectronics.com">www.cricklewoodelectronics.com</a>	components, CCTV, hard to find items
Cyclops Electronics	<a href="http://www.cyclops-electronics.com">www.cyclops-electronics.com</a>	obsolete and rare parts
Dannell Electronics	<a href="http://www.dannell.co.uk">www.dannell.co.uk</a>	passives, hardware, connectors, crystals, ICs. OEM and industry
Display Electronics	<a href="http://www.distel.co.uk/">www.distel.co.uk/</a>	surplus electronics, must see
Easby Electronics	<a href="http://www.easby.com">www.easby.com</a>	distributor, passive, electromechanical, connector, discrete semiconductors
Electronic Projects Online	<a href="http://www.electronicprojectsonline.co.uk">www.electronicprojectsonline.co.uk</a>	components, PCB, kits, hobby supplies
ES Electronic Surplus	<a href="http://www.electronicsurplus.co.uk">www.electronicsurplus.co.uk</a>	surplus electronics, must see
ESR Components	<a href="http://www.esr.co.uk/">www.esr.co.uk/</a>	broadband supplier
Fast Components	<a href="http://www.fastcomponents.co.uk">www.fastcomponents.co.uk</a>	electronic components sets, audio & RF
GH Engineering	<a href="http://www.ghengineering.co.uk">www.ghengineering.co.uk</a>	VHF, UHF, SHF and microwave parts
Greenweld	<a href="http://www.greenweld.co.uk">www.greenweld.co.uk</a>	surplus electronic, gadgets, innovations, tools, home and leisure and hobby products
Hylec-APL	<a href="http://www.hylec-apl.com">www.hylec-apl.com</a>	emec, cables, lampholders; industrial
JAB Electronic Components	<a href="http://www.jabdog.com">www.jabdog.com</a>	parts for radio amateurs
JPR Electronics	<a href="http://www.jprelec.co.uk">www.jprelec.co.uk</a>	distributor, broadband supplier
Kestrel Electronics	<a href="http://www.kestrel-electronics.co.uk">www.kestrel-electronics.co.uk</a>	distributor, PIC, TTL, microprocessor
Maplin Electronics	<a href="http://www.maplin.co.uk">www.maplin.co.uk</a>	broadband supplier, kits, shops nationwide
Mechatronics Online	<a href="http://www.mechatronics-onlineshop.co.uk">www.mechatronics-onlineshop.co.uk</a>	students, hobbyists, schhol, university. Kits, microcontrollers
Mushroom Components	<a href="http://www.mushroom.co.uk">www.mushroom.co.uk</a>	obsolete parts
New Modellers Shop	<a href="http://www.newmodellersshop.co.uk">www.newmodellersshop.co.uk</a>	model railway electronics
Omni Electronics		174 Dalkeith Road, Edinburgh. No website?
Oracle Components	<a href="http://www.oraclecomponents.co.uk">www.oraclecomponents.co.uk</a>	obsolete, rare, military, aerospace, NATO parts
Quasar Electronics	<a href="http://www.quasarelectronics.com">www.quasarelectronics.com</a>	kits, modules, projects, hardware
Rapid Electronics	<a href="http://www.rapidonline.com">www.rapidonline.com</a>	distributor, broadband supplier, Lego
RSH Electronics	<a href="http://www.rshelectronics.co.uk">www.rshelectronics.co.uk</a>	broadband supplier
Tech Supplies	<a href="http://www.techsupplies.co.uk/">www.techsupplies.co.uk/</a>	robotics kits, PICaxe
The Electronics Shop	<a href="http://www.theelectronicsshop.co.uk">www.theelectronicsshop.co.uk</a>	audio and lighting
VTM (UK)	<a href="http://www.vtm.co.uk">www.vtm.co.uk</a>	distributor, crystals, inductors, semiconductors

## Reader feedback

**We received a few responses to our request in the i-TRIXX e-Weekly item for week 35, 2009. Here we would like to share one of them with you.**

**Dear Elektor,**

sadly we have found that all the electronics shops in our region have disappeared. This is not such a great problem for us as a company, since we can do business with all sorts of distributors.

However, I was looking for MRF286 FF transistors for a personal project. We managed to find a few via HK Inventory, so we initiated a request for quotation (RFQ). We received several hundred responses to this request from the Hong Kong and China region, with unit prices ranging from \$5.50 to \$150.

I happened to know from one of my customers that prices in this region depend on whether you are a Chinese or non-Chinese customer. He has a native Chinese employee who requests prices for his needs and has the orders delivered to an address in China, and who personally organises the transport from that location. If suppliers have any idea that you are a foreigner, the prices increase sharply. In addition, the suppliers are not paid until the goods are delivered

to my customer in China, as otherwise you apparently never receive your goods.

Knowing this, I asked my customer for a favour: to have his buyer order the transistors for me. I was quite willing to purchase several hundred, as long as I got a fair price. The specifications were clear: this transistor in this package with this manufacturer code. I sent the buyer a list of the responses I had already received that appeared to me to be plausible. However, it turned out that things weren't that simple. Some people tried to tell me that there were different versions of the transistor (despite the fact that the specifications were so clear that there was only one possibility), while others did their best to sell me development services because it takes professional expertise to solder components on a circuit board.

It ultimately turned out that all the suppliers who initially responded to my RFQ were beating about the bush. They were presumably trying to get a foot in the door so they could supply other products. A year later, some of them are still sending me lists of their product lines. None of them include RF transistors, which is what I am interested in.

The friend of the Chinese buyer also told us that salvaged items are often sold as new. At that point, we put an end to the exercise and started looking for a different solution.

**Jeff V. (Belgium)**

## Prices and charges

The enormous free market created by the Internet results in fierce competition and very price-conscious consumers. This naturally puts strong pressure on the prices charged by suppliers, but the downside is that shipping charges and import duties are almost always added to Internet orders because the shop isn't just around the corner or there simply isn't any shop where the components can be picked up.

Finding the lowest price is an entertaining challenge, but it is sometimes like looking for a needle in a haystack. It often happens that some of the components you need for a project are available at very good prices in one webshop, while some other components are less expensive in another shop. It sometimes takes a lot of calculation to figure out that it would have actually been less expensive to order everything from that webshop with the high shipping charges.

## Overview

To make your searching a bit easier, we have put together two tables with some useful internet addresses. Unbiased and by no means exhaustive, it presents an overview of the best known suppliers of electronic components, along with their characteristics or special features. Where a supplier is marked 'distributor' in the Notes col-

umn it is not usually possible to order from them as a private individual — but feel free to try. "Broadband supplier" indicates that a wide range of components and materials is stocked, including passives, semiconductors, connectors, cables and electromechanical parts. These companies typically pride themselves in publishing catalogues "thicker than the Bible".

We welcome additions and updates to the tables, so all readers can benefit. Naturally, you can also visit our forum [1], where other users may be able to point you in the right direction and where you can tell other users about your favourite supplier or webshop.

(090592-1)

## Internet Link

[1] [www.elektor.com/forum](http://www.elektor.com/forum)

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Assembled Order Code: AS3067 - **£24.95**



Most items are available in kit form (KT suffix) or assembled and ready for use (AS prefix).

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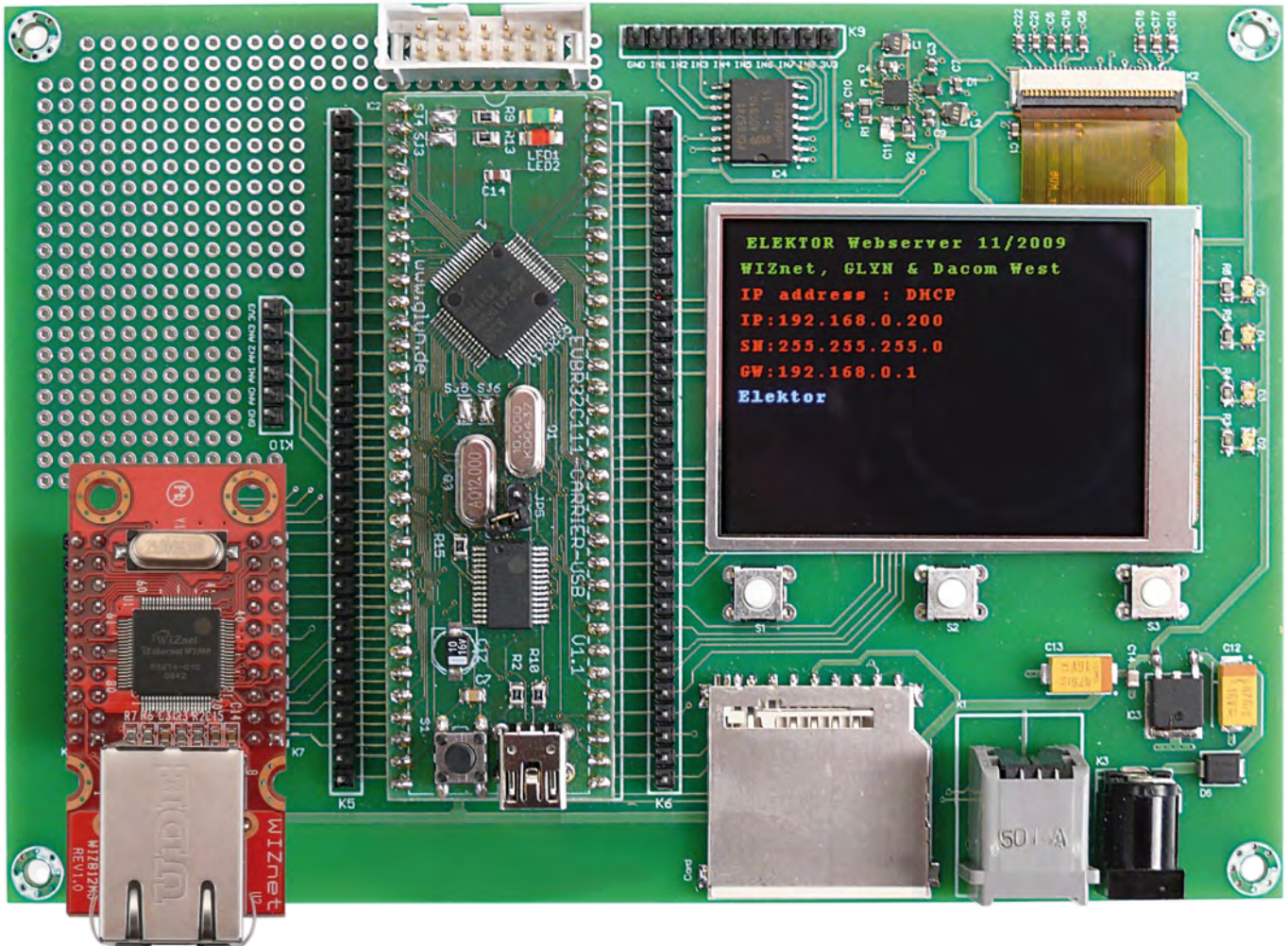
USB PIC programmer for all 'Flash' devices. No external power supply making it truly portable. Supplied with box and Windows Software. ZIF Socket and USB lead not included. Assembled Order Code: AS3128 - **£49.95**



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# R32C Web Server

## Networking module for HTTP,



## e-Mail, FTP and much more

by Jinbuhm Kim (South Korea) and Joachim Wülbeck (Germany)

The R32C microcontroller goes Internet! A small add-on module for the application board from our September 2009 issue combines a TCP/IP chip plus Ethernet interface, a network connection with built-in transformer and status LEDs. This handy combination makes it child's play to implement a web server and many other Internet applications without getting involved in complexities such as TCP/IP protocol. Free downloads of an Open Source driver, a short web server program and other sample software complete this attractive proposition.

The South Korean electronics company WIZnet [1] has its origins at the University of Seoul eleven years ago. Within a short

while it had produced the W3100, the first hardwired TCP/IP chip on the market with a 10/100 MBit/s Ethernet interface. The

Internet protocol stack in this was created in hardware, so as to relieve the MCU of complicated TCP/IP protocol processing.

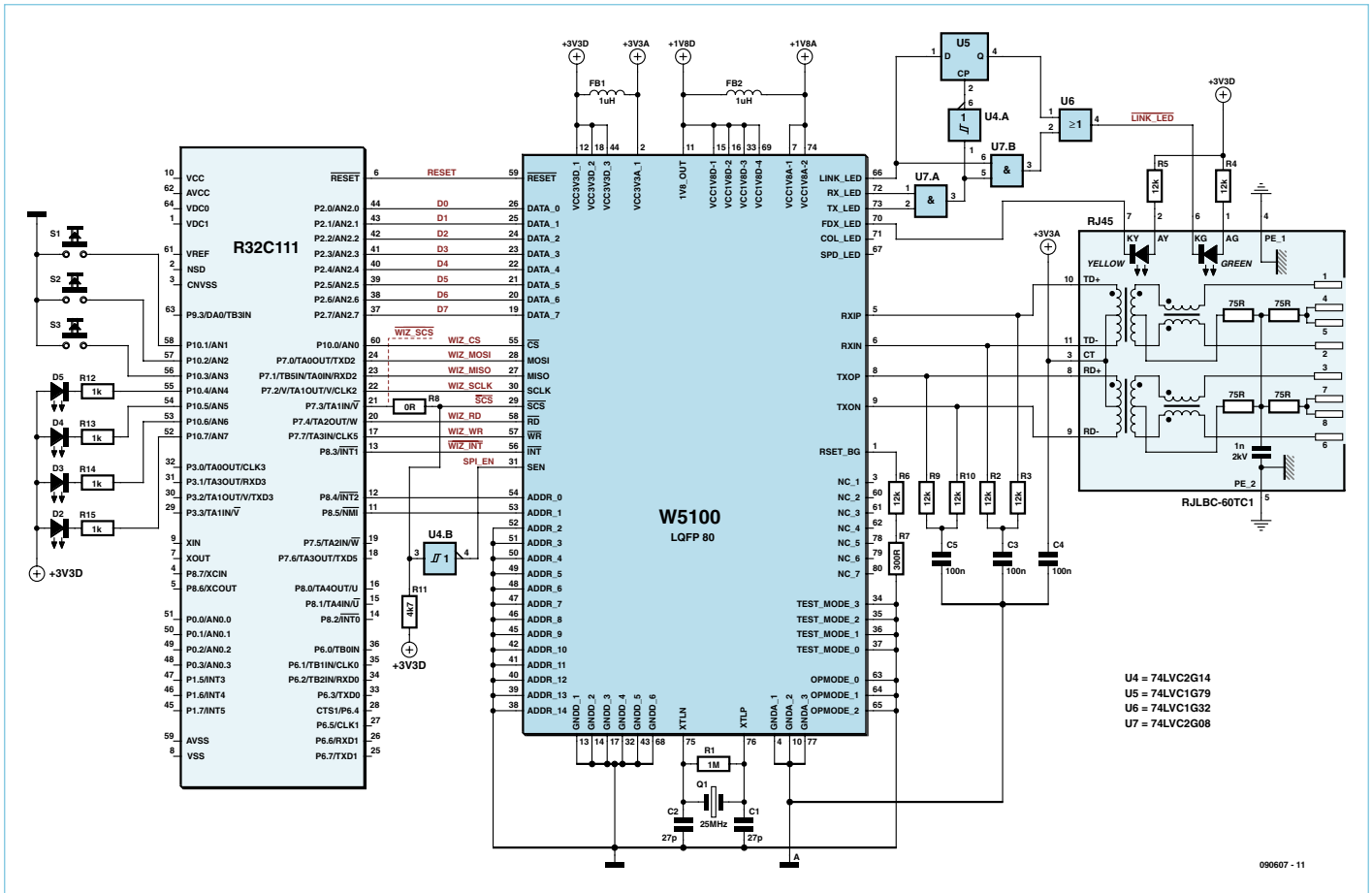


Figure 1. Schematic of the network module and R32C connection (for clarity the application board section shows only the LEDs and press switches, whilst the 3.3 V regulator and some passive components in the network module are not shown either).

This enabled Internet applications such as web server, e-mail, FTP and plenty more to be implemented even on small 8-bit microcontrollers without the need for an operating system. Users need not worry about programming the PHY, MAC, IP and TCP layers but can instead rely simply on the built-in driver functions (see panel for explanation of these abbreviations and [8] for how these layers work).

### Family connections

After the W3100 the company developed several more chips, with varying levels of integration. The W5100 that we are using here is a 3-in-1 chip that combines the TCP/IP, MAC and PHY functions in hardware and is controlled either by SPI bus

or over an 8-bit parallel interface. Network modules in DIL form, comprising the TCP/IP chip and an RJ-45 connector with transformer, simplify the hook-up further. In this project we employ the WIZ812MJ module, which plugs very conveniently into our R32C application board.

WIZnet's product range also offers higher performance Internet chips, handling data rates up to 80 Mbit/s. These are for demanding applications such as HD video or image recognition. In the near future the 4-in-1 chip W7100 will further enhance the range; as well as the protocol functions already mentioned this also includes an 8051 core, 64 kB of RAM and 64 kB + 128 kB of flash memory.

### The hardware

If the WIZ812MJ module is placed in the socket already provided on the application board [2] the R32C/111 can communicate with the W5100 using SPI or an 8-bit parallel connection. In the latter case we must use the so-called indirect mode. In contrast to direct mode the full address bus is not used, which saves a whole load of signal lines. Despite this short cut the indirect mode is just as fast; to read or write a block of data, only the start address needs to be sent (over the data bus). The W5100 now counts up the address independently in auto-increment mode. On the address bus only the two lines A0 and A1 are used. These define whether we have a data byte or the high/low byte of the start address on the data bus.

The schematic in **Figure 1** shows a section of the application board, the connections for the W5100 and the hook-up with the network module. The WIZ812MJ consists of the W5100 plus a crystal, RJ-45 connector and some gates. These gates combine various LED signals from the W5100 in order to produce a steady (non-flashing) link signal. An inverter uses the SPI chip select (/SCS) output to generate the inverted SPI enable (SEN) signal. This means the /SCS connection between controller and Internet chip is all you need to initiate SPI mode.

The internal core voltage of 1.8 V is produced by the W5100 itself. These and all other operating voltages are stabilised by capacitors on the WIZ812MJ module, although for the sake of clarity they (and the external 3.3 V regulator) are omitted from the schematic.

### The Physical Layer

A symmetrical transformer is integrated within the RJ-45 connector. This enables the PHY in the W5100 to swap RX and TX signal lines when necessary. This function is known as auto crossover (auto-MDIX for short) and avoids the need for crossover cables. Consequently you can use normal patch cables for the direct connection to the PC.

The auto-negotiation function determines the physical data rate (10 Mbit/s or 100 Mbit/s) automatically, together with other counterpart connection parameters such as full or half duplex. Once complete, point-to-point connection is made and the link is established.

Signals can be transposed within the pairs RX+/RX and TX+/TX. At

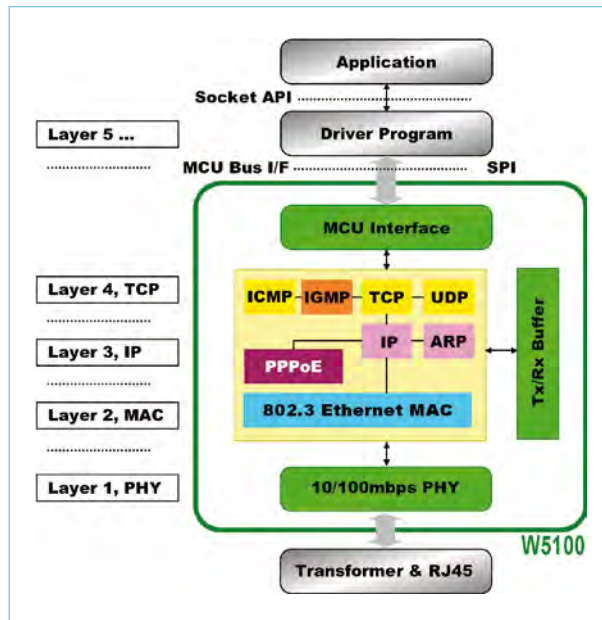


Figure 2. On the W5100 the PHY, MAC and TCP/IP protocols are embedded in hardware to reduce the load on the controller (and on the programmer!).

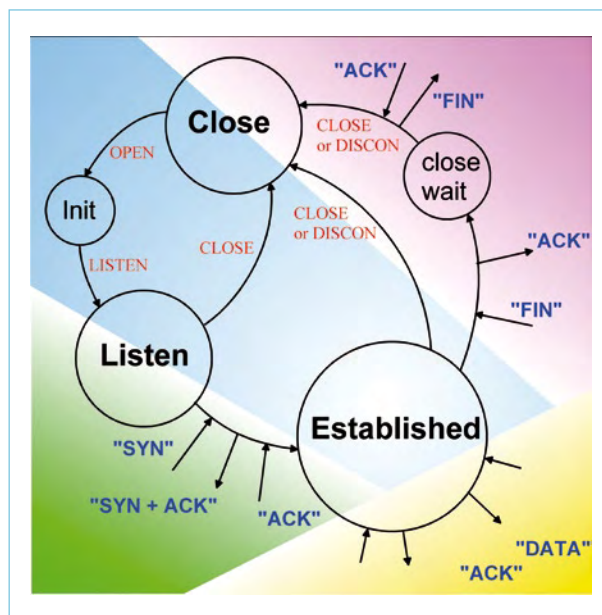


Figure 3. Status diagram of a web server. The W5100 takes charge of the boring details and corresponding driver functions, with the status management function operations clearly visible in the main program (see Listing 2)!

10 Mbit/s speeds the polarity of the PHY will be recognised and inverted when required (polarity reversal). A different technique is used at 100 Mbit/s. There is no longer any polarity here, as ones are signalled as a level change and zeros by breaks. To guarantee reliable clock retrieval, the bit-stream is transcoded specially so that excessive numbers of ones or zeros are never sent in direct succession.

### The TCP/IP protocol

Network connections are always regarded as layers that are constructed one above the other, defined in general terms in the so-called ISO/OSI levels model. In this system data and commands from a higher level are passed down to the next one below, with data and replies received back. In contrast to this kind of 'vertical communication' a virtual point-to-point connection is established horizontally between two equal levels on either side of the communication link. This calls for a number of protocols at the corresponding levels.

The inner construction of the W5100 and the protocol levels are shown in **Figure 2**. The W5100 handles all tasks in the first four layers (PHY + MAC + TCP/IP). Application and driver program activities are processed at Layer 5 and control the W5100. The driver needs to be interfaced correctly to the microcontroller employed and for the mode of communication required (SPI or parallel); WIZnet provides source code for various 8, 16 and 32-bit controllers free of charge. The tasks handled by the application program are confined then to status control (see below) and the specific application.

The application program also assigns the IP address. For this purpose the W5100 has its so-called Common Register in the memory range from 0x0000 to 0x0030, which stores all network-specific information (IP, Gateway and MAC addresses, Netmask, etc.). This register is cleared if you call a Reset. For this reason the network information needs to be stored in a non-volatile EEPROM location (integrated here in the R32C). This makes it possible to request an IP address and other networking details from a DHCP server (e.g. a DSL router) dynamically.

The Socket Registers (address range 0x0400 to 0x0800) store all configuration and status data for a maximum of four simultaneous connections ('sockets'). This is also where we define whether a socket is to operate as a client or server. A socket represents a virtual point-to-point connection and is effectively the interface to the outside world. Using this register the main program is also able to check the status of connections and react correspondingly following an interrupt or by regular polling. The send and receive store (16kB), address range 0x4000 to 0x8000, can be applied variably to serve up to four sockets.

### Setting up connections

**Figure 3** illustrates the states of a socket during a TCP connection. If we wish to implement a web server for example, the first thing to do is to configure a socket to Port 80 and initialise it. We do this using the two commands `socket()` and `init()`. The socket now changes from 'closed' status via 'init' into 'listen' state and is now in receive mode. A connection is not established a Client (for instance the browser in a PC) calls up data from this web server. TCP connections are always opened after double confirmation on both sides. These conformation data packets (handshaking) are generated independently by the W5100. Only after this is the horizontal connection created, when data can be transferred.

During the connection setup process the status of the socket changes from 'listen' to 'established'. The main program recognises this status and can read out and analyse the

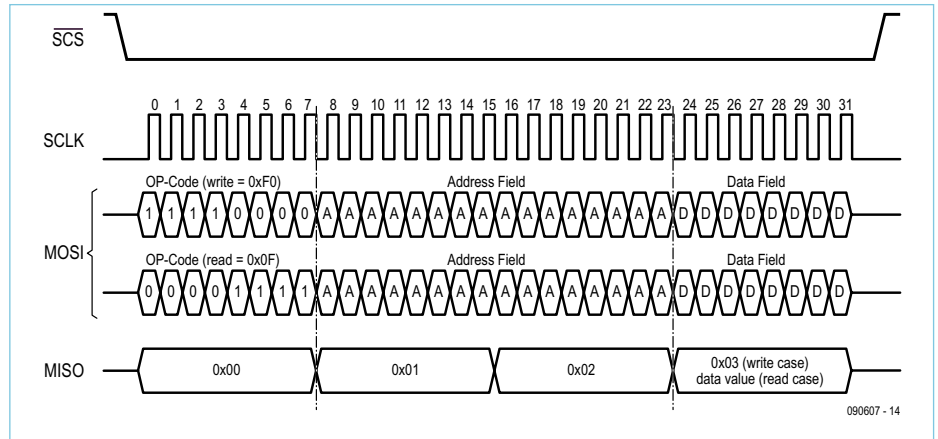


Figure 4. Reading and writing a byte over the SPI bus.

## Abbreviations

**ISO/OSI:** Open System Interconnection (OSI) Reference Model. Defines the various levels of a communication process.

**PHY:** Physical Layer. Driver for data transmission in a specific medium, e.g. Ethernet. Lowest layer.

**MII:** Media Independent Interface. Interface between MAC and PHY.

**MAC:** Media Access Control. Packet relaying via MAC addresses (fixed addresses for relevant hardware, e.g. network cards) at the second lowest layer.

**IP (IPv4):** Internet Protocol. Address-oriented packet relaying at the third layer. IP addresses can be either fixed or assigned dynamically.

**Net Mask:** 32-bit word for dividing the IP address into the network address and a device address within the network.

**DHCP:** Dynamic Host Configuration Protocol. Enables automatic configuration of a network user. For instance DHCP is used to assign IP addresses dynamically to users.

**Port:** A single IP address can support several applications simultaneously, with each of these applications be assigned a different port. Specific port numbers are assigned by default for many applications.

**TCP:** Transport Control Protocol. Packet relaying for various services at the fourth layer with confirmation signal (acknowledgement).

**UDP:** User Datagram Protocol. Communication without acknowledgement, offering advantages of speed, e.g. for wireless Internet.

**Socket:** TCP/IP service or 'horizontal' connection at the fourth layer for delivering incoming data packets to the appropriate application process or thread. A socket is defined by a combination of IP address and port.

**HTTP:** Hyper-Text Transport Protocol. TCP service for retrieving web pages.

**FTP:** File Transfer Protocol. TCP service for transmitting files.

**SMTP:** Simple Message Transport Protocol. Used for sending e-mails.

### Listing 1: Writing data over the SPI bus

```
uint8 WRITE(uint16 addr,uint8 data)
{
    IINCHIP_ISR_DISABLE();           // Interrupt disable
    SET_SCS(LOW);                    // CS=0, SPI start
    SpiSendData(0xF0);               // OP-Code for write
    SpiSendData((addr & 0xFF00) >> 8); // send address high byte
    SpiSendData(addr & 0x00FF);      // send address low byte
    SpiSendData(data);               // send data
    SET_SCS(HI);                     // CS=1, SPI end
    IINCHIP_ISR_ENABLE();
    return 1;
}

void SpiSendData(uint8 Val)
{
#ifdef USE_PORT_IO                  // software SPI
    uint8 i;

    for (i = 0; i < 8; i++)
    {
        W5100_P_SCLK = LOW;
        if (0x80 & (val << i)) W5100_P_MOSI = HI;
        else W5100_P_MOSI = LOW;
        W5100_P_SCLK = HI;
    }
    W5100_P_SCLK = LOW;
#else                                // hardware SPI
    uart_begin( val );
    uart_end();
#endif
}

void uart_begin( register char cmd )
{
    te_u2c1 = 1;                      // enable tx
    uart_tx( cmd );                    // send the command
}

void uart_end( void )
{
    while( !ti_u2c1 );                 // wait for tx buffer to
empty
    while( !txept_u2c0 );              // wait for tx register to
empty
    re_u2c1 = 0;                       // disable rx
    te_u2c1 = 0;                       // disable tx
}
```

received data (for instance the URL of a website requested) from the receive store of the W5100. If requested, the reply data will be written to the output store and the command send() given. When the Client closes the connection, having received all of the desired data (in multiple packets should the need arise), the socket reverts to 'closed' after the corresponding handshake. The socket will now need to be initialised afresh before a Client can be registered again.

Additional protocol information, checksums, flags and so forth are processed by the W5100 internally during transmission and reception of data, with only the payload itself put into store.

The W5100 can handle a maximum of four sockets simultaneously and independently from one another. This means the server remains reachable when a socket is occupied (established), momentarily shut off (closed) or is just initialising itself afresh (init). Different sockets can also act simultaneously as a server or as differing clients and consequently monitor various ports or connect to servers. A socket can be a DHCP client first and when activated call up the network configuration from a DHCP server. Afterwards this socket can then become a web server. At the same time another socket can be forwarding an e-mail by SMTP. The third port is then (for example) another web server and the fourth an FTP server. Source code for all these applications is available free from the chip manufacturer. You can check out more on the subject of TCP/IP protocol on the Internet, for example in the 'TCP/IP Guide' [3].

### Accessing the outside world

As already mentioned, the R32C application board provides not only SPI control but also parallel connection in indirect mode. Using parallel data transmission the W5100 is in a position to achieve data rates up to 25 Mbit/s. Anybody who feels like it is welcome to implement indirect mode and check out the maximum data rate of the R32C/111, but for this article we have concentrated on SPI mode. **Figure 4** sets out the signal timings of the SPI interface for writing and also for



## Architecture and source code files

The web server application consists of a number of source code files that handle the functions listed above. In detail these are:

**Main.c:** The actual web server and status management controller. Can be customised for implementing an individual server.

**Web server.c:** Fundamental web server functions that can be used without alteration for users' own applications.

**HTTPD.c:** HTTP functions that can be used without alteration for users' own applications.

**SOCKET.c:** Functions for socket handling that can be used without alteration for users' own applications.

**W5100.c:** Driver (here in a version for hardware/software-SPI and the R32C controller). Requires rewriting if another form of communication (parallel) is employed.

**hwsetup.c:** R32C-specific hardware set-up.

**OLED28.c:** Driver for the OLED.

If a different controller is used then W5100.c and hwsetup.c will need to be adapted correspondingly (the chip manufacturer has, however, already produced drivers for some controllers [1]).

reading a byte. The protocol is extremely simple and consists of four bytes. The preamble (opcode) signals whether reading or writing is being performed. The middle two bytes contain the 16-bit address and the fourth byte the actual data. To read or write a single byte thus requires four bytes. Maximum clock rate at 14 MHz is so large, however, that a data rate of up to 3.5 Mbit/s can be achieved.

The SPI interface can be realised in software on any desired port pins of a microcontroller. The R32C/111 and many other microcontrollers support SPI with a synchronous serial interface but also in hardware. Renesas calls this method 'clock synchronous serial interface mode'. In the downloadable driver source code files you will find both implementations and can swap between them simply with the compiler directive 'USE\_PORT\_IO'.

Chris Vossen (Elektor Labs) und Jinbuhm Kim (Head of Application & Software for WIZnet) have written an SPI driver for the Renesas M16C product family, especially for the R32C. **Listing 1** includes extracts from the SPI driver. First the interrupts are switched off, in order to avert further interruptions. Then the SPI chip select (/SCS) is set and the four bytes are sent sequentially. Following this the SPI chip select is removed and interrupts are activated once more. Sending a single byte follows by software or hardware SPI.

### Sample web server

A small, very simple sample application is shown in **Listing 2**. The Elektor server monitors Port 5000 and responds to any request that includes the string 'elektor'. The main loop splits into a switch case statement according to the status of the connection in the subroutines SOCK\_ESTABLISHED, SOCK\_CLOSE\_WAIT and SOCK\_CLOSED. If the socket is closed the socket is reactivated with the commands socket() and init(). If data is being received the server responds with („elektor“).

A step from this 'text server' to a proper web server is taken by initialising the socket on port 80 and performing an analysis rou-

### Listing 2: Main loop 'Elektor Server'

```
socket(i, Sn_MR_TCP, 5000, 0x20); // open Socket, Port 5000
listen(i); // go into listen mode = Server
while(1)
{
    sock_status = getSn_SR(i); // get socket status
    switch(sock_status)
    {
        case SOCK_ESTABLISHED:
            len = getSn_RX_RSR(i); // get size of buffer
            if (len > 0)
            {
                if (len > MAX_BUF_SIZE) len = MAX_BUF_SIZE;
                len = recv(i, sock_buf, len); // return received size
                send(i, "elektor\r\n", 9); // send „elektor“
            }
            break;
        case SOCK_CLOSE_WAIT:
            disconnect(0); // send „FIN, ACK“
            break;
        case SOCK_CLOSED:
            close(i); // close Socket
            socket(i, Sn_MR_TCP, 5000, 0x20); // reopen Socket
            listen(i); // to listen mode
            break;
    }
}
```

tine for data received from the client (e.g. URLs from websites you have requested, etc.).

A small, proper web server is waiting for you to download at [4]. **Figure 5** shows what you see in the browser. The application first sends a request by DHCP automatically as client to obtain configuration from the router.

You now have a web server that will respond to requests as a simple website. This example is a web form with two check boxes for indicating the status of two LEDs on the application board. Naturally the user can also switch these LEDs on and off.

Marc Oliver Reinschmidt from Glyn has also integrated the OLED routines that were described in our May issue [5]. Messages can be written to the OLED display line by line using the text input box. Of course the WIZnet logo is included as well.

All the images shown on the website are compiled statically in our sample program. Anyone who wishes to can also implement an FTP server and bring on board image files from the external SD card. The source code files of the small web server (are well commented. Additional sample servers and clients for a variety of controllers are available to download from WIZnet [1] as free Open Source software.

The R32C application board [2], the R32C

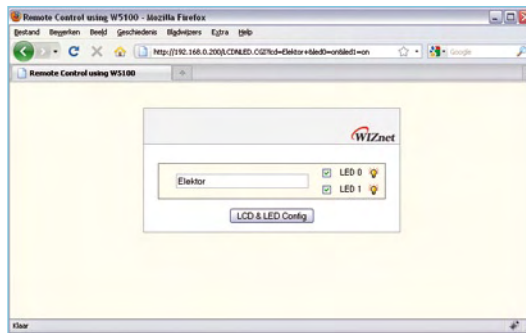
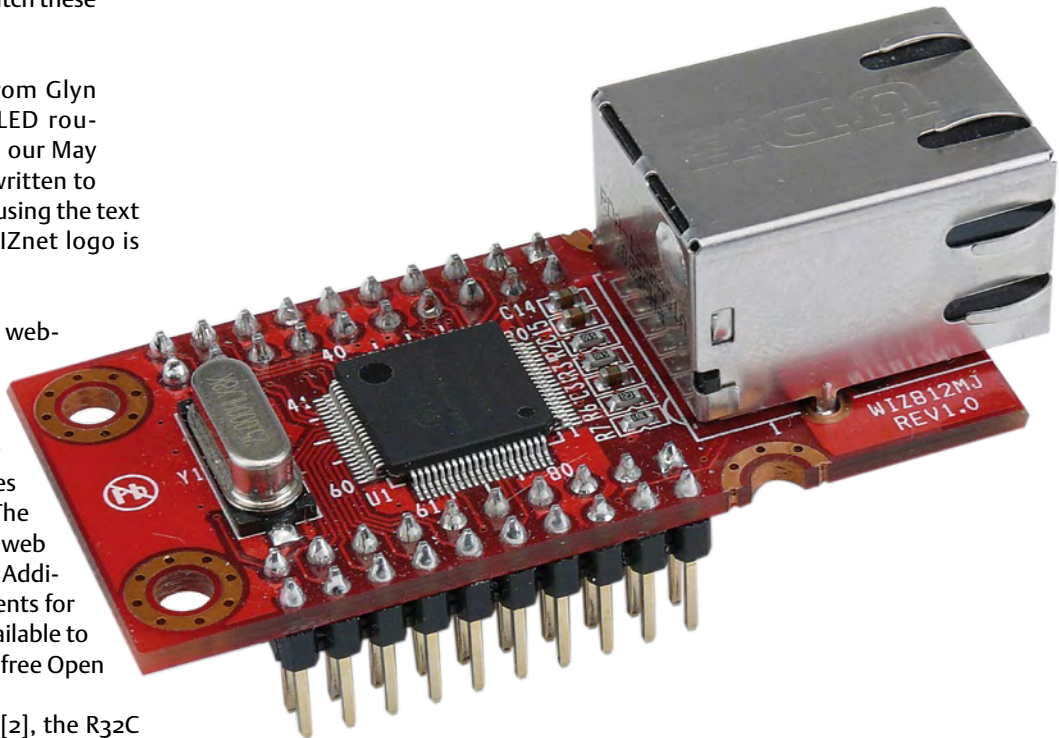


Figure 5. The sample web server software lets you control the LEDs on the application board across the Internet. Words that you type into the text box appear on the OLED!

starter kit including the controller board [6] and the WIZ812MJ network card are all available from Elektor [4]. This versatile and comprehensive range of hardware has in fact so many possibilities that it won't take long for Elektor readers to come up with their own ideas. Tips and suggestions to the editorial address will be most welcome!

(090607-1)



## Internet Links

- [1] [www.wiznet.co.kr/en/](http://www.wiznet.co.kr/en/)
- [2] [www.elektor.com/090209](http://www.elektor.com/090209)
- [3] [www.tcpipguide.com/free](http://www.tcpipguide.com/free)
- [4] [www.elektor.com/090607](http://www.elektor.com/090607)
- [5] [www.elektor.com/081029](http://www.elektor.com/081029)
- [6] [www.elektor.com/080928](http://www.elektor.com/080928)

[7] [www.dacomwest.de/e\\_index.htm](http://www.dacomwest.de/e_index.htm)

[8] [http://en.wikipedia.org/wiki/OSI\\_model](http://en.wikipedia.org/wiki/OSI_model)

## The authors

Jinbuhm Kim manages the applications department at WIZnet [1] and is head of the support team for their global distribution

company.

Joachim Wülbeck is a field application engineer with the distributor Dacom West [7], with responsibility for interfaces and sensor technology.

The authors can be contacted via their organisations' home pages.

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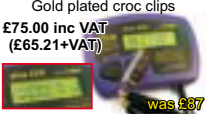
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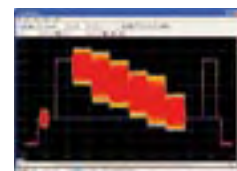
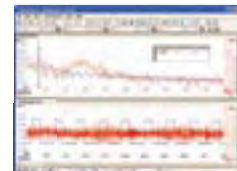


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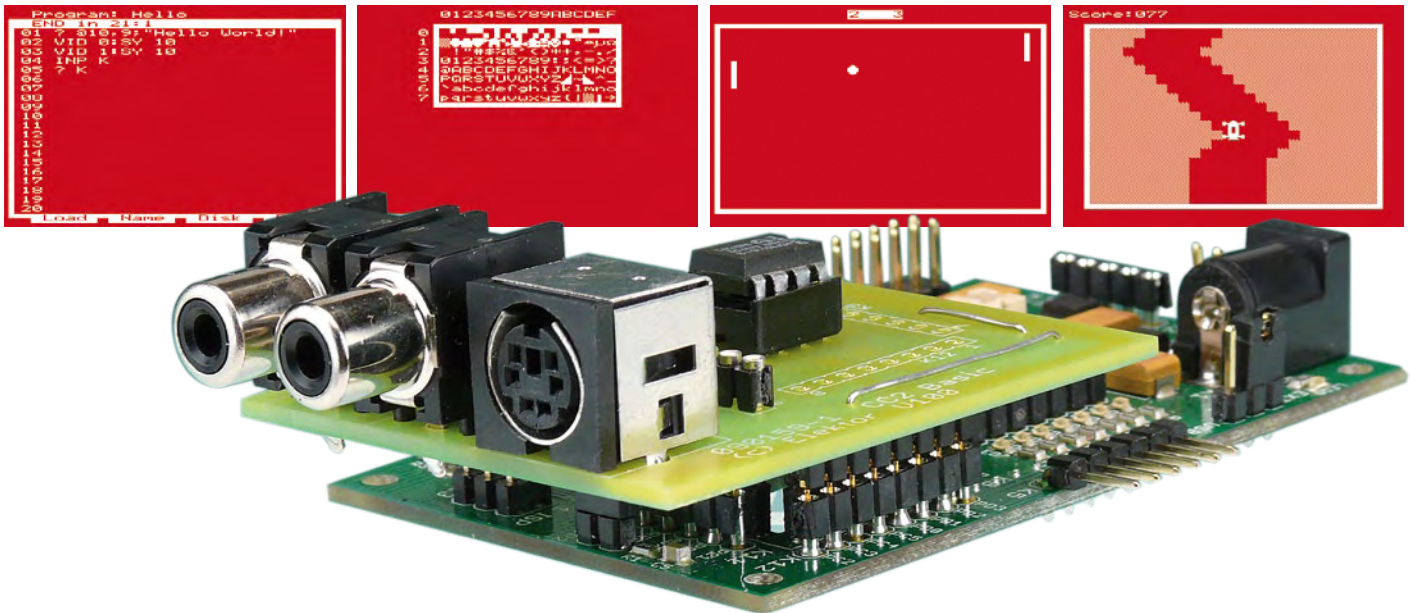
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# ATM18 BASIC Computer

ATM18 simulates vintage home computers



By Wolfgang Rudolph and Jörg Wolfram (Germany)

The constantly escalating processor power of today's PCs makes it a doddle to simulate another computer in software without the user even noticing any difference. Our ATM18 is a feeble performer by comparison but it still does a fine job if all you need is a small BASIC computer. So cast aside all longings for stylish graphics and lavish sound capabilities and get back to basics with this fabulous retro machine. Not that it skimps on essentials though; it features a serial interface, an EEPROM connection for saving programs and a couple of I/O lines. Everything you need in fact!

Let's face it: computers are remarkably dumb devices. After all they're nothing more than hardware. Add some BIOS and you can start to carry out a few basic — and very simple — input and output tasks. Things only get interesting with an operating system, which is what transforms any-dyne hardware into a Windows machine, Linux box or some other characterful computer. Backing up these operating system are the drivers that make hardware-specific hook-ups possible. But even this level of sophistication doesn't let us do anything practical; certainly not write letters, edit photos, create spreadsheets or listen to music. Our maid of all work still needs programs to become a practical servant: equipped with one or more programs the computer is now a radio or a typewriter,

a calculator, a musical notation tool and a million and one other devices! It can even simulate other computers, perhaps many different ones. Devices like this are known as Virtual Machines and they exist not as hardware, only in software. Despite this we can use them as real computers. Making all this possible are the constantly improving combinations of hardware and software — and of course the burgeoning processing power of today's computers.

## BASIC computer

So could our little ATmega do something similar? Could it simulate a totally different computer in the form of a virtual machine? Of course not; it's too slow, the memory is miniscule, there's no sound processor and no graphic chip onboard. It's a player all

right but in a totally different league from the big processors of the Pentium class. But is there a compromise position?

Elektor reader Jörg Wolfram has been giving this consideration and has implemented a small BASIC computer in software. What's more, the program (written in assembler) is so compact that it fits into an AVR controller. Remarkably this includes not only a BASIC interpreter but also an editor for programs! Jörg has modified the 'AVR Chip Basic 8-88' that he developed and optimised it for this ATM18 project.

To make it even better we've also provided convenient input and output capabilities with sound and graphics. Our BASIC computer requires only a normal PS2 computer keyboard for input plus a TV receiver (with SCART or video input) for the output, just

## Features

- BASIC computer implemented in (AVR) software
- Program Editor with 20 lines of code and maximum of 25 usable characters
- 1 program in internal Flash memory
- 26 variables each of 1 byte
- Graphic output via phono socket
- Single-channel audio output (notes in 1 timbre + noise) with envelope curve
- Serial RS-232 interface (1200 baud)
- 4 Port pins deployable as I/O and analogue inputs
- Interface for EEPROM (24C16) for 4 saved programs
- Upload/download of programs via serial interface

like in the old days. The video signal, like the sound, is produced entirely in software! For total authenticity the image is in black and white alone.

## Daughterboard

The necessary I/O hardware is on a small auxiliary printed circuit board (PCB) that plugs in piggyback fashion into the motherboard/test board (directly above the controller, see heading photo). All connections required are made automatically into the multipin socket strips on the test board, without any need for flying leads (see circuit diagram in **Figure 1**). Beyond the Mini-DIN-6 connector for the keyboard the daughterboard provides one phono socket each for sound and vision. The output is a black and white video signal (75 ohms) and an audio signal. We tested the level of the latter signal on a TV set and found it worked fine; you may need to adjust the value of the 5k6 resistor for best matching. Finally there are two multipin connector strips on the board (serial interface and I/O).

## Interfaces

The serial interface is implemented in software because the USART is fully occupied handling the keyboard connectivity. The nature of this system means that the TX (send) line is updated at the same rate as video lines are created on screen (in other words once every 64  $\mu$ s). This explains the rather low data transfer speed of just 1200 bit/s. The serial interface is accessed via pins 4 (RX) and 5 (TX) of the multipin connector strip K5, which are cross-connected to port pins PD5 and PB4. To this we can connect (for example) a TTL USB cable/converter. The allocation of the connector pins is exactly the same as on the ATM18 test board, right down to the jumper that lets you apply the +5 V supply voltage to pin 3 if you wish.

Using the four I/O lines (port pins PC0 to PC3, together with Vcc and GND available on multipin connector strip K4) we can read in and out digital signals. It's also possible to measure analogue voltages in the range 0 to 5 V here. EEPROMs of the type 24C16 using the serial I2C connection to save programs. The signals flow across two lines, SCL (Serial Clock) and SDA (Serial Data).

## Commissioning

Once the controller has been flashed with the software from the project webpage [1] and the finished daughterboard has been plugged in, we can connect a keyboard equipped with a PS/2 connector. The video

cable can then be plugged into a TV receiver or video monitor equipped with a phono socket input. If the set has only a SCART connector it won't cost much to adapt a SCART cable, which will also enable you to inject the audio from the auxiliary board. SCART con-

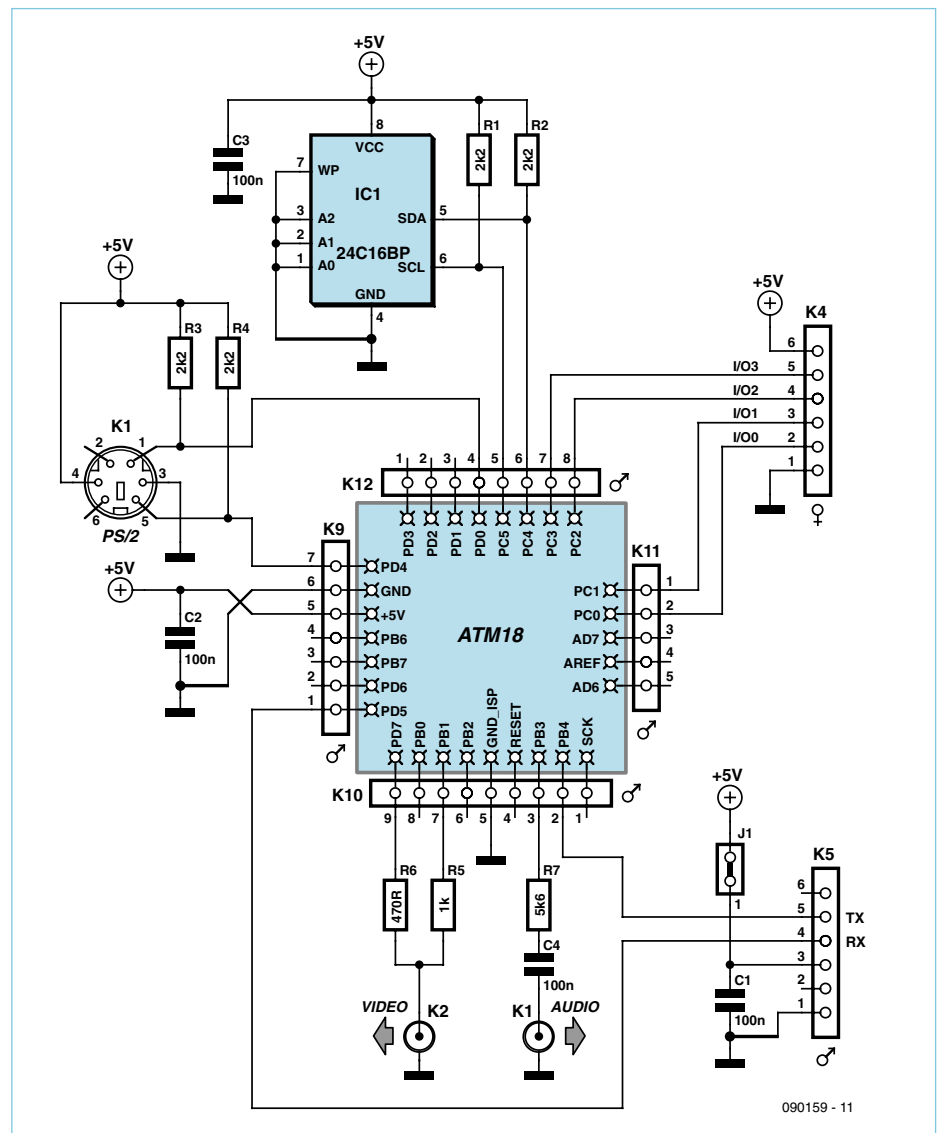


Figure 1. All necessary connections are grouped on the multipin connector strips of the test board.

## The Editor

Programs are written and edited using a simple full-screen editor. At the top is the program name. Below this is the status line, where errors are flagged up for instance. The position of the cursor is indicated by an inverse flashing character. Editing takes place in 'insert' mode, with the characters entered below and to the right of the cursor shifting to the right. On the bottom line there are four menu options for which you use the keys F1, F2, F3 and F4 on the keyboard:

F1	F2	F3	F4
Load	Name	Disk	Run
Load	Load a new program into the Editor		
Name	Edit program name		
Disk	Shows programs saved in the 'Program Selection Box', if the EEPROM is provided		
Run	Saves and starts the current program		

The key F1 has a secondary function. If the CTRL key is also pressed

this enables a program to be input via the serial interface.

In addition the following keys and key combinations provide special functions:

**DEL** Deletes the character under the cursor; remaining characters move up from the right.

**Backspace** Deletes the character to the left of the cursor; remaining characters move up from the right.

**ENTER** Cause cursor to move to the start of the next line.

**ALT+DEL** Deletes the current line and fills it with spaces.

**F11** Outputs the current program via the serial interface.

If the 'Program Selection Box' is displayed, the program to be read or written can be selected by the cursor keys. The L key loads the program into the Editor and the S key saves the program in the Editor into the EEPROM. This takes up to 20 or 30 seconds, as the transfer is made only one byte at a time. Hitting ESC returns you to the Editor without loading or saving.

nections are shown at [2]. An old computer monitor (a C64 one for example) with video and audio inputs would of course be ideal! The system is equipped with a simple auto-start arrangement. To enter normal mode a button must be pressed while the intro screen is being displayed. If no button is pressed or no keyboard is connected, the stored BASIC program starts automatically. This makes it possible to implant a chip running a preset BASIC program, without any need for a keyboard. The software supplied with this article requires a keyboard with keys set out in the German layout, which is mainly the same as those used in other countries but you may need to do some

minor tinkering to adapt the key assignments [3]. Note that the @ symbol is available only by hitting SHIFT+3.

To simplify operation a menu is provided at the bottom of the screen. This has four choices that you select by pressing keys F1, F2, F3 and F4.

There are also a few key combinations that may well be familiar from PCs:

- CTRL+ALT+DEL starts from new, deleting all previous variables and unsaved programs in the process
- CTRL+C interrupts the program at the nearest possible point in time
- CTRL+P sends a screenshot to the serial

interface.

### The most famous program in the world

Now comes our first program, known to every computer enthusiast everywhere: Hello World!

We need to input the following (the line numbers appear automatically):

```
?@10,9;"Hello World!"
VID 0:SY 10
VID 1:SY 10
INP K
?K
```

## Loading and saving programs via the serial interface

The following settings are required on the PC: 8 bits, 1200 Baud, no parity, 1 stop bit.

Normal text transmission is used for all functions. Under Windows you can install HyperTerminal for instance (send/record text) whilst Minicom or the program chiptrans8.pl are recommended for Linux users.

### Sending to the AVR:

1. Select LOAD (CTRL+F1) in the Editor
2. Start transfer to PC with ./chiptrans8.pl -r Filename
3. Program appears on the AVR system, with status shown on the PC.

### Receiving from the AVR:

1. Start transfer to PC with ./chiptrans8.pl -r Filename
2. Activate SEND (F11) to the Editor
3. Indicates status on the PC

You can configure how you send the New Line signal by means of the command CFG n. Currently only the lowest two bits of n are analysed.

Value (binary)	New Line	PC Platform
00	no end of line	for test purposes
01	CR only	MAC
10	LF only	Unix/Linux
11	CR and LF	Windows

This setting is stored in the EEPROM and normally needs to be entered only once.

## A small oscilloscope

This program scans the analogue input I/O 0, taking 50 samples a second. Pressing the space bar freezes the display.



```

PRG:SCOPE-01
01 CLS:B=30:BX 3,3,42,56
02 ?@0,0;"CB8-Oscilloscope"
03 ?@20,0;"0";
04 ?@3,0;"5";
05 A=AD(0)/7
06 DR 41-A,54,41-B,55:B=A
07 SUB 9:SY 1:SCR 3:GO 5
08
09 IF KY(0)=32 GO 9
10 RET
    
```

If we now start this program by hitting F4, the text 'Hello World!' appears on the screen (see Figure 3). After this the screen goes dark for 0.2 of a second, then the

£ 300 in today's money), with less functionality than our ATM18 BASIC machine. Today the processing power of the 'personal computers' of those days is easily matched by a

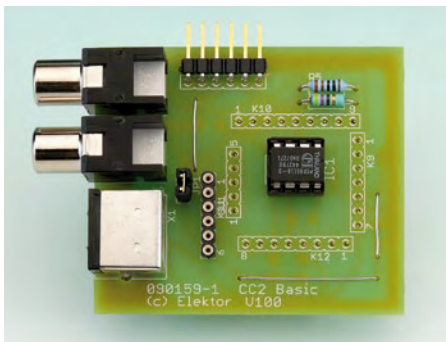


Figure 2. Next to the keyboard connector are twin phono sockets for the video and audio outputs from the board, plus some I/O pins.

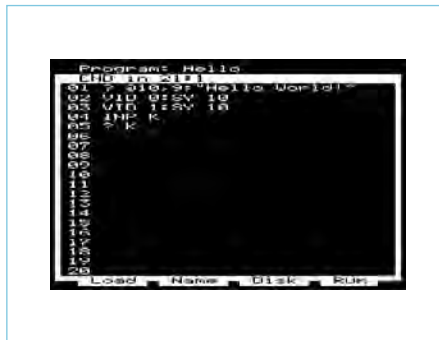


Figure 3. The first program is naturally Hello World!

words appear once more and after another 0.2 of a second comes a prompt. The BASIC computer now waits for an input. All functions of the editor are described in detail in the panel 'The Editor'. The commands available are set out along with some examples in the 'BASIC Reference', available for download from the Elektor website [1].

Take a look at the short sample programs — it won't take long before you are scripting your own applications!

When your new baby boots up for the first time all those old feelings will come flooding back. Just like it was when you had a ZX81. Except that back in 1981 the ZX81 stung you £ 69.95 (equivalent to about

small microcontroller, which is able also to generate a video signal, produce the right sounds and even replicate the serial interface in software. Already a quarter of a century has passed since then!

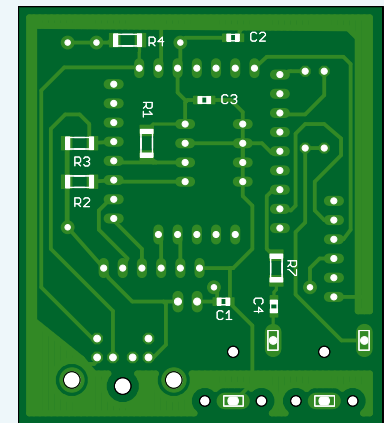
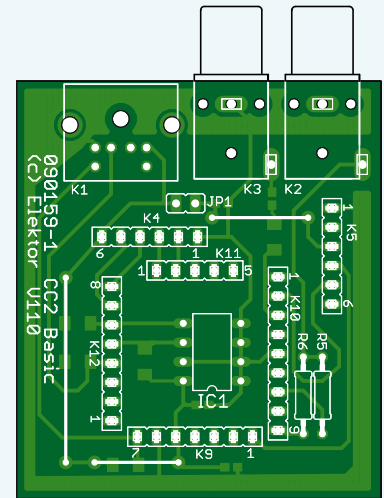
This project gives you a vivid insight into a past that really seems like another world now.

(090159-1)

### Internet Links

- [1] [www.elektor.com/090159](http://www.elektor.com/090159)
- [2] [www.theavguide.co.uk/view\\_page.php?page=23](http://www.theavguide.co.uk/view_page.php?page=23)
- [3] [http://en.wikipedia.org/wiki/Keyboard\\_layout](http://en.wikipedia.org/wiki/Keyboard_layout)

## COMPONENT LIST



### Resistors

R1-R4 = 2.2kΩ  
R5 = 1kΩ  
R6 = 470Ω  
R7 = 5.6kΩ

### Capacitors

C1-C4 = 100nF (SMD 0805)

### Semiconductors

IC1 = 24C16

### Miscellaneous

K1 = 6-way mini-DIN socket (female), PCB mount  
K2, K3 = Cinch socket, PCB mount  
K9 = 7-way SIL pinheader, lead pitch 0.1" (2.54mm)  
K10, K12 = 9-way SIL pinheader, lead pitch 0.1" (2.54mm)  
K11 = 5-way SIL pinheader, lead pitch 0.1" (2.54mm)  
K4 = 6-way SIL socket strip, lead pitch 0.1" (2.54mm)  
K5 = 6-way SIL socket strip, right angled, lead pitch 0.1" (2.54mm)  
JP1 = 2-way pinheader with jumper  
PCB # 090159-1, artwork download at [1]  
Project source code and hex files, free download # 090159-11 from [1]

# Arduino + Theremin = Theremino

## Using a Theremin oscillator as a proximity sensor

By Martin Nawrath (Academy of Media Arts, Cologne, Germany)

The Theremin is one of the very first electronic musical instruments, dating back to the 1920s. It is played by the musician bringing his hands close to its two antennas. The oscillator at the heart of the Theremin remains an interesting circuit in itself, and in this project we connect such an oscillator to an Arduino microcontroller board. The processor can detect the shifts in the HF signal from the oscillator and convert them into an audible sound. However, this is by no means the only possibility: we can also use the circuit to convert hand and body movements into control signals for other musical instruments, servos and computers.

This tiny oscillator circuit, when coupled with the software running on the Arduino microcontroller board, has a huge range of potential applications, allowing proximity-based control of any other circuit or system.

The circuit has already found use in many installations and objects at the author's college. One example is where the device is interfaced to the Max/MSP music and multimedia development environment, which is capable of producing sounds that provide a pleasant contrast to the square waves that the Arduino can generate directly.

### What makes a theremin a theremin?

The *Elektor* editorial team felt it was possible that calling this project a 'Theremin' might be a little misleading. The musical instrument named after Russian inventor and engineer Léon Theremin (born Lev Termen) consists of two antennas, each connected to an oscillator. One oscillator controls the pitch of the instrument and the other the volume. The original Theremin is a purely analogue device, with the conversion from the modulated high-frequency signal to an audible frequency being performed by

a superhet circuit: the oscillator output is mixed with a fixed frequency generated by a further oscillator, arranged so that the difference frequency is in the audible range. Our circuit has just one oscillator, nevertheless designed around the same principle as the Theremin. The oscillator is connected to an antenna, and the oscillator's

frequency changes when a human hand (or other electrically conductive object) is brought near to the antenna. The additional capacitance of the hand affects the frequency of the resonant circuit in the oscillator (**Figure 1**). It seems reasonable to call this circuit a 'Theremin oscillator'. As in the original Theremin, we convert the modulated high-frequency signal into the audible range; but rather than using a superhet converter, we do the job in software on the Arduino board. Our 'Theremino' therefore replicates just the pitch control part of the original instrument. It would be possible to build a second Theremin, suitably modified to provide a volume control, to emulate the analogue Theremin fully.

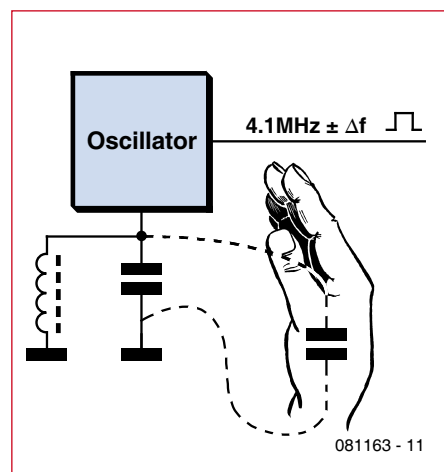


Figure 1. The parallel capacitance of a human hand near to the oscillator affects its frequency.

### LC oscillator using a 74HC00

The circuit shown in **Figure 2** consists of an amplifier, made to oscillate by coupling its output signal back to its input. At the input to the amplifier is a parallel resonant circuit, made from a coil and a capacitor, which determines the frequency of the oscillator. Any extra parallel capacitance due to the connected antenna will affect this frequency.



The amplifier is made from two NAND gates from a 74HC00 connected in series. Each is equipped with a resistor (R1 and R2) to provide negative feedback, which causes the gates to behave as amplifiers. C3 provides feedback from the output to the resonant circuit at the input consisting of L1 and C1. C4 couples the signal on the resonant circuit into the input of the amplifier. The resonant circuit is also connected to the antenna. The theoretical resonant frequency of the LC combination is 4.11 MHz.

The oscillator is followed by the two remaining gates of the 74HC00, used to square up its output waveform into a TTL-compatible signal. This signal is suitable for connection to a digital input on the Arduino board.

### Components and construction

Capacitor C1 in the LC network should be a ceramic NP0 type (such as Farnell order code 9411720) for best temperature stability. L1 should have a high Q factor. A suitable type is the Fastron SMCC-100K-02, which has a Q factor of 65; it is difficult to do better than that, even with a hand-wound coil.

The circuit can be built, like the author's prototype, on a small piece of prototyping board. To reduce drift with temperature, it is a good idea to mount the board in a small plastic enclosure. The software running on the Arduino board also has features to help compensate for temperature drift and component tolerances.

The antenna that is connected to the LC circuit should be no longer than about one metre (3 feet). A loop of 1.5 mm copper wire (or, for greater mechanical strength, steel wire) works well.

With the antenna operating at 4 MHz metal objects and cables near to it (including USB cables) will also act as parasitic antennas. It is therefore important to keep the unit fixed in place to avoid unwanted frequency drift.

### Arduino software

For our tests in the Elektor lab we used an Arduino Diecimila board [1] with software downloaded from the author's project website. In principle any Arduino board could be

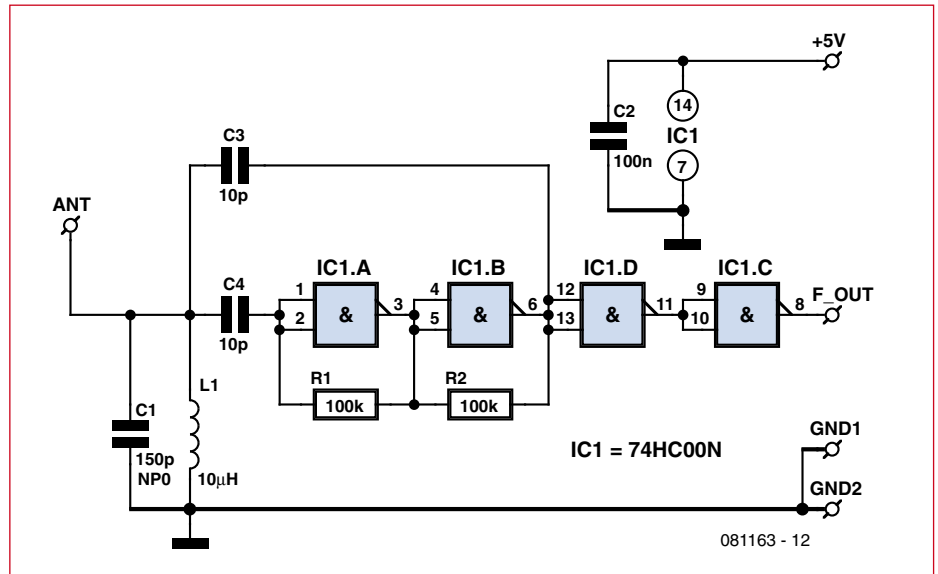


Figure 2. Circuit of the LC oscillator using the 74HC00. To increase the sensitivity of the circuit to the proximity of a human hand, an antenna, made from a length of wire, is connected to the LC network.

used, including the 'Elektorino' design that we published in February 2009 [2]. The oscillator circuit of Figure 2 is provided with +5 V and ground from the Arduino board and the oscillator output ( $f_{out}$ ) is connected to dig-

ital pin 5 (PD5, pin 11 on the ATmega168 [3]). This pin has the extra function of acting as an input to hardware counter/timer Timer1 in the ATmega168. To detect the frequency shifts of the oscillator, an accurate fre-

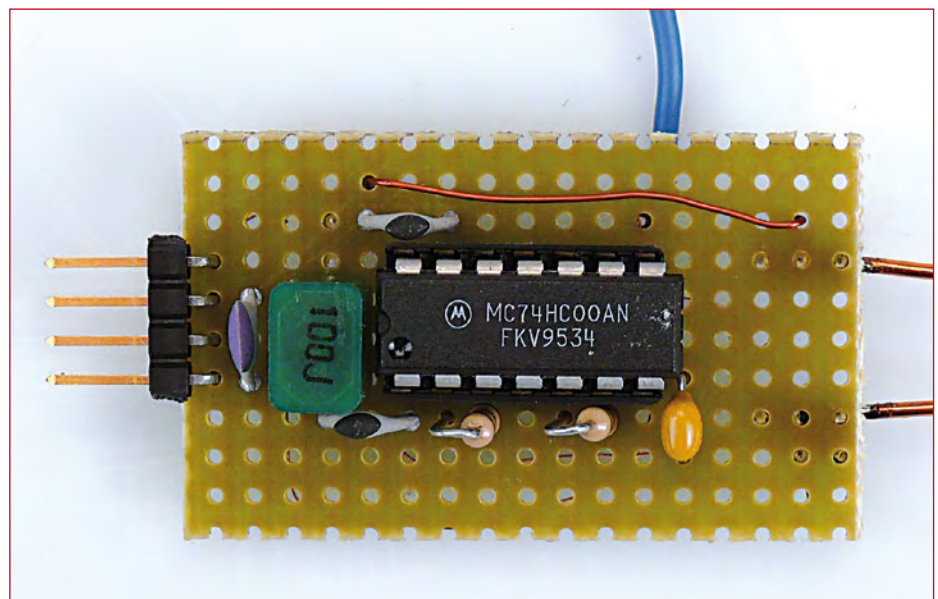


Figure 3. The oscillator can be built on a small piece of prototyping board.

### Listing 1. Frequency is measured using Timer1 as a counter and Timer2 to measure the gate time.

```
//*****
void f_meter_start() {
  f_ready=0;           // reset period measure flag
  i_tics=0;           // reset interrupt counter
  sbi (GTCCR,PSRASY); // reset prescaler counting
  TCNT2=0;           // timer2=0
  TCNT1=0;           // Counter1 = 0
  cbi (TIMSK0,TOIE0); // disable Timer0 again // millis and delay
  sbi (TIMSK2,OCIE2A); // enable Timer2 Interrupt
  TCCR1B = TCCR1B | 7; // Counter Clock source = pin T1 , start counting now
}

//*****
// Timer2 Interrupt Service is invoked by hardware Timer2 every 2ms = 500 Hz
// 16Mhz / 256 / 125 / 500 Hz
// gate time generation for freq. measurement takes place here:

ISR(TIMER2_COMPA_vect) {

  if (i_tics==50) { // multiple 2ms = gate time = 100 ms
                    // end of gate time, measurement ready
    TCCR1B = TCCR1B & ~7; // Gate Off / Counter T1 stopped
    cbi (TIMSK2,OCIE2A); // disable Timer2 Interrupt
    sbi (TIMSK0,TOIE0); // enable Timer0 again // milli-s and delay
    f_ready=1; // set global flag for end count period

                    // calculate now frequency value
    freq_in=0x10000 * mlt; // multiply number of overflows by 65536
    freq_in += TCNT1; // add counter1 value
    mlt=0;

  }
  i_tics++; // count number of interrupt events
  if (TIFR1 & 1) { // if Timer/Counter 1 overflow flag
    mlt++; // count number of Counter1 overflows
    sbi (TIFR1,TOV1); // clear Timer/Counter 1 overflow flag
  }
}
}
```

quency counter is realised in the Arduino firmware using Timer1 as a counter and Timer2 as a timebase. When suitably configured by the software, the counter increments by one for each pulse on the input pin, typically over four million times per second. Timer2 provides a gate time of exactly 1/10 s (100 ms). With an input frequency of 4.1 MHz Timer1 will increment 410 000 times during the gate period, and the frequency can be measured to a resolution of 10 Hz. This precision is required in order to detect the relatively small frequency shifts caused by the Theremin effect.

Timer1 is only a 16-bit counter and so it will overflow several times in each gate period. The overflows are counted and combined with the counter value to produce a final result at the end of the gate period. All the timing work is handled by an interrupt func-

tion, called every two milliseconds under control of Timer2 (see Listing 1).

At the end of the gate period a global flag variable is set. This signals to the main code (see Listing 2) that a new result is ready. Since we are only interested in relative changes in the input frequency and not its absolute value, we subtract the first measured frequency after power-up from each reading. If after a preset number of readings the frequency shift is less than a certain threshold value, an automatic calibration is performed: this compensates for the effect of long-term oscillator drift. The two parameters (number of readings and threshold value) can be adjusted to suit a particular application. The calculated frequency shift value (variable 'tune' in the listing) can be used as a starting point for your own application ideas.

The frequency shifts and calibration values are output on the serial port for further processing or for viewing using a terminal program on a PC.

A rudimentary DDS tone generator function is implemented in software to produce an audible frequency on port B. The signal can be heard by connecting a piezo transducer or small loudspeaker to digital pin 8 (PB0, or pin 14 of the ATmega168) via a 1 kΩ series resistor. You can see and hear the circuit in action in a video on the author's project website [4].

(081163-1)

**Listing 2. Excerpt from the main loop. The variable 'tune' contains the frequency shift as produced by the proximity sensor. Automatic calibration compensates for the effect of long-term oscillator drift.**

```
void loop()
{
  cnt++;

  f_meter_start();

  tune=tune+1;
  while (f_ready==0) {          // wait for period end (100ms) using interrupt
    PORTB=((dds+=tune) >> 15);  // kind of DDS tone generator: connect speaker to portb.0 = Arduino pin8
  }
  tune = freq_in-freq_zero;
  // use the tune value here for your own purposes like control of servos, midi etc.

  // startup
  if (cnt==10) {
    freq_zero=freq_in;
    freq_cal=freq_in;
    cal_max=0;
    Serial.print("*** START ***");
  }

  // automatic calibration
  if (cnt % 20 == 0) { // try automatic calibration after n cycles
    Serial.print("");
    if (cal_max <= 2) {
      freq_zero=freq_in;
      Serial.print(" calibration");
    }
    freq_cal=freq_in;
    cal_max=0;
    Serial.println("");
  }
  cal = freq_in-freq_cal;
  if ( cal < 0) cal*=-1; // absolute value
  if (cal > cal_max) cal_max=cal;
}
```

## Internet Links

- [1] [www.arduino.cc/en/Main/ArduinoBoardDiecimila](http://www.arduino.cc/en/Main/ArduinoBoardDiecimila)
- [2] [www.atmel.com/dyn/resources/prod\\_documents/doc2545.pdf](http://www.atmel.com/dyn/resources/prod_documents/doc2545.pdf)
- [3] [www.elektor.com/080931](http://www.elektor.com/080931)
- [4] <http://interface.khm.de/index.php/lab/experiments/theremin-as-a-capacitive-sensing-device/>

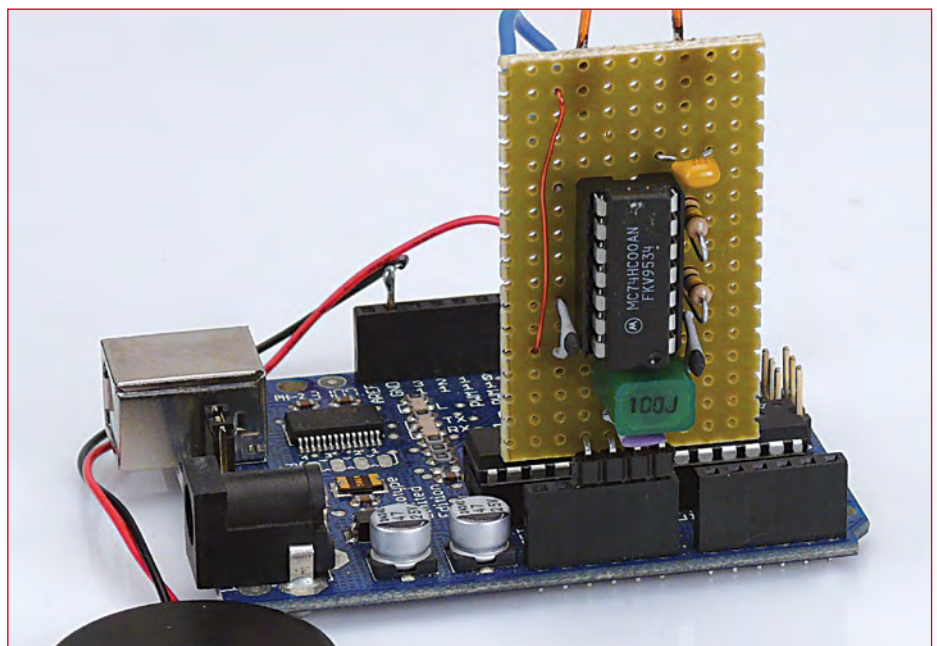


Figure 4. Arduino board with oscillator circuit and piezo transducer.

# New Developments in Class D reduced EMI and no output filter

By Thijs Beckers (Elektor Netherlands Editorial)

There's no stopping technological progress, including Class D amplifier technology. New developments reduce the amount of electromagnetic interference (EMI) and enable amplifiers to work without an output filter. Read more to learn how clever designers managed to pull this off.

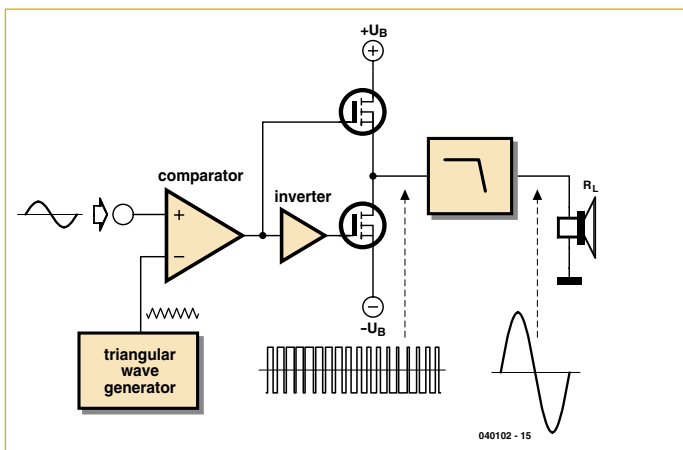


Figure 1. Simplified schematic diagram of a Class D amplifier.

Thanks to their high efficiency, Class D amplifiers are ideal for compact and portable applications. However, conventional Class D amplifiers need an external low-pass filter to recover the audio signal from the pulse-width modulated signal (see below). In addition, they often lead to EMI problems, and the distortion level (THD+N) is not especially good. However, advanced techniques are used in modern Class D amplifiers to overcome these problems and eliminate the need for an output filter, which not only reduces the amount of space necessary on the PCB but also in many cases reduces the overall cost of the compact or portable system.

## Class D

First let's have a brief look at how Class D technology works. A Class D amplifier does not simply amplify the input signal as is (see **Figure 1**). Instead, it uses a technique called pulse-width modulation (PWM). The output voltage is proportional to the width of the pulse

(see **Figure 2**). Increasing the switching frequency improves the match between the output signal and the original signal. Unfortunately, high switching frequencies create all sorts of problems, such as interference and high switching losses. Consequently, a switching frequency in the range of 250 kHz to 1.5 MHz is commonly used, depending on the application.

The PWM signal is passed through a low-pass filter to recover the original signal in amplified form. The switching pulses are largely filtered out, leaving the 'average' value. The necessary filter not only increases the cost and the amount of space required on the PCB, but also increases the likelihood of distortion due to nonlinearities in the filter.

## Filter-free

Due to the ongoing demand for circuits that are even more compact and provide even better performance, circuit techniques that do not require an output filter have been developed. An example is the technique used in the Maxim MAX9700 (see the schematic diagram in **Figure 3**).

This technique works as follows. Each push-pull output stage has its own comparator, so each output stage can be driven separately. The comparators are driven by differential audio signals and a shared sawtooth generator. When the outputs of both comparators are low, the two outputs of the Class D amplifier are both High. At the same time, the output of the NOR gate is High, but this signal is delayed by the RC network  $R_{ON} / C_{ON}$ . When the delayed output of the NOR gate exceeds a certain threshold level, switches S1 and S2 are closed. This causes OUT+ and OUT- to both go Low until the start of the next sampling interval. As a result, the two outputs are active (High) for only a minimum period  $t_{ON(min)}$ . The duration of this period is determined by the values of  $R_{ON}$  and  $C_{ON}$ .

If the signal level at the input is zero, the OUT+ and OUT- outputs are exactly in phase and the pulse width is  $t_{ON(min)}$ . When the amplitude of the audio signal at the input varies, the two comparators trigger at different times. In combination with the minimum  $t_{ON}$  circuit, this causes the pulse width of one output to vary while the pulse width of the other output remains the same ( $t_{ON(min)}$ ). The average value of the signal present on each of the outputs corresponds to a half-wave rectified version of the audio signal. The difference between the two average values on the outputs forms the full audio signal.

As the outputs are in phase when the input signal is zero, there is no difference signal across the load under this condition and the power consumption is minimal, all without any need for an output filter.

The circuit also makes use of the impedance of the connected loudspeaker. This impedance consists of a real part ( $R_e$ ) and an inductive part ( $L_e$ ) where the subscript 'e' indicates the electrical component. They effectively form a first-order low-pass filter with a corner frequency

$$f_c = 1 / (2\pi L_e / R_e) \text{ [Hz]}.$$

With most loudspeakers, this first-order filter is sufficient to restore the audio signal and prevent excessive power dissipation (from the high switching frequency) in the loudspeaker. However, this requires the loudspeaker to maintain an inductive characteristic at the switching frequency of the amplifier in order to ensure that the maximum rated power can be achieved.

### Power spectrum

Class D amplifiers typically emit a relatively large amount of power at the switching frequency in the form of electromagnetic radiation. The steep edges of the pulse waveform at the output of the amplifier make it difficult to design a circuit that can comply with the applicable EMI and EMC standards without an output filter.

One way to circumvent this problem is to use a ‘spread spectrum’ switching frequency. With this technique, the switching frequency of the amplifier is varied randomly over a certain range (such as 10%). Although this broadens the frequency band within which the amplifier emits HF signals, it considerably reduces the peak values in this band (which otherwise would often exceed the maximum permissible value), with the result that the amplifier remains within the allowable emission limits. Here it is important to ensure that the duty cycle of the PWM signal remains constant, as otherwise part or all of the audio signal will be lost.

In other words, the total amount of power in the output spectrum remains constant, but it is spread over a broader frequency range. The peak values of the HF signals are reduced, and the amount of EMI emitted by the speaker cables is lower.

Although spread-spectrum modulation significantly reduces EMI, it has the disadvantage that the length of the loudspeaker cables is limited. The amount of EMI increases with the length of the cables, with the result that at a certain point the circuit no longer complies with the CE mark of approval. At this point, a filter is necessary, although in many cases a simple ferrite bead is sufficient.

### ERC

There is also another way to tackle this problem. The latest design innovations minimise EMI and THD+N without sacrificing efficiency. A technique called edge rate control (ERC) has been developed to further reduce the EMI generated by devices. The high-frequency power emitted by a Class D amplifier results from the edges of the pulses in the output signal. The shorter the rise and fall times of these pulses, the more HF power that produced by the edges. If these times are increased so the edges are not as steep, the amount of radiated high-frequency power is reduced.

However, putting this idea into practice is not so easy. Increasing the lengths of the transition times can have a negative impact on the performance of the amplifier. The longer the output stages remain in the state between fully on and fully off, the more power they dissipate in the form of heat, which reduces the efficiency. In addition, the PWM signal will deviate from the ideal pulse waveform, which will cause the distortion (THD+N) to increase.

Although ERC can have a negative impact on amplifier performance, designers are forced to use this technique to improve their designs in order to achieve potential EMI reductions. If the technique is implemented properly, power losses as well as THD+N can be minimized. The correct approach is to slow down only part of the

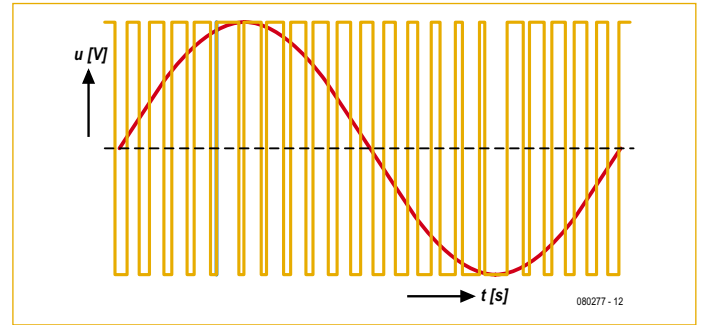


Figure 2. After filtering, the PWM signal (yellow) yields a sine-wave signal (red).

edge. In this way, EMI is minimized and power dissipation is reduced to the same level as with a Class D amplifier that does not use ERC. Errors in the PWM audio signal are corrected by means of internal feedback.

### Practical aspects

Despite the fact that the techniques described here can significantly reduce EMI, it is still necessary to observe certain design guidelines very closely when designing a PCB for a Class D amplifier. These guidelines include isolating the tracks that carry switched signals and separating the analogue inputs and supply lines from all switching components.

With the constantly increasing demand for portable, energy-efficient devices, Class D amplifiers are being used more and more due to their high efficiency. Improvements in quality and EMI performance have considerably simplified the design of these amplifiers. Relaxed layout rules and fewer external components help reduce design time and drive down overall cost while enabling more compact designs and longer battery life in portable use, all without sacrificing the quality of the audio signal. As a result of all these improvements, Class D is no longer inferior to Class AB, and in the future it will probably be the only reasonable choice when energy-efficient, compact amplifier circuits are necessary.

(090557-1)

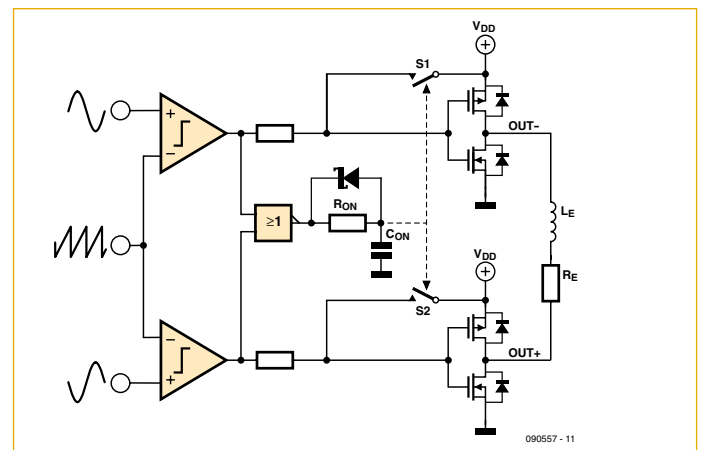


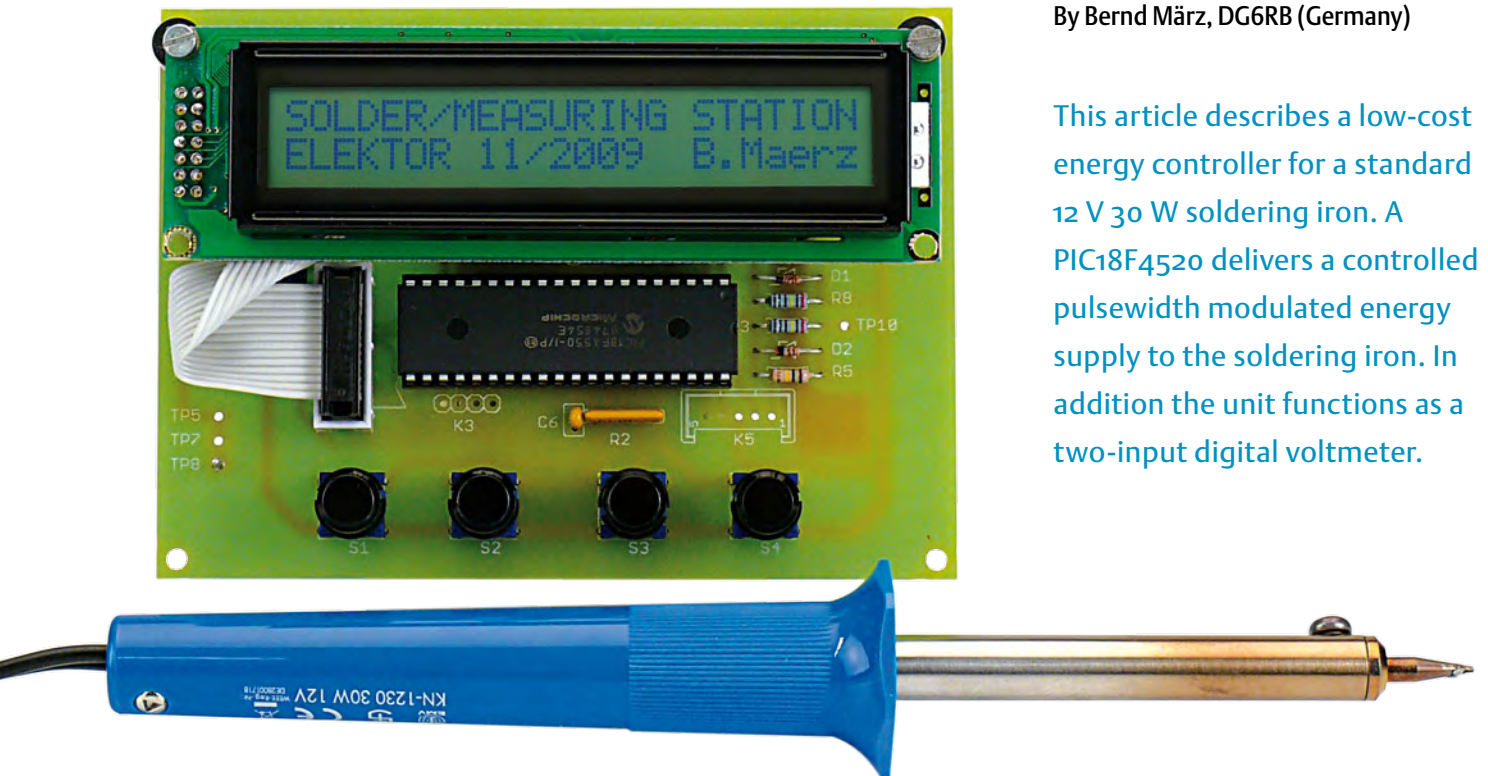
Figure 3. With suitable adjustments, a Class D amplifier can manage without an output filter.

# Solder Station 'Plus'

temperature control and DVM in one unit

By Bernd März, DG6RB (Germany)

This article describes a low-cost energy controller for a standard 12 V 30 W soldering iron. A PIC18F4520 delivers a controlled pulsewidth modulated energy supply to the soldering iron. In addition the unit functions as a two-input digital voltmeter.



## Main Features

- Suitable for use with 12 V / 30 W (max.) soldering irons.
- Temperature control using PWM.
- Power supplied from a low-cost 12 V / 3.33 A mains adapter.
- Two DC voltage measurement inputs.
- Measurement ranges: 0 to 10 V (channel 1), 0 to 40 V (channel 2)
- Displays supply voltage.
- Microcontroller PIC18F4520 with flash memory
- LC display 2 lines of 24 characters (with HD44780 controller)
- Software calibration of measurement channels.

The author is a radio amateur and a member of the German Amateur Radio Club (DARC). Each year the club organises a practical activity for the younger electronics enthu-

siasts to occupy them during the holidays. Every year the members come up with a new circuit design to build, the main criteria are that it should be low-cost, useful, simple and fun to build. The project described here was the subject of one of these events.

All together the materials for this solder station/DVM design cost around 25 pounds. The same amount of money would probably buy you a simple soldering station but it would not give you the same satisfaction as one that you built yourself and besides it would not have the energy control or DVM features of this design with its in-built microcontroller. A combined soldering iron and DVM would undoubtedly be a useful addition to the workbench of any young engineer or electronics enthusiast.

## Measurement and Control

A low cost microcontroller type PIC18F4520 (IC2) from Microchip is the main element in

the circuit diagram shown in **Figure 1**, its clock is derived from an economical ceramic 4 MHz resonator (X1). The firmware stored in microcontroller flash memory performs temperature control of the soldering iron and all the measurement functions. The four pushbuttons (S1 to S4) are used to select menu options.

The display (LCD1) shows two lines of text with 24 characters per line. It is an LCD with an on-board HD44780 compatible controller. To reduce costs this type of display can often be salvaged from an old telephone or similar piece of redundant equipment. Alternatively it is a completely standard display which can also be ordered quite cheaply from the majority of component suppliers. To reduce the number of microcontroller I/O pins required by the LCD it is driven in 4-bit mode. The spare I/O pins are connected to the pin header K2 to K4. With suitably modified software these pins could

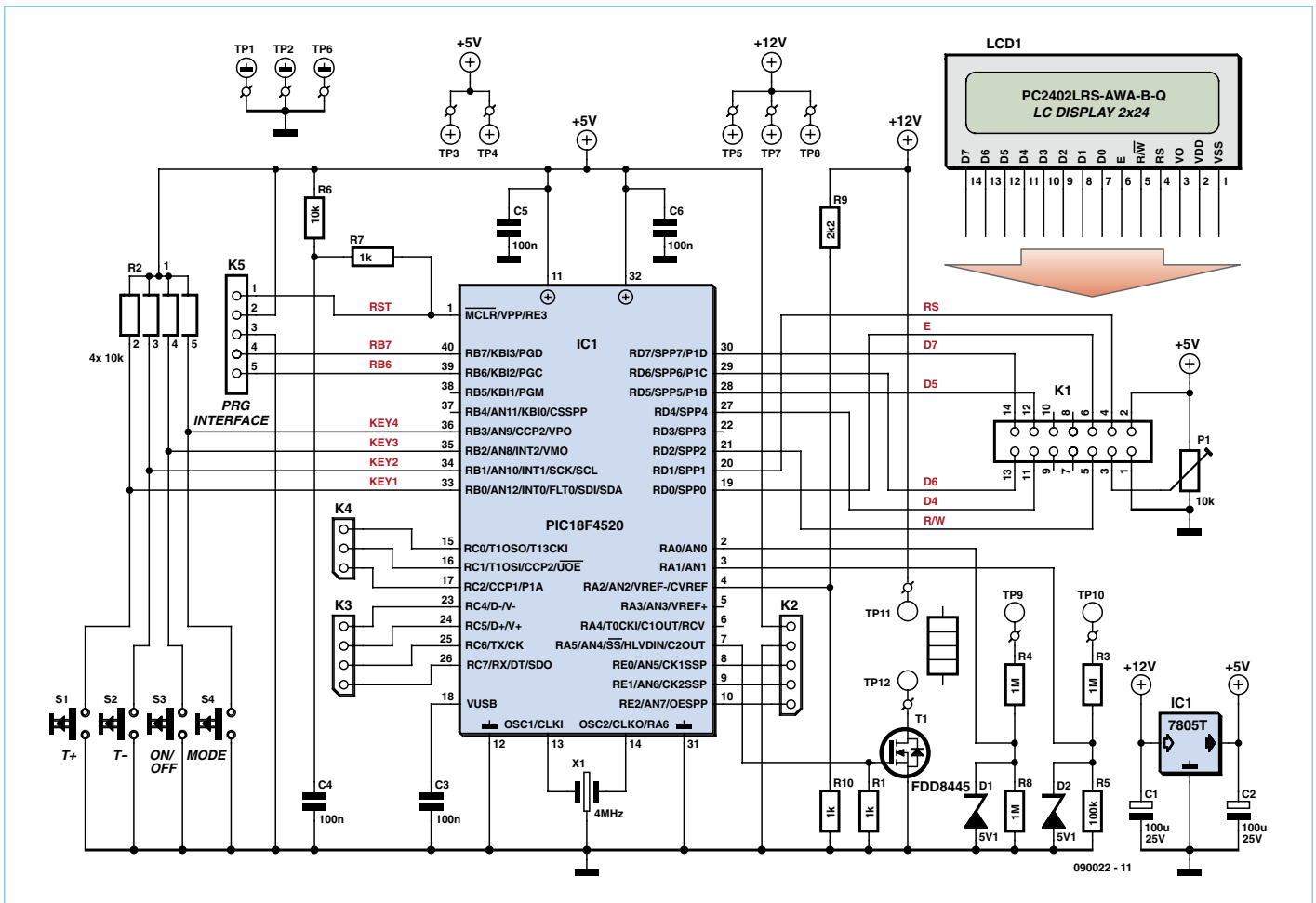


Figure 1. The simple circuit uses a PIC microcontroller for control and measuring.

be used in the future, for example, to measure values of capacitance. Pin header K5 is the programming interface to the microcontroller allowing the software to be updated or changed as necessary. A ribbon cable on K1 connects to the LCD and preset P1 is used to adjust the display contrast.

Pushbuttons S1 and S2 control the soldering iron temperature. These buttons change the on/off ratio of the Pulse Width Modulated (PWM) signal output from pin 7 of the microcontroller. The waveform switches power MOSFET T1 which supplies current to the soldering iron connected to points TP11 and TP12 on the circuit diagram. Power control is very smooth and the front panel display shows the amount of power supplied to the iron as a percentage of the iron's power rating (30 W max). The type of soldering iron used is a standard low-cost 12 V iron without any temperature sensor.

The red measurement input sockets are wired to TP9 for channel 1 and TP10 for channel 2. Voltage divider networks on these inputs formed by (R4/R8 and R3/R5) scale the measured input voltages so that they are within the input range of the controller's ADC inputs pins 2 and 3. The 1 MΩ resistors define the impedance of the meter inputs. Zener diodes D1 and D2 prevent damage to the input if the applied input voltage is too high. The third ADC input of the microcontroller (pin 4) measures the power supply voltage (nominally 12 V) scaled by the voltage divider network R9/R10.

Power to the unit can be supplied by a 12 V DC mains adapter rated at 3 A (minimum). A quick trawl through some supplier's websites identified several 12 V switched-mode supplies with an output rated at 3.3 A retailing for less than 10 pounds. The 5 V supply for the circuit is produced by the 7805 voltage regulator IC1.

### Putting it all together

The simple single-sided PCB layout (Figure 2) ensures that construction is quite straight forward even for a novice. Start by fitting the IC socket ensuring that pin 1 lines up with 1 on the layout. Next fit the ceramic capacitors, the wire link between TP3 and C1, the resistors, diodes (make sure they are the right way round) and the preset resistor. The resistor network R2 is fitted so that pin 1 is nearest to C6.

Both electrolytic capacitors C1 and C2 must lie flat on the board otherwise there will not be enough room for the LCD which is fitted 15 mm above the PCB.

Voltage regulator IC1 is mounted on the board using a short M3 nut and bolt. The power FET T1 has an SMD outline and is the only component mounted on the underside of the board. It is not necessary to make any connection to the middle pin (see Figure 3).

## COMPONENT LIST

### Resistors

R1,R7,R10 = 1k $\Omega$   
 R2 = SIL array 4x10k $\Omega$  (5 pins)  
 R3,R4,R8 = 1M $\Omega$   
 R5 = 100k $\Omega$   
 R6 = 10k $\Omega$   
 R9 = 2.2k $\Omega$   
 P1 = 10k $\Omega$  multiturn preset, vertical, top adjustment, e.g. Bourns type 3266X-1-103LF

### Capacitors

C1,C2 = 100 $\mu$ F 35V radial  
 C3,C4,C5 = 100nF

### Semiconductors

D1,D2 = zener diode 5.1V 0.5W  
 T1 = FDD8445 (Fairchild, N-channel MOSFET, 40V, 5A, 8.7m $\Omega$ )  
 IC1 = 7805  
 IC2 = PIC18F4520-I/P, programmed, Elektor Shop # 090022-41

### Miscellaneous

S1–S4 = pushbutton, single contact, e.g. Multimec 3FTL6 with cap 1D09  
 K1 = 14-way IDC connector for flatcable LCD module, 2x24 characters (5.55mm height), 118x36x14 mm, e.g. Powertip PC2402LRS-AWA-B-Q (Farnell # 1671511) with connector and flatcable.  
 40-way DIL socket (for IC2)

X1 = 4MHz ceramic resonator, 3-pin  
 1 M3x5 screw with nut (for mounting IC1)  
 2 M3x20 screw with nuts (for LCD mounting)  
 2 plastic spacers, 15mm length (for LCD

mounting)  
 12V / 30W soldering iron simple version without temperature sensor  
 PCB no. 090022-1 [1]

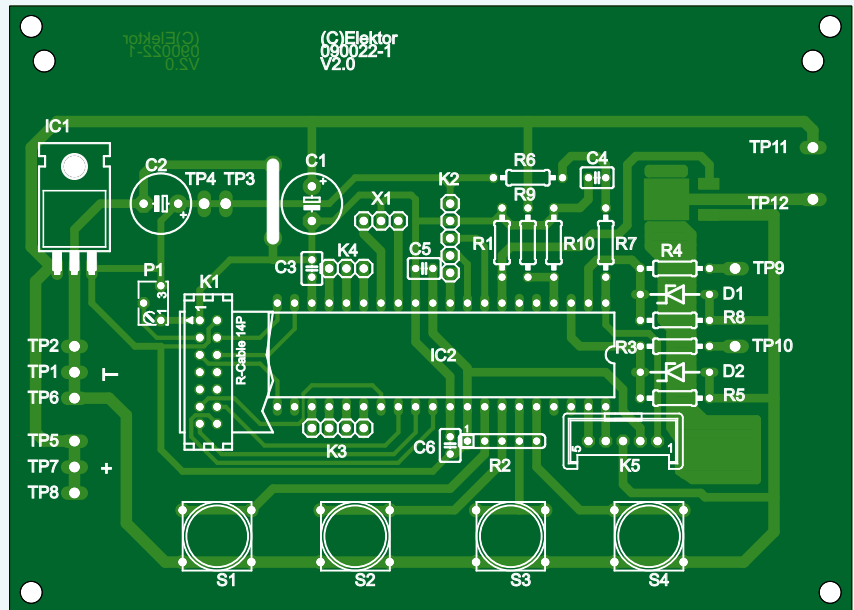


Figure 2. Fitting the components will be no problem on this single-sided PCB.

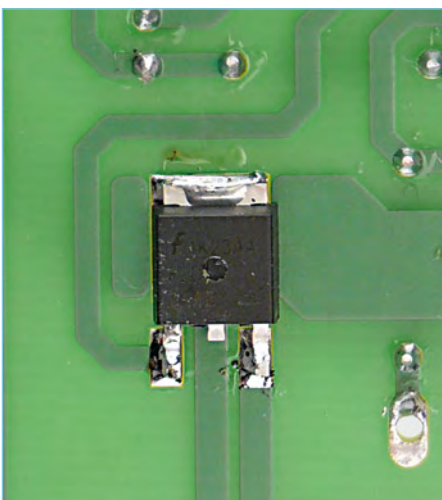


Figure 3. The power MOSFET is soldered to the PCB underside. No connection to the centre pin is necessary.

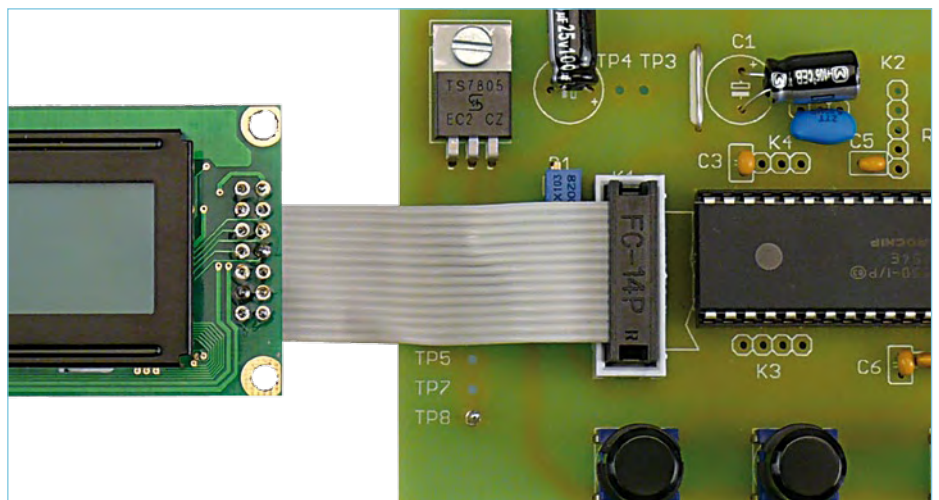


Figure 4. A 14-way ribbon cable connects the LCD module to the PCB.



The only cable required is a 14-pin connector and ribbon cable to connect between the PCB (K1) and the LCD module as shown in **Figure 4**. The pin headers K2 to K4 are available for future expansion of the circuit and K5 is not required unless you plan to program/reprogram the microcontroller 'in circuit'.

The 12 V mains adapter and 12 V soldering iron are the only two external components connected to the controller. The circuit does not include a diode in series with the input supply to protect against reverse polarity supply so it is important to ensure that the board is wired correctly to the mains adapter output. The polarity symbols are printed on the PCB: plus to TP7, minus to TP2. The polarity of the supply to the soldering iron itself is not important; connect the two wires from the soldering iron to TP11 and TP12.

This only leaves wiring between the PCB and the voltage measurement input sockets (two red and two black). The black sockets are wired to ground (TP1 or TP6). As already described the red socket for channel 1 (10 V range) is wired to TP9 and red socket for channel 2 (40 V range) with TP10.

The mechanical layout is simplified if the 4 mm sockets for the measurement channel inputs are positioned to the right of the PCB and mounted on the front panel of a suitable enclosure. The PCB itself can either be mounted behind the front panel in which case cut-outs will be required for the display and pushbuttons or the simpler solution used by the author is to fit the PCB on the outside of the front panel. The result is not quite so neat but allows easy access to the circuit.

### Programming and Function

The simple option is to buy the PIC controller ready-programmed from the Elektor Shop but alternatively if you prefer to compile and program the chip yourself all the C source files including the compiled program file are available for free download from the Elektor website [1]. The author has written the firmware in C using the CCS-C-Compiler for PIC18 processors [2] and the MPLAB V8.20

development environment from Microchip [3]. The last link in the chain if you are programming yourself is the Microchip ICD2 programmer which connects to the target board at the pin header connector K5. Fuses HS, NOWDT, NOPROTECT and NOLVP must be set in the software.

Before the circuit is first powered-up spend a few minutes checking all solder joints and the polarity of the wires from the mains adapter to the PCB. Check that the microcontroller is correctly inserted in its socket (and of course don't forget to program the controller firmware into flash memory!). When the circuit is powered up it enters soldering mode and the display indicates the soldering iron power level (**Figure 5**). Should you see nothing on the display try adjusting the contrast (P1) failing that it could be a hardware failure (check your soldering!) or (hopefully not) a software problem. Pushbuttons S1 to S4 provide the following control:

S1: Increase bit temperature.  
S2: Decrease bit temperature  
S3: Soldering iron ON/OFF  
S4: Switch the unit between soldering and voltage measurement modes.

Pressing S4 toggles the unit through the following modes:

1. Solder (Figure 5)
2. Voltage measurement on channel 1, DC 0 to 10 V (Figure 6)
3. Voltage measurement on channel 2, DC 0 to 40 V (Figure 7)
4. Voltage measurement on channel 3, the 12 V nominal DC input to the circuit (Figure 8)
5. Display all three measurements (Figure 9).

### Calibration and use

Before we can have any confidence in the measured voltages it will be necessary to calibrate the unit. The circuit enters calibration mode when button S1 is held down as the circuit is powered up. The display shows Multi: 1000 indicating calibration mode for multimeter input 1 where 1000 is the mul-



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Figure 5. The start menu at power-up shows the soldering iron control.



Figure 6. Measurement using channel 1 (range 10 VDC).



Figure 7. Measurement using channel 2 (range 40 VDC).



Figure 8. Channel 3 measures the supply voltage to the circuit (12 V nominal).



Figure 9. Display of all three channels.

tiplication factor of the measured value. Using the calculation: measured value x Multi/1000. The unit can be accurately calibrated using a reference level. Pushbuttons S2 and S3 are now used to change the displayed value. S4 switches to the next channel for calibration using S2 or S3 as before. The measurement functions of the unit are designed for low voltage applications only. This includes jobs such as measuring dry or rechargeable cell voltages, DC test point voltage level monitoring in a circuit or adjustment of DC input voltage to a circuit. It is vital that the input is **never connected to mains voltage!**

Power control of the soldering iron is not as sophisticated as you might expect from a professional workstation costing a couple of hundred pounds but it is suitable for a beginner or anyone who only occasionally needs to use a soldering iron. It gives very fine control of power to the soldering bit and with a little practice it's possible to produce good results on different types of soldering jobs. Another advantage of this design is that it uses a low-cost iron which can be replaced quite cheaply. Any low-voltage 12 V iron, for example fine soldering irons with a power rating of 6 W or 7.5 W (up to 30 W maximum) are suitable for use with this design. The display indicates power supplied to the iron as a percentage of the iron rating.

(090022 I)

### Internet Links

[1] [www.elektor.com/090022](http://www.elektor.com/090022)

[2] [www.ccsinfo.com](http://www.ccsinfo.com)

[3] [www.microchip.com](http://www.microchip.com)

# AVR, dB and LDR collide at D/A Junction

By Daniel Rodrigues (Elektor Labs)

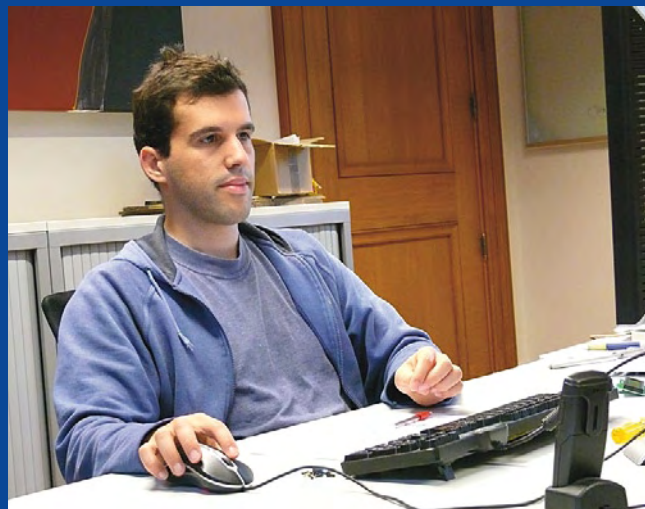
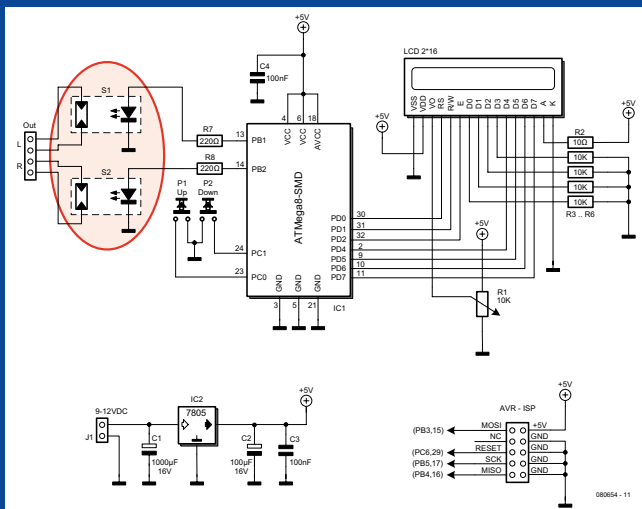
Nothing exceptional about it, I thought, and in line with most of the article proposals we have the pleasure of seeing in the earliest stages of publication. The circuit and the idea behind an 'Innovative Digital Volume Control' proposed by one of our very remote freelance authors was duly taken through our evaluation system and considered a fine candidate for the Summer Circuits edition by the joint editorial team. So we pressed ahead and the paperwork was landed on my desk.

In the original circuit, the key component was an LDR (light dependent resistor) in series with the loudspeaker connection. The LDR is illuminated by a white LED whose brightness is controlled by a PWM



In plain English, the power variation using that finest of LDRs is, oh dear, 16 dB, which is disappointingly low. As a practical example, 16 dB equals the variation of raising speech from a soft whisper to whispering, well, a little louder.

The idea proposed by our valiant author is still nice, but sadly not for an audio volume control as he had hoped. After all, what we have here is a nice and inexpensive gadget which can be safely called a digital potentiometer, or 'DigiPot' in electronics jargonese. Corny



signal produced by a microcontroller — there you have it: state of the art contactless audio volume control! However, when I started testing the device I realised the span of the volume control wasn't too impressive, to put it mildly. In an attempt to overcome the problem I looked for an LDR with a larger resistance variation and the best I was able to locate at the time was rated 50 to 2,000 ohms. Now let there be Science instead of AVR programming. If we take into account that the human ear is able to comfortably handle sound levels within a range of 30–90 dB we should expect something like 60 dB of span to be afforded with ease by our volume control. Let's not forget that power is inversely related to resistance, meaning the lower the resistance, the higher the power. So, the sound power level ratio can be expressed as

$$\begin{aligned}
 L_w &= 10\log(P_{\max}/P_{\min}) \\
 &= 10\log[(U^2/R_{\min}) / (U^2/R_{\max})] \\
 &= 10\log[(U^2/50) / (U^2/2000)] \\
 &= 10\log(40) = 16 \text{ dB}
 \end{aligned}$$

as it may sound, the use of the LDR based DigiPot is only limited by your imagination: control of currents, voltages, brightness, gain, you name it. All optically — sort of — but with better resolution, stability and dynamic control than some more traditional approaches.

Fine AVR programming, no doubt, but with insufficient attention paid to the real world of human hearing and some basic physics, specifically where the dB comes in.

(080654-1)

**Daniel Rodrigues** (1983) has a B.Eng. degree in Electronics and Telecommunications Systems from ISEL Higher Polytechnic Institute in Lisbon, Portugal. Daniel's fortes and hobbyhorses include radio, digital communications and microcontroller systems. Daniel started working in the Elektor Labs in June 2008. When not pondering over electronics on his desk or computer screen, he enjoys hiking and cycling.



## to be honest the libraries that came with Altium were a big disappointment initially

More than once you need to search where a settings is 'hidden' or think how you solved a particular problem on an earlier occasion. It is of course also a consideration that no one in our lab has a full-time job as PCB designer and the complexity of designs varies enormously. The more complex functionality of Altium is not used very often and it is then difficult to become very familiar with it.

Every now and then it's also difficult that there are multiple roads that lead to Rome in Altium. It is a frequent occurrence that you ask a colleague for help and that he happily uses a different set of menus than those that you are used to yourself, this is not always enlightening. On the other hand it can, of course, be very useful that you can obtain the same result using different methods. Altium is very capable at importing PCB layouts from other CAD packages. Unfortunately the very popular Eagle is not one of them, this CAD software that is by far the most popular among our readers, for as far as we can determine. We have asked Altium whether this option can be added to the program, but unfortunately we have not yet received a positive response to this request. That is why in our lab we also frequently use Eagle to change board layouts so that they meet our needs or requirements.

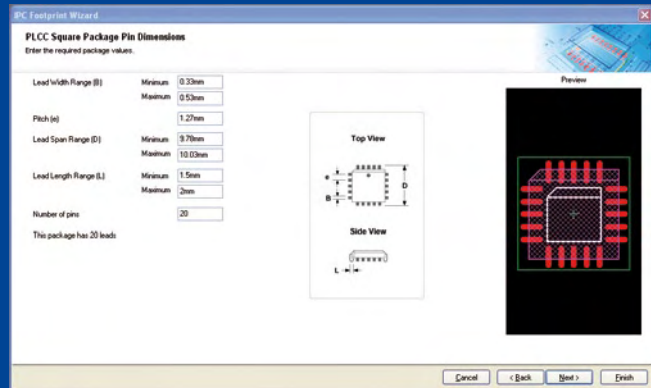
### Handy 3D viewer

The Altium software even has the option of running Delphi scripts, but we have not used that feature yet. Such scripts could be used, for example, to generate parts lists to your own requirements or formatted appropriately, but can also be used to carry out batch operations on schematics or PCBs. We haven't looked into the details too deeply, but it appears that you could control just about anything within Altium. Although everything is extensively documented in the help files, looking at the number of questions on the Altium Designer forum it nevertheless appears to be quite challenging.

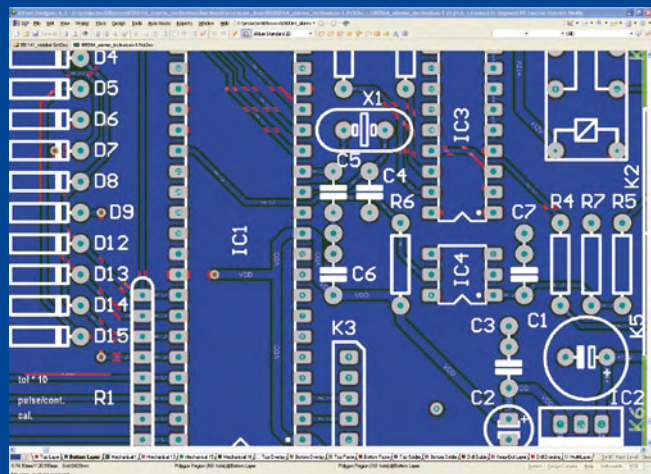
Like every (??) other self-respecting PCB design program, Altium has a 3D viewer which can show a model of the final assembled board from any angle. A prerequisite is that for each component there is a correct 3D model available. Not only does it result in nice pictures on the screen, it can also be of practical value if the finished board has to fit inside a particular enclosure.

Altium also offers the functionality to develop FPGAs, core and embedded projects, programming and testing. The version 6.9 of Altium that we acquired three years ago does require a separate licence for that. At the time we bought only one such licence, which is sufficient for our lab. We mainly use the program for the 'classic' tasks, that is, drawing schematics and designing printed circuit boards.

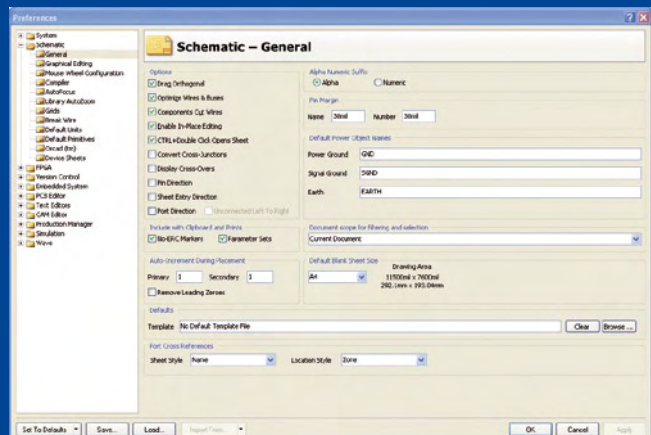
Everything considered, it may appear that we are shooting at a mosquito with a cannon, considering the average Elektor design, but it does save a lot of time. As already mentioned, we have discovered a few drawbacks in the program, but it is still head and shoulders above the other CAD packages we have tested and used here.



Using the Footprint Wizard the Elektor designers have increased the size of solder pads and holes, so that hand soldering is made much easier.



Part of the circuit board for the October 2009 Car Tilt Alarm, developed in Altium Designer.



The Altium CAD program offers an overwhelming number of settings!

(090586-1)

# Sine Wave Service

By Jens Nickel (Elektor Germany Editorial)

We are lucky to have so many subscribers who have been reading Elektor long term. Occasionally when we get a plea from a loyal subscriber we have been known to go the extra mile...

A few months ago I took a call from a gentleman from Munich who had built a function generator featured in the December 1984 edition of Elektor. Unfortunately his trusty old 'scope had recently given up the ghost and he was faced with the problem of how to calibrate the circuit. Any chance he could maybe send the equipment in for us to have a look at?

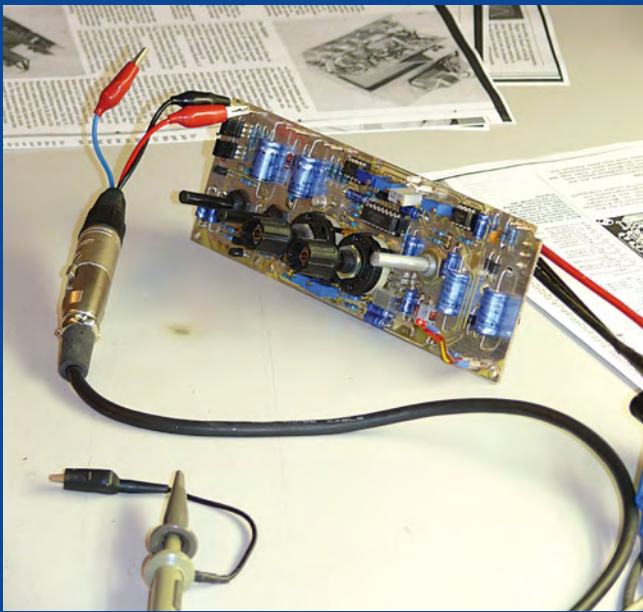
You have probably already guessed how it turned out... normally pressure of work in the lab means that there's no time at all to even consider looking at reader's builds and besides that's your job! Well he must have been in a good mood because after a short discussion the ICE (international coordinating editor) decided that for once we could make an exception and try to revive a 25 year old function generator originally published by Elektor.

those were the days: design engineers writing the articles and editors cheerfully soldering!

The 1984 design was an improvement on an even earlier generator published in the UK edition in January 1978. A rotary wafer switch on the front panel selects sine, square or triangular output waveform. One preset allows optimisation of the sine wave purity. BNC sockets on the front panel provide SYNC output and VCO input. Although the output amplifier is built with discrete components it has the configuration of an opamp with a differential input stage and symmetrical output drivers. The PCB is double-sided but does not have through-hole plating so it is necessary to solder both top and bottom pads of some components on the board.

## Twiddling the presets

Calibration of the unit requires adjustment of nine pots and presets. Thanks to the systematic description of the procedure provided in the original article, Ton Giesbert's expertise and an old Hameg



## Those were the days...

I am probably the only one amongst the team of Elektor editors who was not raised from an early age on a diet of banana plugs and breadboards. This, I thought, is going to be an ideal opportunity for me to get to grips with some real engineering. The original article 25 years ago stated that "A digital solution (with the waveform stored in an EPROM followed by a D/A converter) would be very up to date but would require expensive, difficult to find components". For this reason the design used the Exar XR2206 function generator chip. The chip was not new in fact it had already been available for ten years (and is still available to this day!).

Ernst Krempelsauer, a venerable member of the Elektor editorial group, was keen to point out that a few years earlier he had worked on the design which first introduced the chip to Elektor readers. Ah

1507 oscilloscope it took around 15 minutes to get the generator working again. Out of interest we connected up an Audio Precision System 2 distortion analyser (according to Ton "one of the best audio analysers there is") to test sine wave purity. Harmonic distortion was around 0.5 % and it was possible to adjust the 1 kHz low end to within 0.5 Hz. Calibration complete, but a gentle tap on the case caused the output frequency to shoot up to the upper end of the scale plus around 5 %. Clicking the frequency band selector switch backwards and forwards settled it down to the correct value again. This intermittent fault is probably the result of a flaky connection; we checked all solder joints and switches before we wrapped up the case and sent it back to the grateful gentleman from Munich.

(090606-1)

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# Light Therapy Box

## Blue LEDs combat the Winter Blues



By Ton Giesberts (Elektor Labs)

During the winter many people suffer from Seasonal Affective Disorder (SAD), which is commonly known as the winter blues. With the help of blue light these symptoms can be reduced. The blue-light generator described here has a built-in timer and is perfect for this task.

### Specifications

Power line adapter (9 V / min. 0.5 A)

Current consumption:

0.03 A (minimum brightness)

0.46 A (maximum brightness)

Duty cycle: 8% (f = 1 kHz) to 92% (f = 750 Hz)

Programmable period:

from about 4 to 30 minutes

When the days become shorter after the summer months many people start to feel fatigued. This could manifest itself as anything from a slight tiredness to heavy depression. The most noticeable symptoms are lethargy and problems with eating and sleeping.

This condition is nowadays officially recognised and is called 'Seasonal Affective Disorder' although it is more commonly known as the winter blues.

When the days become shorter and the

amount of daylight reduces, Nature tends to slow down and this is therefore perfectly normal. However, some people with the winter blues are affected so much that their normal way of life is severely disrupted.

Much research has been carried out into the causes of the winter blues and most conclusions show that the biological clock is affected by the reduction in the amount of light that is experienced. The sunlight that strikes the retina triggers chemical processes that affect the working of the pineal gland in the brain. This pineal gland is responsible for the production of melatonin, a hormone that plays a big role in the sleeping process and regulating the internal biological clock.

It is assumed that an excess of melatonin has a depressive influence. It is possible that the production of melatonin has been adversely affected in people who suffer from winter depression. To counteract this phenomenon people are given light therapy, where the retina is exposed to bright artificial light

for a certain time every day. The result of this is that the production of melatonin is reduced.

Recent research has found that the light therapy doesn't necessarily have to be carried out using white light. It appears that it is predominantly blue light with a wavelength between 445 nm and 475 nm that is most effective at combating the winter blues. As a result of this, Philips developed a number of therapy lights (goLITE BLU) that uses a matrix with a large number of LEDs to produce a good amount of blue light.

These therapy lights are not exactly cheap and as electronics enthusiasts we have the tendency to see if we could make such a circuit ourselves (and cheaper). This resulted in the idea to make a blue-light lamp with a built-in timer in the Elektor lab, which was suitable for use by the whole family.

### The circuit

For this project we decided not to use a microprocessor for a change. We've used



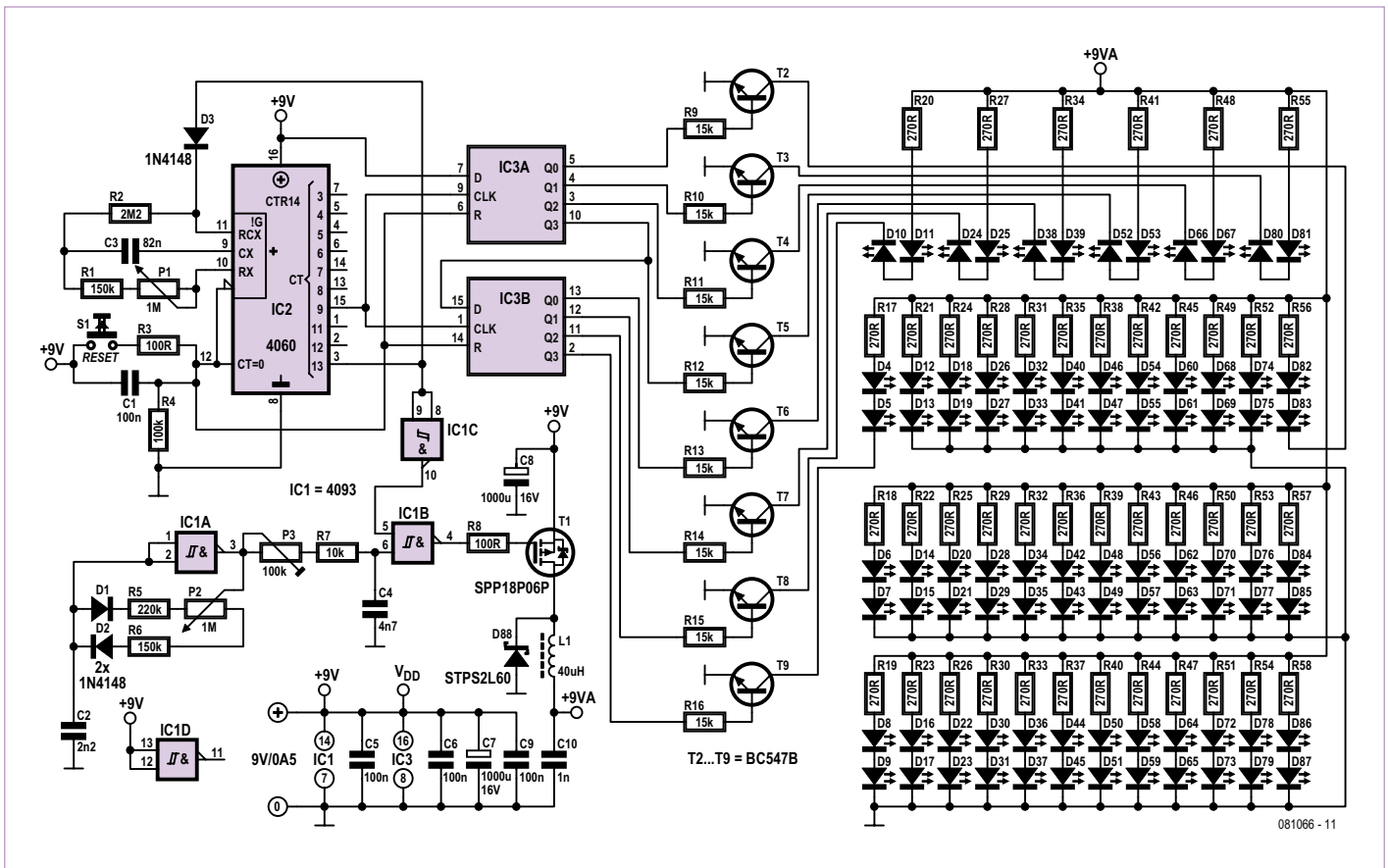


Figure 1. The most conspicuous part in this circuit is the matrix containing 84 blue LEDs.

ICs from the standard CMOS 4000 series in the trusted through-hole packaging. The largest part of the circuit in **Figure 1** is obviously taken up by the numerous LEDs: there are 84 of them. In this case it makes sense to buy 100 pieces, since that usually works out cheaper due to quantity pricing. The LEDs have been positioned fairly close together on the board, so they present a uniform area of light. One row of LEDs is used as a simple display for the timer. The time that the LEDs are lit for can be adjusted with a potentiometer from about 4 minutes to 30 minutes. After this period has elapsed the LEDs are automatically turned off. A second potentiometer is used to adjust the brightness of the LEDs steplessly. Because we've used pulse-width modulation instead of normal voltage regulation the brightness range isn't affected by the value of the forward voltage drop of the LEDs. As we wanted to make the turn-on time fairly accurate we've used a 4060 for the clock, which is an asynchronous counter

with an oscillator. Due to the long period involved we had to use an RC oscillator (if we used a crystal oscillator we required a much larger frequency division). By taking the output from the last stage of the divider (pin 3) and choosing a value of 1 M $\Omega$  for the potentiometer, the value of the capacitor used in the oscillator section (C<sub>3</sub>) can be kept small. For the longest period the frequency is theoretically 4.61 Hz. The frequency of the RC oscillator is about

$$1 / (2.3 \cdot RC) \text{ [Hz]}$$

The time before the last (14<sup>th</sup>) divider output becomes high is then about 1776 seconds (2<sup>13</sup> x 4.61<sup>-1</sup>), or 29.6 minutes. For the shortest period a frequency of about 35 Hz is needed, which results in a period of 3.86 minutes. In practice the period will be affected by various tolerances. Often the potentiometer, which can have a tolerance of 20%, will be the cause of a difference in the period.

The output of the last divider stage is connected via a diode to the oscillator section. When this output becomes high the oscillator stops and the 4060 will stay in this state until the reset input (pin 12) is pulled high. With S<sub>1</sub> the 4060 can be reset at any time, after which the turn-on period starts again. The indication of the time elapsed is achieved using a 4015 shift register. This twin 4-bit shift register is used as an 8-bit shift register by connecting the fourth output of the first register to the data input of the second register. This 8-bit shift register is clocked by output Q<sub>9</sub> (pin 15) of the 4060. The data input of the first register is connected to the positive supply line, resulting in ones being shifted along every clock pulse. The clock input of the shift register acts on the rising edge of the pulse. After 8 clock pulses from Q<sub>9</sub> the register has become 'full'. One clock pulse later output Q<sub>13</sub> of the 4060 goes high and blocks the oscillator via diode D<sub>3</sub>. In this way the selected time period is visualised by the shift

## COMPONENT LIST

### Resistors

R1, R6 = 150k $\Omega$   
 R2 = 2.2M $\Omega$   
 R3, R8 = 100 $\Omega$   
 R4 = 100k $\Omega$   
 R5 = 220k $\Omega$   
 R7 = 10k $\Omega$   
 R9–R16 = 15k $\Omega$   
 R17–R58 = 270 $\Omega$   
 P1, P2 = 1M $\Omega$  potentiometer, linear  
 P3 = 100k $\Omega$  preset, horizontal

### Capacitors

C1, C5, C6, C9 = 100nF MKT, lead pitch 5mm or 7.5mm (0.2" or 0.3")  
 C2 = 2.2nF MKT, lead pitch 5mm or 7.5mm (0.2" or 0.3")  
 C3 = 82nF MKT, lead pitch 5mm or 7.5mm (0.2" or 0.3")  
 C4 = 4.7nF MKT, lead pitch 5mm or 7.5mm (0.2" or 0.3")  
 C7, C8 = 1000 $\mu$ F 16V axial, lead pitch 28mm (1.1")  
 C10 = 1nF ceramic, lead pitch 5mm (0.2")

### Inductor

L1 = 40 $\mu$ H 2A, axial (Epcos B82111EC23, Farnell # 9753354)

### Semiconductors

D1, D2, D3 = 1N4148  
 D4–D87 = blue LED, 5mm, 300mcd, wavelength 465nm, (e.g. Optek OVLLB8C7, Farnell # 1678692)  
 D88 = Schottky diode 60V 2A, (e.g. STPS2L60, Farnell # 9907637)  
 T1 = SPP18P06P (P-channel MOSFET 60V 0.13 $\Omega$ , Farnell # 1056550)

T2–T9 = BC547B  
 IC1 = 4093  
 IC2 = 4060  
 IC3 = 4015

### Miscellaneous

S1 = push button, panel mount

2-way pinheader, right-angled  
 2-way pinheader  
 2 3-way pinheader, right-angled  
 2 3-way socket  
 PCB # 081066, see [www.elektor.com/081066](http://www.elektor.com/081066)

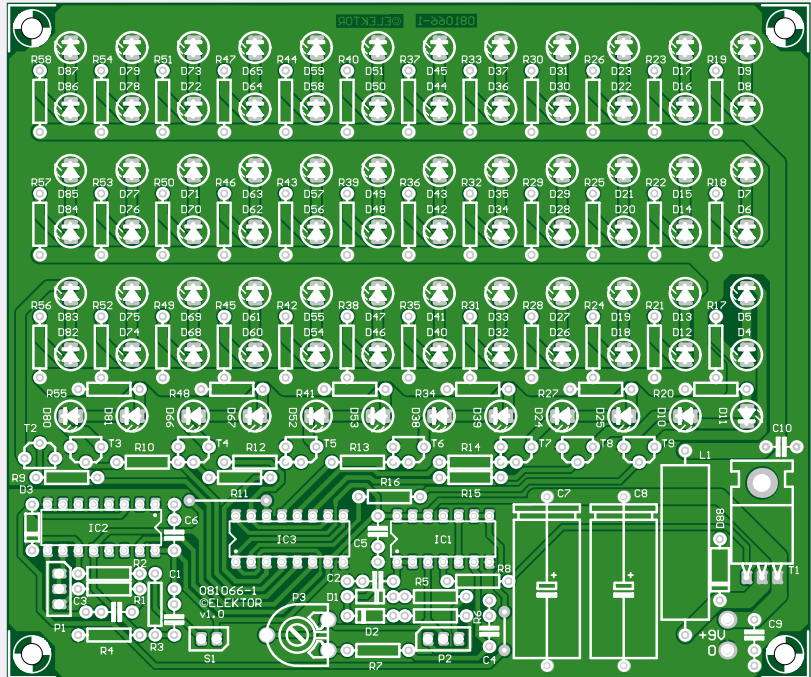


Figure 2. The size of the board is mainly determined by the LEDs.

register on the LEDs in eight equal steps. At the bottom of the matrix are eight groups of two LEDs that are driven by the register outputs via T2 to T9. In order to keep the intensity of these LEDs as similar as possible to the others in the matrix a 'discrete' circuit with normal transistors was chosen, instead of driver ICs (these often contain darlington, which results in too high a knee voltage; the knee voltage of T2 to T9 in the prototype turned out to be close to only 10 mV). There are many ICs available for the pulse-width section that are specifically designed for this task. However, it can also be done simpler, using a modified Schmitt-trigger oscillator designed around the 4093 (quad NAND with Schmitt-trigger inputs). The standard resistor in the feedback loop is replaced by two resistors, each of which have a diode in series in opposite polarities, and a potentiometer in between. The ratio of the charge and discharge times of C2 is greater or smaller than 1, depending on the position of the potentiometer. At one

extreme the charge time is determined by R6 and the discharge time by R5+P2. At the other extreme the charge time is determined by R6+P2 and the discharge time by R5. Since the hysteresis of the 4093 doesn't occur around exactly half the supply voltage, the values for R5 and R6 had to be adapted to provide an almost symmetrical control range, for example from 10% to 90%. Due to this asymmetrical behaviour of the 4093 the frequency changes when the duty cycle is adjusted. In our prototype it was between 1 kHz and 750 Hz. This variation won't be visible to the eye; it only reacts to the pulse width.

A simple integrator has been added after the oscillator in order to be able to turn the LEDs fully on or off. The time constant of R7+P3 and C4 can be adjusted using preset P3 such that the voltage across C4 won't cross the threshold voltage of IC1B at the minimum pulse-width setting (for both positive and negative pulses) and the output of

this gate stays low or high. The integrator has been made adjustable because the hysteresis window of the Schmitt-trigger is not the same for different manufacturers and can even deviate within the same series of a single manufacturer. The output of IC1B is the control signal for P-channel MOSFET T1, which in turn provides the driving voltage for the LEDs.

When the set time has expired, pin 3 of the 4060 goes high and is inverted by gate IC1C and the other input of IC1B is made Low. The output of IC1B stays High and T1 no longer conducts.

For the LEDs a type made by Optek was chosen (OVLLB8C7), which combines ample brightness (min. 170 mcd, typ. 300 mcd) with a large viewing angle of 85°. The wavelength of the generated light is 465 nm. The maximum DC current through the LEDs is 20 mA. The difference in brightness between an LED current of 10 mA and 20 mA was so small for this type that we decided to limit the current to 11 mA.

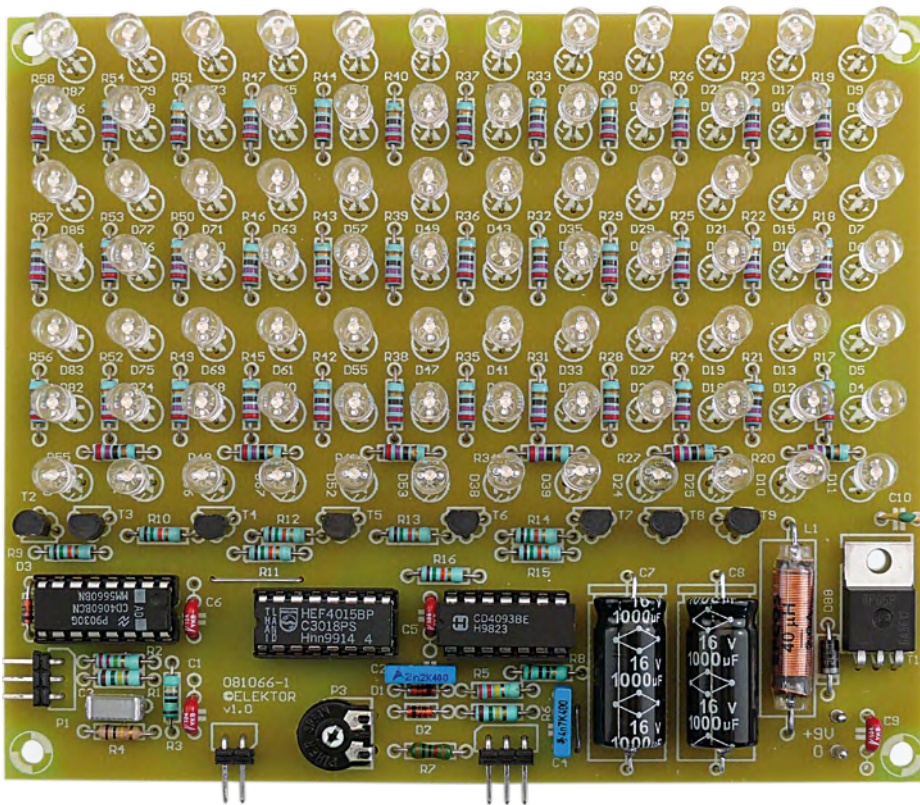


Figure 3. The completed prototype in all its glory.

A somewhat higher voltage drop across the series resistors was chosen in order to reduce the effect of any differences in the forward voltage drop of the LEDs. Using a 9 V mains adapter as a power source, we can connect two LEDs in series. The LEDs in the prototype were found to have a forward voltage drop of just over 3 V, which resulted in a value of  $270\ \Omega$  for R17 to R58. The total current consumption of the LEDs adds up to almost 0.5 A ( $42 \times 11\ \text{mA}$ ).

Inductor L1 has been connected in series with the positive supply to the LEDs for interference suppression. It is therefore not meant to smooth out the current through the LEDs. The same applies to C10. Schottky diode D88 is a freewheel diode that prevents negative spikes from damaging the LEDs.

Two electrolytic capacitors of  $1000\ \mu\text{F}$  have been placed close to L1 and T1 to provide decoupling of the supply voltage. A side effect of these relatively large decoupling capacitors is that when the supply voltage drops below the forward voltage drop

of the LEDs (temporarily unplug the mains adapter) the supply will drop very slowly and the circuit continues running for a considerable time.

### Construction

The population of the board (Figure 2) is fairly standard. The LEDs are best mounted last. Start with the two wire links, followed by the resistors, IC sockets, preset, capacitors, transistors T2 to T9, L1, T1 and finally the two electrolytic capacitors (C7 and C8). For connecting the potentiometers and S1 you can use pin-headers (right-angled versions due to the height restriction) with sockets, but you can also solder the wires directly onto the board. To keep the height of all components to a minimum, we've used axial versions for electrolytic capacitors C7 and C8 and inductor L1, and T1 has been mounted flat on the board.

The LEDs can be mounted in different ways. The easiest method is to solder all of them as closely as possible to the board. That

## Instructions for use

- The recommended daily usage period is between 10 and 30 minutes. The exact period has to be found by trial and error, along with the optimum brightness setting. Start with a short period and see if it has any effect. If it doesn't work, try it for a longer period.
- Start with a fairly low setting for the brightness and increase this in step with the duration until you notice a result.
- The blue-light generator has to be positioned next to you at an angle, so you won't be looking directly into the light. The intention is that the blue light shines onto your eyes from the side. Place the circuit at a distance of about 50 to 80 cm, for example next to your monitor on the desk if you're working with the computer.
- This therapy works best if you start at the beginning of the winter (before any of the winter blues symptoms are noticed) and have a blue light session daily, preferably in the morning.

**Warning:** Don't look directly into to burning LEDs for long periods since they produce a significant amount of light at higher brightness settings!

way they will automatically be in position and may at worst have to be bent slightly into line. If you prefer to mount the LEDs through a front panel, and hence have to mount them about 2 cm above the board to stick out above the other components, things become more difficult. In this case it helps if you first make a template. Take a piece of experimenter's board and drill 5 mm holes in the right places (the LEDs are mounted at every fifth hole of the experimenter's board).

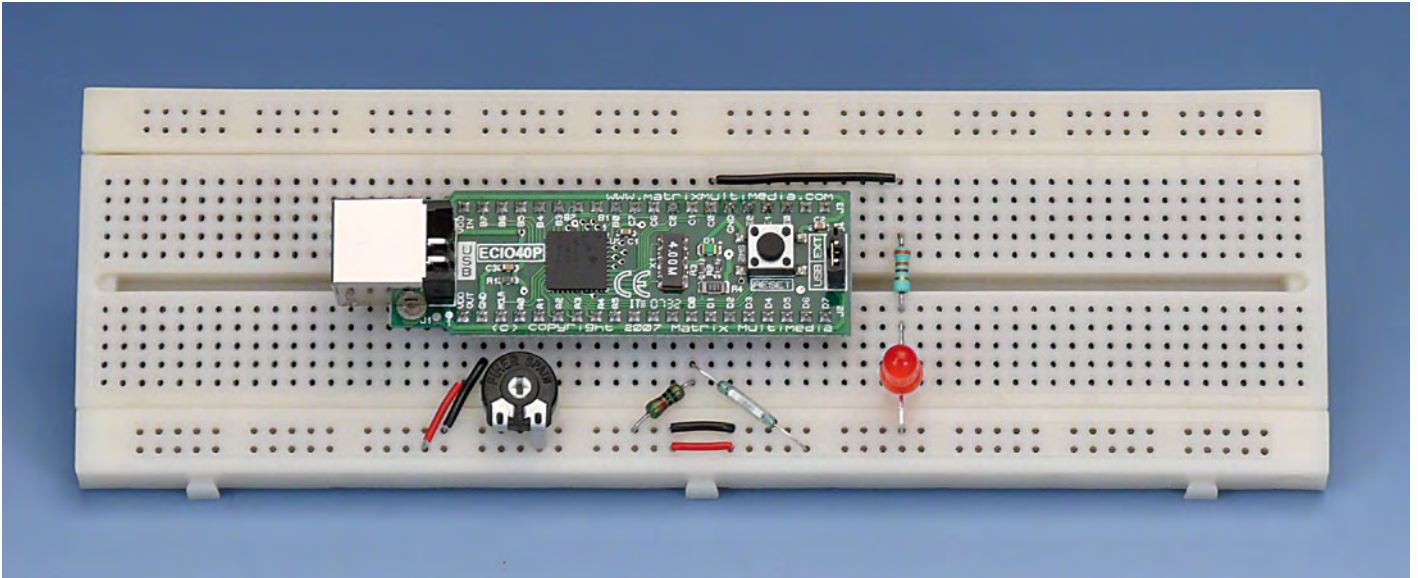
For the case it should be easy to find something to your liking. You can place a piece of Plexiglass in front of the LEDs. Remember to add a riser at the back of the case, so it will be angled when you place it on the table.

And finally here is a little tip: if you're not interested in the time progress bar, you can replace transistors T2 to T9 with wire links (from emitter to collector). In this case there is also no need to mount IC3 and R9 to R16.

(o81o66-1)

# Driver-free USB Interface

## Data collection using ECIO and an HID



By Bert van Dam (The Netherlands)

The ECIO40 is a modern 18F4455 PIC microcontroller mounted on a miniature PCB and sporting a ready to use USB bootloader. The latter enables you to program the ECIO40 without having to buy an expensive programmer. The only things you need are a USB port on your PC and a small (free) program.

In the E-Blocks article published in the March 2009 issue of Elektor, you could read how to measure an analogue and a digital signal using the ECIO40 and make these visible on your PC using the USB interface and a suitable driver. In this article we do *not* use a separate driver, but use the standard HID driver which is already present on all modern Windows based computers.

### This is what we'll do

The purpose of this project is to send an analogue signal via the keyboard interface to a PC, where this information can be used immediately in any software application. You can, for example, open a spreadsheet and position the cursor in the first cell. You now push a button on your circuit or press a key on your normal keyboard. The analogue measurements will now be carried out and are entered into the spreadsheet completely

automatically. The data collected in this way can then be analysed in Excel using methods with which you are already familiar, for example plotting the values in a chart.

### HID

HID means Human Interface Device and is specifically intended for peripherals that are operated by people, such as a mouse or a keyboard. Devices in the category can be connected to the USB interface and do not need a special driver. The operating system in your computer (Windows XP in this project) does effectively take over the task of the driver.

When the device under consideration is connected for the first time, it sends (among other things) two numbers to the PC, the PID (Product Identification number) and the VID (Vendor Identification number). In this project we use a PID code of  $F040$  and a

VID of  $12BF$ . If the PC does not already know these numbers then the circuit has to supply additional information. First the type of device is supplied, this is called *usage*. In this case the usage is a keyboard. This is sometimes also called *usage page 7*.

The exchange of information takes place in groups. These groups are called a *report*. The next step therefore is to detail the contents of the reports, the so-called *report descriptors*. In this case two are required. One to send data to the PC and one to receive data.

Note: when the PC already knows the PID/VID combination, the connection is started immediately. Once you have established a usage page and report descriptors you cannot then change them very easily. That is because the PC does not request

them again and assumes that you have not changed anything.

### Send report

The send report contains the data that the circuit will send to the PC. Note that because we use a standard HID (i.e. that of a keyboard), we cannot change the contents of these reports. The reports consist of eight fields. The first field contains the status of the special keys such as Alt, Ctrl, etc. The second field is reserved. This must contain a '0'. The remaining fields can be used for keystrokes. **Table 1** shows an example of a Send report.

Offset	Field	Length	Description
0	modifiers	1	status of keys such as Alt, Ctrl, etc
1	reserved	1	reserved (0x00)
2	keycodes[0]	1	keyboard code 1
3	keycodes[1]	1	keyboard code 2
4	keycodes[2]	1	keyboard code 3
5	keycodes[3]	1	keyboard code 4
6	keycodes[4]	1	keyboard code 5
7	keycodes[5]	1	keyboard code 6

In a normal keyboard there are two scan codes associated with every key. The first code is sent when the key is pressed and the second when the key is released again. In this way the computer can detect the difference between a very rapid series of key presses and a key held down for a long period of time. **Table 2** lists a few examples.

Key	Make code	Break code
A	1C	F0,1C
5	2E	F0,2E
F10	09	F0,09
Right arrow	E0,74	E0,F0,74
Right Ctrl	E0,14	E0,F0,14

There is fortunately a simpler method. When a scan code is followed by an empty report the PC interprets this as the release code for the most recently pressed key. In this project we do not worry about the make and break codes, we simply send the make code followed by an empty report. You have probably already noticed that the keyboard scan codes do not correspond to the ASCII-code that you are familiar with. **Table 3** shows an overview of the keyboard scan codes that are relevant to this project.

Key	HID make code		Number key	
	HEX	decimal	legend	ASCII
Return	28	40	-	-
Tab	2B	43	-	-
Num Lock	53	83	-	-
Keypad Enter	58	88	-	-
Keypad 1 End	59	89	1	49
Keypad 2 Down	5A	90	2	50
Keypad 3 PageDn	5B	91	3	51
Keypad 4 Left	5C	92	4	52
Keypad 5	5D	93	5	53
Keypad 6 Right	5E	94	6	54
Keypad 7 Home	5F	95	7	55
Keypad 8 Up	60	96	8	56
Keypad 9 PageUp	61	97	9	57
Keypad 0 Insert	62	98	0	48
Keypad . Delete	63	99	-	-

### Receive report

The receive report (**Table 4**) contains the information that the circuit has to receive from the PC. We are actually only interested in the state of the LED for the NumLock key, but the report which contains that information also contains the status of other special keys. You can therefore easily add other functions to the circuit. This report consists of only one 8-bit number, where each bit indicates which LED is on or off. Among these are also the *Compose* and *Kana* keys which are used in Asia for the entry of, for example, Japanese characters.

Offset	Field	Length	LED description	
0	indicators	1	Bit 0	NumLock
			Bit 1	CapsLock
			Bit 2	ScrollLock
			Bit 3	Compose
			Bit 4	Kana
			Bits 5...7	Reserved

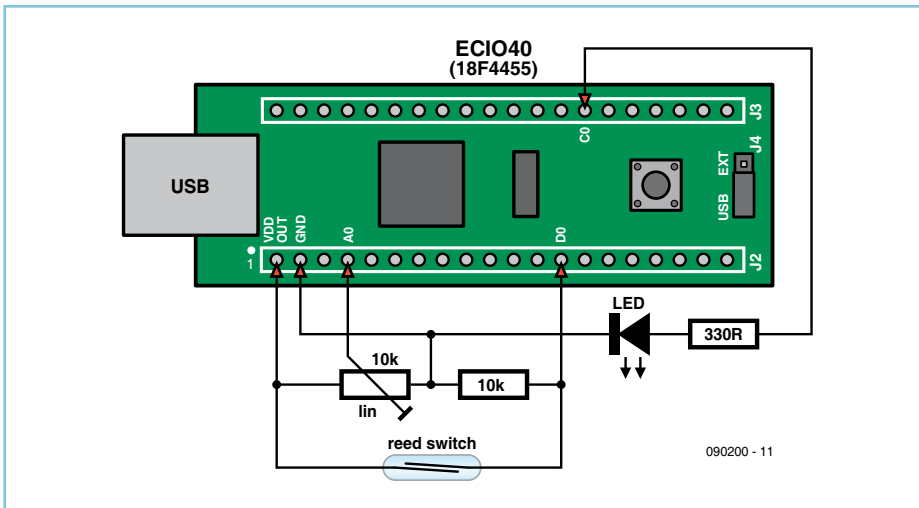


Figure 1. The 'schematic' of the circuit. Only five external components are required.

### Hardware configuration

The analogue signal is generated from a potentiometer which is wired as a voltage divider and can provide a voltage in the range from 0 to 5 volts to pin A0. An LED is connected to pin Co via a series resistor of 330 Ω. Instead of using an ordinary push button for the switch you could also, for example, use a reed switch. This is a switch that reacts to a magnetic field. Such a switch, which consists of two contacts in a glass tube, is normally open. When a magnet is held in the vicinity of the switch it will close. Of course, you can also use a normal switch. The schematic is shown in **Figure 1**.

We start by building the circuit on, for example, a breadboard. The power supply for the circuit comes from the USB-port in the PC. You therefore do not require a separate power supply. The jumper link on the ECIO40 has the be in the USB position.

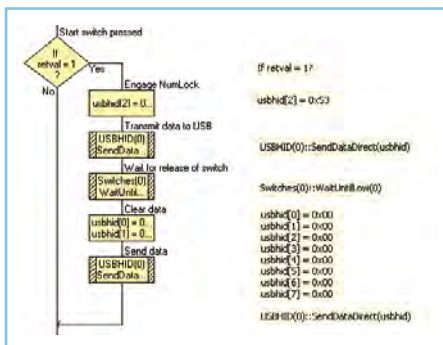


Figure 2. The generation and sending of a send report.

### USB pack

If you are using Flowcode V4 then you already have the required USB functionality available by default and you can skip this section. If you are using V3 then you will have to install the USB-pack from Matrix Multimedia [1] into your version of Flowcode. It is probably a good idea to upgrade to the most recent version of Flowcode V3 first. After you have unpacked the USB pack, you copy the Flowcode V3 directory over the top of the directory with the same name in the Flowcode installation directory (this is usually C:\Program Files\Matrix Multimedia). You subsequently have to run the 'Install USBPack.bat' file in the Flowcode V3\components directory to register the new components. On most PCs you will have to be logged in as an administrator or have administrator rights. When you start Flowcode there will now be three additional hardware components in the component toolbar.

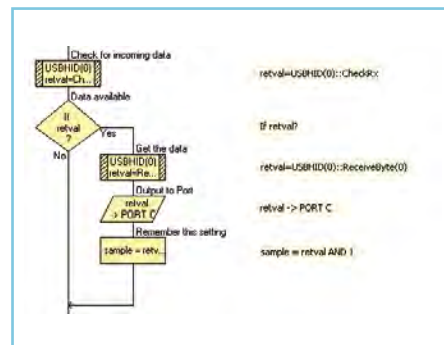


Figure 3. Part of the code for processing the receive report and possibly starting the data logging.

### Software

In this article we use the 'HID' component. Click on this to add the HID component to your project and the following macros can now be used:

- Initialise\_HID
- UpdateData
- SendData
- SendDataDirect
- CheckRx
- ReceiveByte
- ReceiveString

Open the USB component and ensure that the correct PID and VID codes are entered (PID F040 and VID 12BF). Select the HID Options tab. Here you have to indicate how large the packets are. A packet is the sum of all the reports. We are using one send report which contains eight bytes, so the total send packet is eight bytes. We also use only one receive report and that is one byte in size, so the complete receive packet is therefore only one byte. We increase the maximum current to 100 mA, so that there is sufficient current available from the USB-port for our circuit including the LED.

For the Subclass we select *Boot* and for the Interface *Keyboard*. Subclass *Boot* means that we want to make use of the standard reports that are loaded by the operating system when the PC starts up (boots). Now click on the HID Descriptors tab and select *keyboard*. The other settings are not relevant for this project.

We start the program with an *Initialise\_HID* macro. When the USB connection is functioning properly the program ends up in an endless loop where first the state of the (reed) switch is checked. You can therefore use the Flowcode switch component. When the switch is closed an HID send report for the PC is generated which contains the keyboard scan code for the NumLock key, 0x53 according to **Table 3**, at offset 2, the first location where we may place our codes. This report is sent immediately, see **Figure 2**. After that, the program will wait until the switch is opened, after which an empty report will be sent to indicate that the 'key' has been released.

Before we actually send any information we have to wait for the answer from the PC. The PC has to confirm that the key has been received. Incoming answers are sent directly to port C. Only pin Co of this port is used (connected to a red LED), but you could easily extend the circuit by using the other pins of port C as well. This allows you to receive various different commands. Once the PC confirms that NumLock (Co) is turned on, the data logging can begin. To indicate this, the variable *sample* is given the value '1'. In the program the instruction

```
sample = retval AND 1
```

is used for that. When bit zero (that is NumLock) of the answer from the computer (*retval*) is equal to '1' then the value of *sample* will have the value of '1'. In all other cases the value will be 0 (you can therefore use this variable to check whether the USB connection has actually been established (*retval*=0) or not (*retval*=255). If *retval* is not equal to zero the program will stop in our project). The handy feature of this method is that it does not matter what the values of the other bits in *retval* are. Only the value of bit 0 is tested (see **Figure 3**).

By starting the logging only after the PC has sent the confirmation, it is also possible to start the logging by pressing the NumLock key on the keyboard of your PC. This also results in a confirmation from the PC, which is sent to both the normal keyboard and our circuit. For the same reason the NumLock light on your keyboard turns on and off at the same time as the LED in the circuit.

The analogue measurements are done the familiar way using pin Ao. First the ADC component is placed on the work area and assigned to the analogue-to-digital converter on pin Ao (that is, ADCo). From now on the ADC measurement is carried out

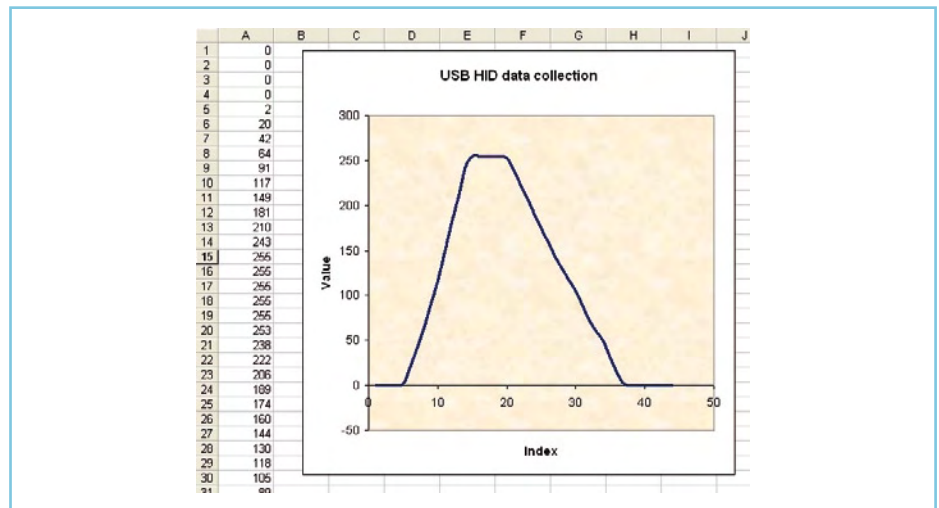


Figure 4. Example of collected data represented in a chart.

which results in a data byte. The measured value ends up in the variable *retval*.

You cannot just send this value to the PC, when the value is 28, for example, you would first have to type the 2 and then the 8 on the keyboard, and not both at the same time. The circuit therefore also has to send the different digits of the measurement one by one. We do that by converting the value into a string and then taking the characters from the string one at a time in the form of an ASCII value. The next step is to convert these characters into keyboard scan codes. Since NumLock is active it makes sense to use the codes from the numeric keypad area of the keyboard. The easiest way is to add 40 to the ASCII value, see **Table 3**. This goes wrong with the number zero, but we correct for this afterwards. After each number we send an empty report to indicate that the key has been released. We finally send an ENTER, again followed by an empty report. In Excel this ENTER ensures that the cursor moves to the next cell down.

### In practical use

To make practical use of this application, carry out the following steps:

1. Start an empty Microsoft Excel spreadsheet and place the cursor in cell A1.

2. Operate the (reed) switch or press the NumLock key on the keyboard.

3. The LED will turn on and every 100 ms the voltage on pin Ao is measured. This value is added to the column in the spreadsheet.

4. Operate the (reed) switch again and the data collection stops (and the LED turns off).

5. The data can now be processed into, for example, a chart (see **Figure 4**).

### What if it does not work?

If it doesn't work as you expect, check that you have selected an unused PID/VID combination. When the circuit is connected there should be an 'HID keyboard device' in Device Manager. If that is not the case then you will have to use another PID/VID combination.

You can also check whether the jumper on the ECIO is in the USB position (if the jumper is in the EXT position an external power supply is expected).

The source code and the HEX file for the program discussed here can be downloaded from the Elektor website [2] as usual.

(090200-1)

### Internet Links

- [1] [www.matrixmultimedia.com/FlowcodeUSBPack.php](http://www.matrixmultimedia.com/FlowcodeUSBPack.php)
- [2] [www.elektor.com/090200](http://www.elektor.com/090200)

### About the author

Bert van Dam writes books for Elektor: PIC Microcontrollers (50 JAL projects for beginners and experts), Artificial Intelligence (23

JAL projects to bring your microcontroller to life), Microcontroller Systems Engineering with Flowcode (45 Flowcode projects for ARM, PIC and AVR microcontroller).

# IGLOO Nano & Icicle FPGA kits

## Cool, cooler, igloo!

By Clemens Valens (Elektor Editorial France)

Often when we talk about FPGA, the first we think of are Altera or Xilinx (in alphabetical order) – but these are not the only manufacturers of this type of devices. Actel is another one. Among its ICs, we find the Fusions, the ProASIC3s and the IGLOOs. Actel is currently playing the low consumption card and states that its IGLOO ICs are the most energy-efficient on the market. We tried out two IGLOO evaluation boards, the Icicle and the nano. Here are the results we got.



You will have realised that the name of the IGLOO family refers to its power consumption, so low that the ICs always stay cool, round the clock. The Icicle board is the size of a ‘Magnum’<sup>®</sup> ice-cream (less the stick) – only it doesn’t melt in your hand! In spite of what you might think, the IGLOO nano board is more than twice as big as the Icicle, and its large number of pins (226) will undoubtedly delight the fakirs out there.

### The IGLOO family

This currently comprises a dozen or so devices, from 15,000 to 3 million gates, and they’re almost all available in several different packages. The family breaks down into three branches: IGLOO (AGL), IGLOO nano (AGLN), and IGLOO PLUS (AGLP). The nanos are aimed at compact, low-consumption products, while the PLUS

offer more I/Os, with greater possibilities.

These ICs achieve their low consumption thanks to optimized power management, particularly through the Flash\*Freeze mode. This stand-by mode makes it possible to ‘freeze’ the FPGA without losing what’s in it. Its memory stays intact, just like the register, and the output pins can maintain their levels. In the Flash\*Freeze mode, the consumption is 5  $\mu$ W for the smallest IC, as against 114  $\mu$ W for the largest. Enabling or disabling this mode takes only 1  $\mu$ s and is achieved via a dedicated input.

Among other specifications, we can also mention a dual-port SRAM of 504 kb maximum, up to six built-in PLLs (phase-locked loops), and up to 620 input/outputs (in an 896-pin package). Certain members of the family are optimized to take a Cortex-M1 ARM processor.



## Specifications of the nano kit (around £45 / €50):

- IGLOO AGL250 FPGA with 250,000 gates
- 8 LEDs
- 5 push buttons (one of which is a reset)
- 8 DIP switches
- Flash\* Freeze
- USB serial port
- All pins accessible via an expansion connector
- Test points
- Programmable I/O and core voltages
- FlashPro3 programmer included
- Libero DVD
- two USB cables

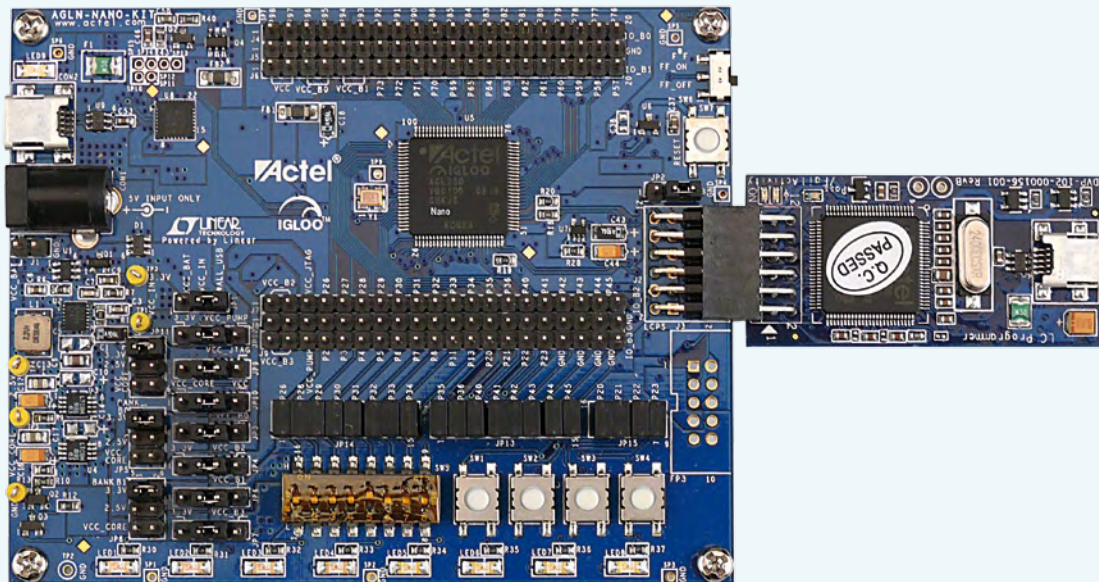


Figure 1. The IGLOO nano kit has lots of pins.

These ICs need no other components to operate, no configuration memory nor crystal, and they work as soon as power is applied.

### The IGLOO nano kit

The nano board is a development and evaluation board. Its name may lead to confusion, since the board does not carry an IGLOO nano, but an AGL250 IC with 250,000 gates. It also includes a PSU, a USB serial port, and a few LEDs and switches. Numerous jumpers allow you to configure the voltages for the FPGA's I/O banks, or its core voltage. Certain contacts allow you to measure various currents — this is the evaluation side of the board.

On the development side, there are two strips of 3×20 contacts on a 2.54 mm (0.1") pitch that make almost all the FPGA's pins accessible. In this way, it's possible to fit a piggy-back board onto the nano

board and incorporate the FPGA into a personal circuit. Thanks to the JTAG programmer via USB, the FPGA is very easy to program.

In the kit box, we find two boards, two USB cables, a bag of screws and spacers, a bag with some jumpers, a Libero v8.4 DVD-ROM (Actel's development tools, see below) and a quick-start guide. The two boards are of course the nano board and the FlashPro3 programming board. The quick-start guide contains a table showing the jumper positions to make the demonstration application work. Once our board was powered up, via one of the two USB cables supplied, the demo application didn't seem to work, even with all the jumpers (except JP1) correctly positioned. Fortunately, the explanation was soon found: you also have to fit the 20 jumpers supplied in the bag onto JP13, JP14, and JP15. These jumpers make it possible to connect the boards LEDs and switches to the FPGA.

## Specifications of the Icycle kit (around £90 / €100):

- IGLOO AGL125 FPGA with 125,000 gates
- 96 × 16 pixel OLED graphic display
- 3 LEDs
- 3 push-buttons (one of which is a reset)
- Flash\* Freeze
- 120 mAh Li-ion battery
- USB serial port
- Expansion connector for 34 I/Os
- JTAG port
- Test points
- FlashPro3 programmer included
- two USB cables
- CD-ROM with documentation, tools, and software

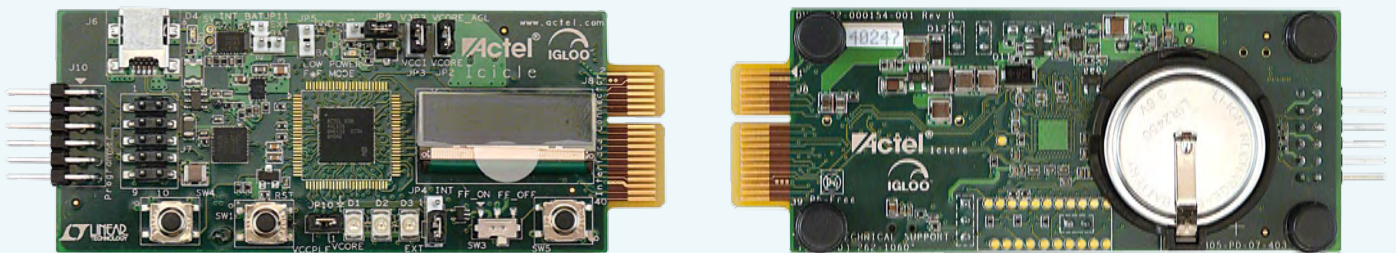


Figure 2. The IGLOO Icycle board is a bit lop-side due to the battery on the solder side.

With **all** the jumpers properly in place, you can play around a little with the LEDs by pressing the buttons or changing the switch positions. (It's worth noting that the references for the buttons and switches in the quick-start guide are wrong). The demonstration application also lets you check the board's USB serial port. If you run, for example, HyperTerminal on the computer and configure the serial port correctly (9600n81), the board will send back the characters transmitted by HyperTerminal. Our board passed this test too.

### The IGLOO Icycle kit

About the size of a mobile phone, the Icycle board includes on one side of the PCB an AGL125 FPGA with 125,000 gates, a tiny (25×7 mm) green or blue 96×16 pixel OLED graphic display, three LEDs, three push-buttons, a switch, a few jumpers, a USB serial port, a JTAG port and an extended JTAG port for the FlashPro3 programmer. On the other side of the PCB we find an LIR2450 format Li-ion battery with a capacity of 120 mAh. The Icycle board can be used in one's own circuit thanks to a 2×19 contact (2×20 if you count the keyway) expansion connector in the Mini Edge Card format. This connector gives access to 34 of the FPGA's I/Os.

All the Icycle's devices are low-consumption, which means the board can be powered just from the battery. Note that when the battery is charged, the only way to turn off the power to the board is to remove jumper JP11.

Besides the Icycle board itself, the Icycle kit contains a FlashPro3 programmer, two USB cables, and a CD-ROM on which are found the data sheets for the Icycle board, the programmer, and certain

devices, and the circuit diagrams of the card, along with the programmer driver, the software for the FPGA, and other potentially interesting documents.

Everything is packed in a recyclable brown box made from recycled cardboard. So it's a kit with low environmental impact – it's 'green'!

The board's manual describes how to measure the current in the different parts of the board and the influence the Flash\*Freeze mode has on these measurements. So we measured the core current running at 1.2 V (2.7 mA) or at 1.5 V (3.6 mA), but the In view of this problem, added to the fact that the pre-loaded application failed to behave as described in the manual, we decided to reprogram the board with the software found on the CD-ROM.

The latter compiled with no problem, though Libero v8.5 (see below) had to convert the project, which had been created with an earlier version. About a minute later, the time taken to reprogram the FPGA, the board worked as described. The LEDs worked differently now (a 3-bit binary counter) and the core current at 1.2 V had dropped to 1.5 mA, or 2.0 mA for a core voltage of 1.5 V. The most important thing is that now the Flash\*Freeze mode was working. We measured around 28 µA at 1.5 V and around 16 µA at 1.2 V. As a result, the board's indicator, which shows if the core current is below 100 µA, also lights up when Flash\*Freeze mode is enabled.

### Libero

Like the other FPGA manufacturers, Actel also makes available a free version of its development tools. The suite, called Libero Gold, includes not only the manufacturer's own tools, but also 'light' versions of other software for FPGA programming specialists, like Mod-

## Libero IDE v8.5 specifications:

- Windows XP Pro with SP2 or Vista Business Edition
- Graphical environment
- Design via circuit diagram entry or programming
- Synthesis
- Simulation
- Placement and routing
- Programming

eSim from Mentor graphics and Synplify from Synplicity. There's also a demo version of WaveFormer by SynaptiCAD.

We started off by installing Libero v8.4, supplied with the nano board. Note that Libero requires Windows XP Pro SP2 or Vista Business Edition as a minimum. The installation went off alright (though you do need to allow nearly 4 GB of space free on your hard drive) apart from a message at the end saying that the installation wizard couldn't find the drivers for FlashPro3, the little FPGA programmer. The Actel website<sup>[2]</sup> mentions this error number SAR 46033. After obtaining a licence, we started the 'Libero IDE Quick Start Guide & Tutorial'<sup>[3]</sup> (don't forget to download the Design Files as well, also available from<sup>[3]</sup>) Concerning the error message at the end of installation, we had to manually create the links in Libero between the tools and their location on the hard drive.

Everything was going fine until we needed to use the WaveFormer Lite tool to create graphically a stimulus file for a simulation. This tool simply refused to recognise the temporary licence supplied by the manufacturer. There was nothing to be done about it, even with the help of the manufacturer's tech support. This was all sorted out by uninstalling Libero v8.4 completely – and manually, to boot, as the installation wizard that also takes care of uninstallation didn't want to know either. Fair enough, all this was probably owing to a slip-up on our part – but all the same, we preferred to order a free DVD of Libero v8.5 (the current version at the time of our experiments) from the Actel website before continuing. It is also possible to download the DVD.

We received the DVD a few days later, and it was as simple to install as the previous version, with the same error at the end. For your information, our test computer runs under Windows XP Pro SP3. The licence management seemed simpler, but perhaps because we hadn't (properly) deleted all the licences etc. from the previous installation. Once the IDE (integrated development environment) was running, everything worked and the tools were recognised. Windows recognised the FlashPro3 programmer when we con-

nected it to a USB port, and this time WaveFormer Lite worked perfectly. So go for Libero v8.5 (or better still v8.6, which had just come out as we were finishing off this article), and follow the instructions given in the messages accompanying the licences to the letter.

The tutorial refers to v8.4 of Libero, and certain details are no longer correct. There's nothing serious and with a bit of patience, you can get through all the stages. But there are a lot of them, and it can take one to two hours. The reward is a board that can make three LEDs flash thanks to a 3-bit counter. It's decidedly less spectacular than the demo application preloaded onto both boards (which you delete as you go through), but it's so gratifying that you stay watching, mesmerised, for a long time.

Just to finish, let's once again clarify one little subtle point. Libero needs to know which FPGA is being used, and offers a long list of all the models it knows, from which you have to choose the right one. In this list, there are two versions of the AGL250 on the nano board, V2 and V5 (the same goes for the AGL125 on the Icicle board). However, the version is not marked on the device itself, and on the Actel website<sup>[1]</sup> the information is well hidden. But if you know where to look, you can find it – for example, on the AGL family data sheet<sup>[5]</sup> (the note on page III, of course!) It's simple: if there is no version shown on the device, it's a V2. This model can operate with a core voltage between 1.2 V and 1.5 V, unlike the V5, which only works with a core voltage of 1.5 V.

### Final remarks

Actel has gone to a lot of trouble to create comprehensive evaluation and development platforms that are easy to use and relatively cheap. The systems are not very complicated to use and are accessible even for novices. The two nano and Icicle kits are supplied with matching FlashPro3 programmer (blue for the nano board which is blue and green for the Icicle board which is green), which shows a certain attention to detail (or a lucky coincidence!) With such a complex product, encountering a few minor hiccups is acceptable.

(090528-1)

### Internet Links

[1] [www.actel.com](http://www.actel.com)

[2] [www.actel.com/download/program\\_debug/flashpro/fpro85.aspx](http://www.actel.com/download/program_debug/flashpro/fpro85.aspx)

[3] [www.actel.com/products/hardware/devkits\\_boards/igloo\\_starter.aspx#docs](http://www.actel.com/products/hardware/devkits_boards/igloo_starter.aspx#docs)

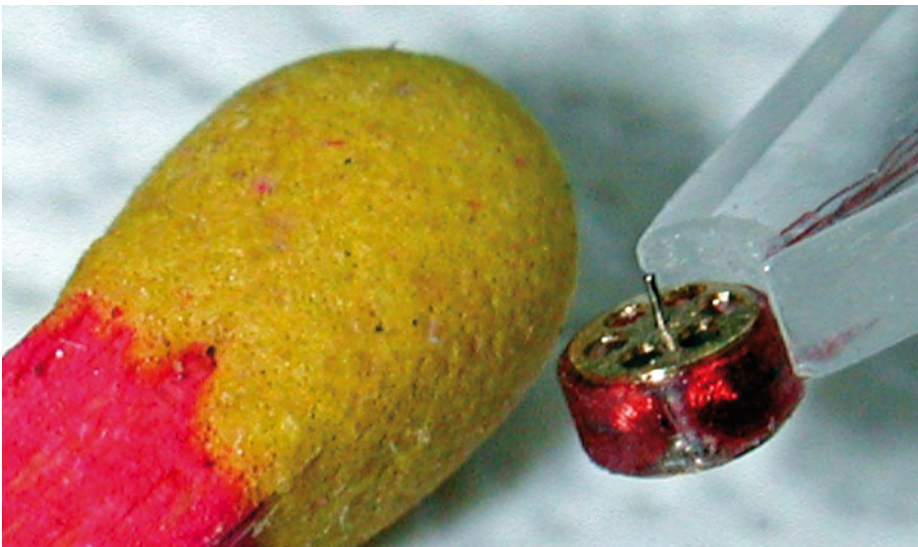
[4] [www.elektor.com/090528](http://www.elektor.com/090528)

[5] [www.actel.com/documents/IGLOO\\_DS.pdf](http://www.actel.com/documents/IGLOO_DS.pdf)

# The World's Smallest Electric Motor

Elektor reader listed in the Guinness Book of Records

By Harry Baggen (Elektor Netherlands editorial staff)



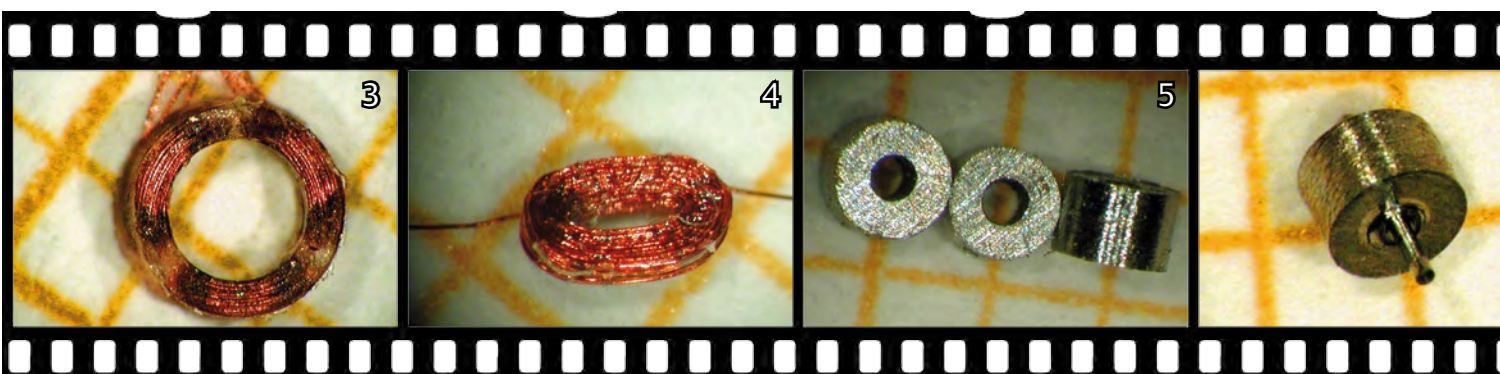
What would you say to an electric motor smaller than the head of a pin, and what's more, mostly hand made? It really exists. With this motor, Jos d'Haens recently established an official world record recognised by Guinness World Records.

Jos d'Haens is an especially versatile individual who has done many different things in his life. Although he was especially interested in technical subjects in his youth, he began his professional career as an economist with Bell Telephone in Antwerp. There he had an opportunity to switch to engineering and concentrate more and more on technical matters and electronics. He was especially interested in microelectronic and micromechanical aids for industrial and medical applications.

His first invention was a tiny electric motor for use in biomedical applications, which at the time (1958) was the smallest electric

motor in the world. In 1962 he developed an 'endomotor probe', which is a device for examining the gastrointestinal tract. To improve his theoretical knowledge, in 1966 he enrolled in a course of study at the Faculty of Science of the Sorbonne. His further career consisted of a variety of large projects, such as setting up and managing two PCB plants in Belgium and several electro-optical plants outside Belgium, as well as pursuing his own inventions. These involved a wide variety of devices, such as equipment for measuring air pressure and relative humidity and the very first European wristwatch calculator.

We could mention a lot more examples, but in any case it's clear that what we have here is an inventor and engineering adept who always has to be doing something. It should thus come as no surprise to our readers that Jos has been a faithful reader of *Elektor* magazine since the very first issue. Now that he is retired, he still keeps busy with electronics and engineering. In his well equipped personal shop, he works regularly on his favourite hobby: making micro-motors. His latest product is a hand-made miniature electric motor that, according to him, is the smallest mechanical motor in the world.



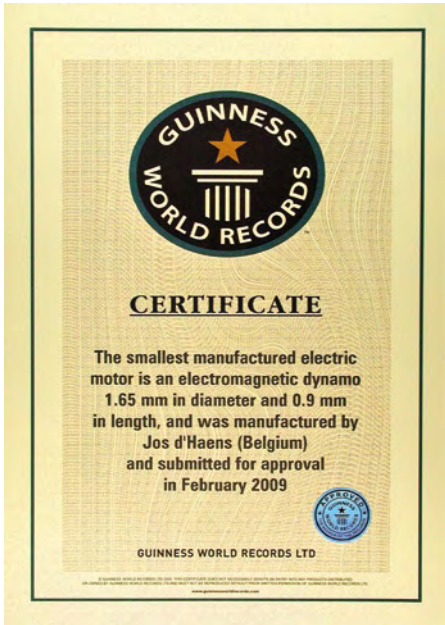


Figure 1. The Guinness World Records certificate.

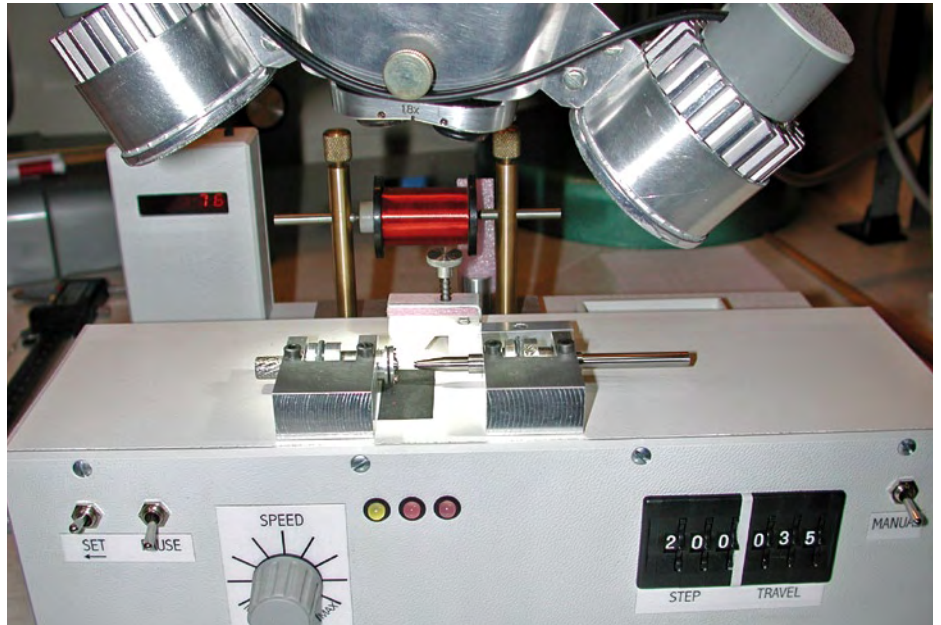


Figure 2. Special equipment was developed to fabricate the miniature components.

A few months ago, Jos reported this remarkable device to Guinness World Records, in the hope that his product would be recognised as the world's smallest electric motor. After a long wait, in February he received a certificate from Guinness World Records stating that his new electric motor established a new world record, which of course will be reported in the next edition of the *Guinness Book of Records*.

The primary stimulus for the development of a new, even smaller motor was a contest, but it is entirely possible that the resulting motor will be used in a practical application.

Although Jos can make use of special equipment of his own design (as shown in Figure 2) in the preparation of his prototypes, we imagine that Elektor readers would be especially interested in the design and construction of this motor. If the dimensions are enlarged somewhat, a motor of this sort can also be built using ordinary tools.

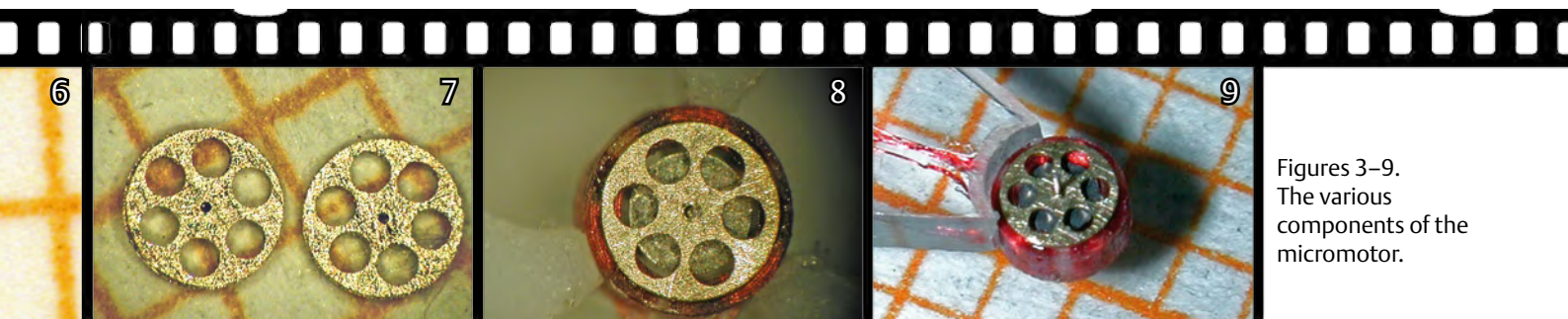
First let's have a look at some of the specifications of the micromotor:

- Diameter:** 1.65 mm
- Length:** 0.90 mm
- Weight:** 9.8 mg
- Volume:** 1.92 mm<sup>3</sup>

- Operating voltage:** 0.220 V
- Operating current:** 18 mA
- Speed:** 600 to 6000 rpm (variable)

The miniature electric motor has three windings that are driven by an electronically generated three-phase signal. It is thus an example of what is called a 'brushless DC motor'.

Figures 3 to 9 show the various components of the motor. Figure 3 shows one winding, which consists of 80 turns of 0.02-mm copper wire. A total of three such windings are necessary. They are formed into the proper shape (flattened and slightly curved) as



Figures 3–9. The various components of the micromotor.

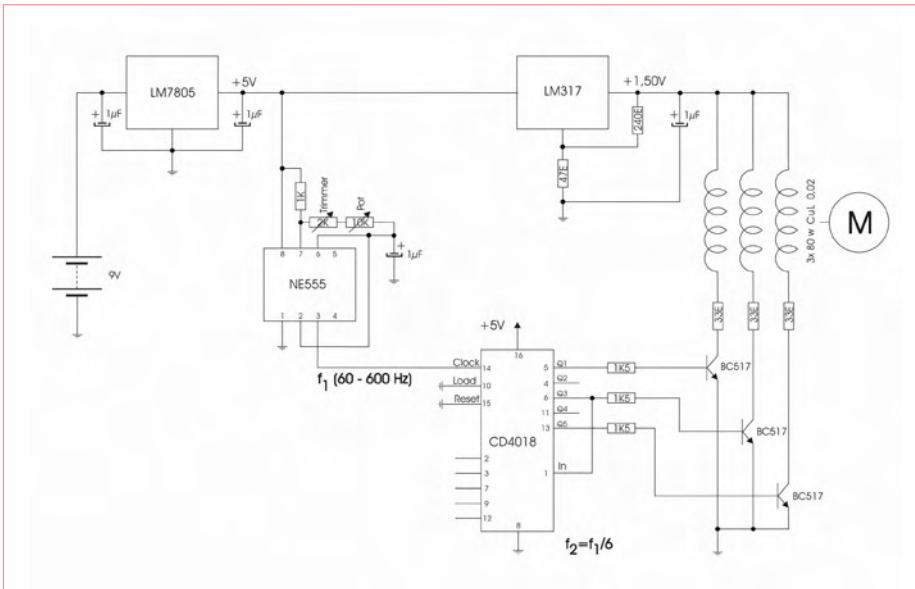


Figure 10. Schematic diagram of a micromotor drive circuit. With suitable modifications to a few component values, this circuit can also be used to drive larger motors with three windings.

shown in Figure 4. The rotor consists of a very small magnet (5) that is eroded and ground to the right dimensions and has a hole for the attachment of the shaft (6). Two tiny plates with cutouts (7) act as the upper and lower portions of the motor housing. Figures 8 and 9 show the complete assembly. The winding are glued in place between the upper and lower plates, so they effectively

form the rest of the housing. If you want to experiment with your own DIY motor, you can use the schematic diagram shown in **Figure 10**. This is the original circuit that Jos used to drive his micromotor. The design is simple but very effective. Starting from a 9-V supply voltage (provided by several penlight cells in a battery holder or a single 9-V battery, which is

adequate for a micromotor), a 7805 voltage regulator generates a stable 5-V operating voltage. This voltage is used to power the other ICs in the circuit. A second voltage regulator (an LM317) is used to reduce the voltage to 1.5 V, since the windings of the micromotor require a relatively low operating voltage.

The frequency of the three-phase drive signal is controlled by a 555 configured as a square-wave generator whose output frequency can be adjusted by a potentiometer over the range of 60 to 600 Hz. This signal is fed to the clock input of a CD4018 presettable divide-by-N counter. The Q1, Q3 and Q5 outputs of this counter drive the motor windings via a set of BC517 Darlington transistors with 33-Ω series resistors to limit the motor drive current. The CD4018 is configured to operate as a divide-by-six counter by connecting pin 6 to pin 1. The signals on the Q1, Q3 and Q5 outputs drive each of the windings in sequence with a certain amount of overlap, which creates a well-defined rotating magnetic field in the motor.

If you want to use this circuit for your own projects, you can modify the frequency and voltage of the winding drive as necessary. Bear in mind that the BC517 transistors have a maximum rated peak current of 1 A, so a larger type must be used if higher currents are necessary.

(090499-1)

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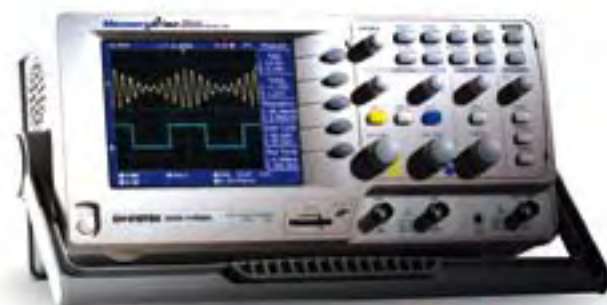
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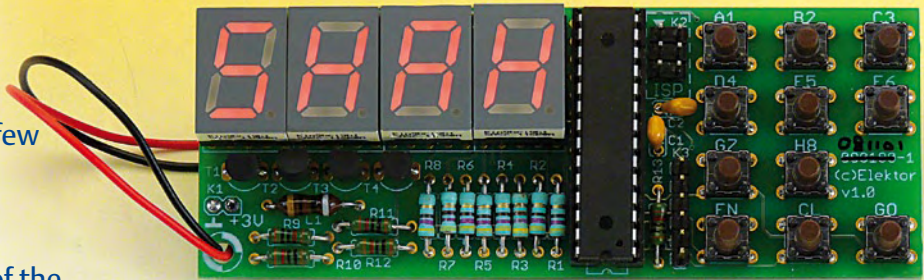
# AVR-Max Chess Computer

## A minimalist homebrew chess computer

With contributions by Andre Adrian (Germany)

For just a few pounds you can take a microcontroller, add a few pushbuttons and some 7-segment displays to build a chess computer reminiscent of the legendary Mephisto I.

The low component count (and no SMDs!) allows the entire machine to be shrunk onto a neat pocket-sized PCB. Despite LED displays it draws just 20 mA and will run until the battery supply falls below 1.9 V.



Following on from last month's feature on the ATM18 Mini Chess Computer for the Elektor AVR board we now present, as promised, a dedicated stand-alone chess computer featuring the same firmware with optimised hardware. This mini project originates from the SHAH computer developed by Andre Adrian, described in detail last month. The original firmware has been ported to run with 7-segment displays and the prototype PCB produced by the author was reworked in the Elektor Labs to produce a professional job just half the size of the original. The computer's basic operation has already been described in the previous article so we will just concentrate on construction and operation with the 7-segment LEDs which replace of the two-wire serial interfaced LCD display of the ATM18 project.

### The circuit

The central element in the circuit diagram (Figure 1) is an ATmega88 microcontroller in a 28-pin skinny DIP package. The controller's clock is derived from its on-board RC oscillator running at 8 MHz (max). A 3 V supply is provided by two series connected AA or AAA batteries via coil L1. On power-up the network formed by R13/C2 generates a reset to the microcontroller. Connector K2 provides an ISP programming interface for either the AVRISP-MKII or compatible Elektor USB AVRprog [1]. The controller firmware is available for free download from the Elektor website [2].

A ready-programmed controller is also available from the Elektor Shop so you don't need to program it yourself.

Port pins PDo and PD1 connected to K3 provide a serial interface for a PC. The signal levels are compatible with the USB TTL adapter cable featured in Elektor June 2008 [3].

### Features

- Minimal component count
- Low power (20 mA @ 3 V)
- Battery power using two AAA or AA cells
- Nine playing levels
- Look-ahead 20 halfmoves
- Elo rating approx. 1200-1399
- Display of principal variant mode (on/off)
- Opening set-up possible
- Select black/white at start of play
- Change sides during play
- Computer can also compete against itself

The rest of the circuit consists of a multiplexed interface to drive the 7-segment LED displays (LD1 to LD4) via transistors T1 to T4. Seven port pins read the push button matrix S1 to S11 in precisely the same way as the 'ATM18 Mini Chess Computer' described last month. The C routines driving the display and scanning the push button matrix are optimised to help reduce power consumption. The C source code is well documented and worth downloading.

### And PCB

Construction is quite simple, despite the small (100 mm x 40 mm) PCB (Figure 2) no SMD components are used in the design. The layout is double-sided and through-hole plated. For simplicity all components are mounted on one side only (Figure 3). Connectors K2 and K3 need not be fitted if you do not intend to program the controller in-system. Use an IC socket for the ATmega88. The project is also available as a kit from the Elektor Shop, with all the necessary components. To make a really neat job the finished board can be fitted into a suitable enclosure.

### Game on...

The chess engine and keypad input routines are identical to those used on the ATM18 mini chess computer described last month. The AVR-Max chess computer however has a more basic 4-digit LED display which allows it to display a maximum of four characters. Before powering the unit up take a few minutes to inspect all the soldered joints to make sure you have not accidentally bridged two pads with a blob of solder and that IC1 is fitted the correct way round. Once you are sure that the supply leads are correctly connected the unit can be powered up. If everything is in order the word 'SHAH' appears on the display. Pressing the CL button clears the display ready for your first move to be entered. Enter for example E2E4 and press the GO



# COMPONENT LIST

## Resistors

R1–R8 = 470Ω  
R9–R13 = 10kΩ

## Capacitors

C1, C2 = 100nF (lead pitch 0.1" / 2.54mm)

## Inductor

L1 = 10μH (fixed inductor)

## Semiconductors

LD1–LD4 = SA52-11 (Kingbright), 7-segment LED display, red, common anode, 13.2mm height  
T1–T4 = BC559C (or -B)  
IC1 = ATmega88P-20PU (Atmel), programmed, Elektor Shop # 081101-1

## Miscellaneous

S1–S11 = push button, 1 make contact, PCB

mount, e.g. Multicomp MCDTS6-5N  
K1 = 2-way pinheader or 2 solder pins  
K2 = 6-way DIL pinheader  
K3 = 6-way SIL pinheader, right angled (optional)  
Battery holder for 2 AA or 2 AAA batteries

Kit of parts # 081101-71 (see Elektor-Shop, www.elektor.com)  
PCB # 081101-1  
Project software, free download # 081101-11.zip from www.elektor.com/081101

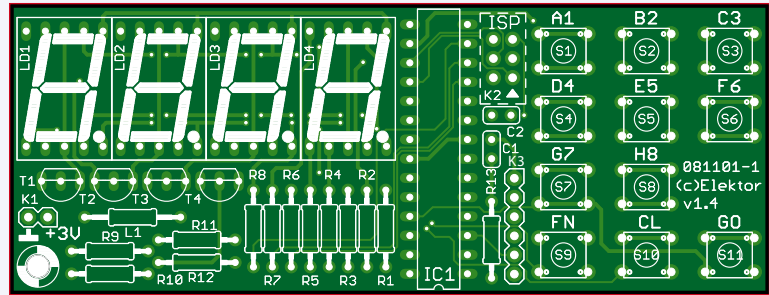


Figure 2. The double-sided PCB measures just 100 mm x 38 mm but does not use any SMDs.

button twice to enter the move and instruct the computer to calculate its move. An

attempt to enter an illegal move will generate 'ILL' on the display. A blinking display

shows the players move while a static display shows the computers move. When

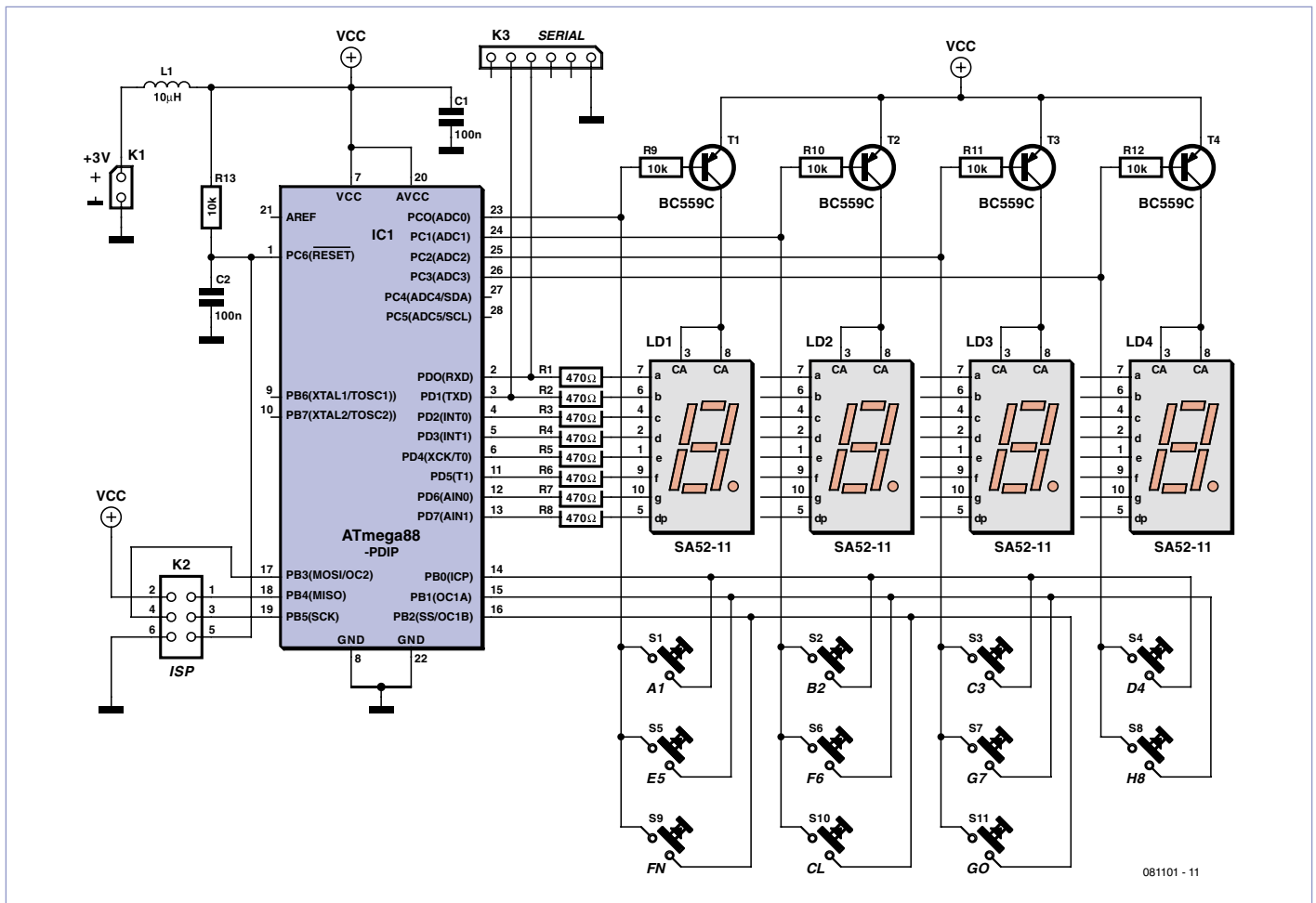


Figure 1. AVR-Max circuit diagram. The ATmega88V uses its internal 8 MHz RC oscillator.

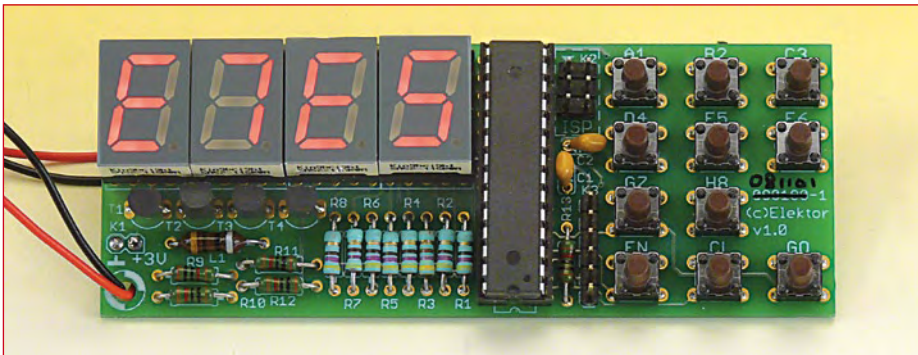


Figure 3. The fully populated circuit board.

checkmate occurs 'MATE' is displayed. At power-up the computer will always play black. To switch it to white press CL then GO. To set up an opening position (e.g. E2E4, E7E5, G1F3 and B8C6) enter both black and white moves while pressing the GO button once only after each move. The FN button gives access to all the set up functions. FN and 1 starts a new game, FN and 2 changes the playing level (press GO

to return from play level setting). FN and 3 switches the principle variant mode off or on (see last month's 'ATM18 Mini Chess Computer' feature). The CL button clears input values. The philosopher and AI sceptic Hubert Dreyfus predicted that a computer would never be capable of playing chess at the highest level. Since then we have seen Grandmasters humbled by super-computing number-

crunchers. One tip for the faint-hearted: When your situation looks a little grim during a game just press the GO button to swap places with the computer, see if it's smart enough to get itself out of the position it played you into! Too bad we don't have a GO button to get us out of tricky situations in real life!

(081101-I)

### Internet Links

[1] [www.elektor.com/080083](http://www.elektor.com/080083)

[2] [www.elektor.com/080947](http://www.elektor.com/080947)

[3] [www.elektor.com/080213](http://www.elektor.com/080213)

Author's website (German):

[www.andreadrian.de/schach/](http://www.andreadrian.de/schach/)

Author's email: [Andre.Adrian@gmx.net](mailto:Andre.Adrian@gmx.net)

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# 'Say It' MODULE

The Parallax **Say It Module** (#30080) provides voice recognition functions for 23 built-in pre-programmed or up to 32 user-defined commands. The GUI software for the BASIC Stamp 2 provides an easy interface for training the module and producing template code. Or use the simple and robust serial protocol to access the Say It module functions from other microcontrollers. The 10-pin SIP fits the Board of Education AppMod header, and code for the Boe-Bot robot is provided.

**Application ideas include: voice controlled robots, home automation, and voice activated projects.**

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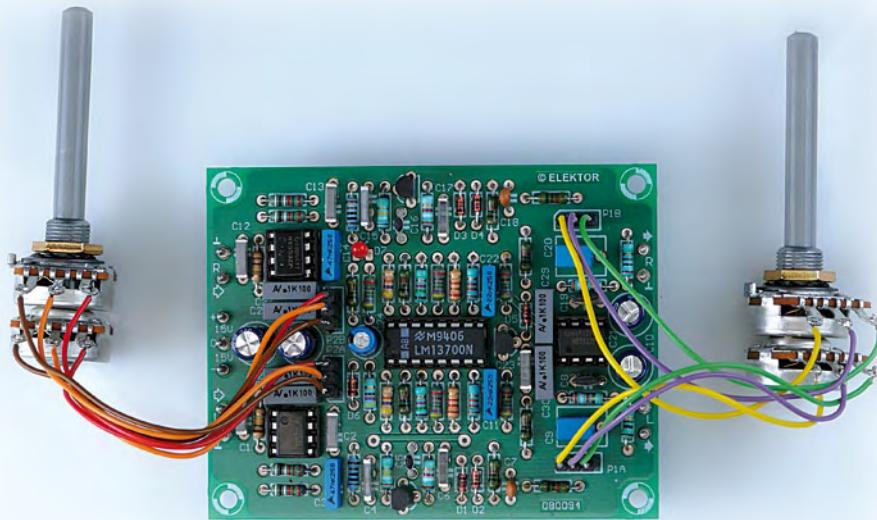
# Booster for Audio Signals

## Cranks up bass & treble

By Markus Aebi (Switzerland)

Dull and washed-out sound? With modern recording technologies this is unlikely to happen.

There are nevertheless situations where a fuller sound would do no harm (live bands, for example, but cheap headphones could also benefit). A small amount of 'effect' could make the sound experience just 'perfect'.



Weak bass and dull treble frequencies are things of the past with this circuit. The ingenious principle of the project described here makes the reproduction more delicate, fuller and subjectively louder. The circuit was originally intended to be built into a mixing desk (immediately before the Master Fader), but works just as well as a standalone device when the input and output voltages are adjusted appropriately (about 1.5 V<sub>p</sub>/0 dB at the first op amp).

### The principle

The high and low frequencies are processed independently of each other. The left and right channels are identical, with the exception of the part of the circuit controlling the amplification of the low frequencies, which is used for both channels and therefore does not need to be implemented twice (see **Figure 1**).

After the high-pass filter with C<sub>4</sub> (C<sub>15</sub> for the right channel) the high frequencies are amplified 'quick and dirty' with the circuitry around T<sub>1</sub> (T<sub>2</sub>). The diode pair D<sub>1</sub>, D<sub>2</sub> (D<sub>3</sub>, D<sub>4</sub>) generates higher harmonics which are added to the original signal with potentiometer P<sub>1A</sub> (P<sub>1B</sub>). This makes it sound 'fresher'.

The low frequencies are separated from the original signal with the network around IC<sub>1B</sub> (IC<sub>2B</sub>) and subsequently passed on to the current-controlled operational transcon-

ductance amplifier (OTA), which is configured as a VCA here (Voltage Controlled Amplifier, IC<sub>4A</sub> and IC<sub>4B</sub> respectively). The 'Dynabass' potentiometer P<sub>2A</sub> (P<sub>2B</sub>) determines how much of the original signal is processed. RC network R<sub>16</sub>/C<sub>11</sub> acts as a variable low-pass filter (and also has a variable phase shift with respect to the original signal, which results in a subjective amplification of the low frequencies). The values of the RC pair affect the tuning of the filter. The selected resistor of 33 kΩ in combination with a capacitor of 22 nF gives optimum tuning.

The control current of the VCA, which determines the gain of this IC, is generated with the circuit around T<sub>3</sub>. This circuit works as a kind of limiter circuit (quasi limiter function) and shows via LED D<sub>7</sub> how much 'control' is applied. The processed signal is added to the signal immediately after the 'Harmonics'-potentiometer (P<sub>1A</sub> and P<sub>1B</sub> respectively).

When both potentiometers are set to their minimum positions the signal passes through unchanged.

An external symmetrical power supply of ±15 V completes the story. The current consumption at this voltage is about 40 mA for the positive supply rail and 35 mA for the negative supply rail. Each IC is provided with

decoupling capacitors and the PCB is fitted with additional 100 μF buffer electrolytics.

### Construction

When assembling the PCB you follow the traditional procedure: first the 'small' parts such as resistors and diodes, then the 'bigger' parts such as capacitors and transistors. We used sockets for the ICs so that swapping the op amps for a different sound is very easy. The construction is not all that difficult because no SMD components are used.

In our prototype we chose to use headers and sockets for the connections to the two double potentiometers. These are mentioned in the parts list. It is, of course, also possible to omit those headers and connect the potentiometers directly to the board using short wires.

The double-sided PCB has been made as compact as possible (88 × 69 mm) and has not been designed with a specific enclosure in mind (see **Figure 2**). The PCB layout can be downloaded from the project page [1].

### Measurements

The two graphs summarise how the circuit influences the signal. The graph in **Figure 3** shows the amplitude characteristic of the low-pass filter. This shows that the low-fre-

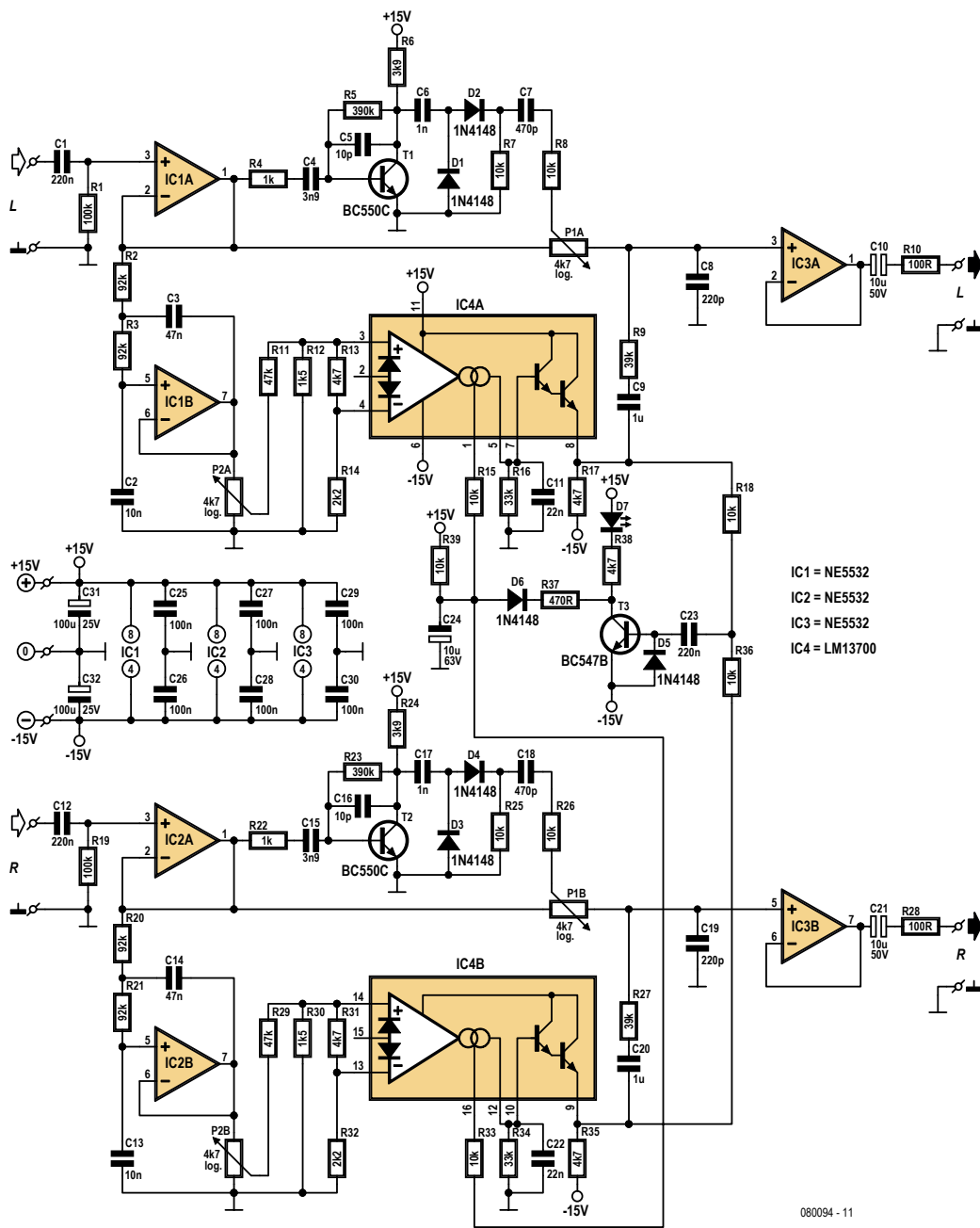


Figure 1. The schematic may strike as quite sizeable, but the dimensions of the PCB are very reasonable.

quency part of the circuit operates below about 100 Hz. At the high-frequency end the circuit operates from around 5 kHz, based on the clipping of T1 (T2). The second curve (Figure 4) shows the ratio

between the amplitudes of the input and output signals of the VCA (green curve), measured at pin 9 of IC4. It shows that the curve is linear up to about -10 dB, after which compression occurs. The effect of

this is that the low frequencies are accentuated a bit more and the entire sound sounds fuller. The same graph also shows the distortion of the output signal at 60 Hz and 1 V input

## COMPONENT LIST

### Resistors

R1,R19 = 100k $\Omega$   
 R2,R3,R20,R21 = 92k $\Omega$   
 R4,R22 = 1k $\Omega$   
 R5,R23 = 390k $\Omega$   
 R6,R24 = 3.9k $\Omega$   
 R7,R8,R15,R18,R25,R26,R33,R36,R39 = 10k $\Omega$   
 R9,R27 = 39k $\Omega$   
 R10,R28 = 100 $\Omega$   
 R11,R29 = 47k $\Omega$   
 R12,R30 = 1.5k $\Omega$   
 R13,R17,R31,R35,R38 = 4.7k $\Omega$   
 R14,R32 = 2.2k $\Omega$   
 R16,R34 = 33k $\Omega$   
 R37 = 470 $\Omega$   
 P1,P2 = 4.7k $\Omega$  logarithmic, stereo

### Capacitors

C1,C12,C23 = 220nF, lead pitch 5 or 7.5mm  
 C2,C13 = 10nF, lead pitch 5 or 7.5mm  
 C3,C14 = 47nF, lead pitch 5 or 7.5mm  
 C4,C15 = 3.9nF, lead pitch 5 or 7.5mm  
 C5,C16 = 10pF, ceramic, lead pitch 5mm  
 C6,C17 = 1nF, lead pitch 5 or 7.5mm  
 C7,C18 = 470pF, ceramic, lead pitch 5mm  
 C8,C19 = 220pF ceramic, lead pitch 5mm  
 C9,C20 = 1 $\mu$ F, lead pitch 5 or 7.5mm  
 C10,C21 = 10 $\mu$ F 50V, radial, bipolar, lead pitch 2.5mm, diam. 8.5mm max.  
 C11,C22 = 22nF, lead pitch 5 or 7.5mm  
 C24 = 10 $\mu$ F 63V, radial, lead pitch 2.5mm, diam. 6.3mm max.  
 C25–C30 = 100nF, lead pitch 5 or 7.5mm  
 C31,C32 = 100 $\mu$ F 25V, radial, lead pitch 2.5mm, diam. 8.5mm max.

### Semiconductors

D1–D6 = 1N4148  
 D7 = low current LED, red, 3mm  
 T1,T2 = BC550C  
 T3 = BC547B  
 IC1,IC2,IC3 = NE5532, 8-DIP case  
 IC4 = LM13700 16-dip (e.g. Farnell # 1651866)

### Miscellaneous

11 pcs PCB solder pin  
 4 pcs 3-way pinheader (P1,P2)  
 4 pcs 3-pwy socket  
 PCB, # 080094-1 see [1]

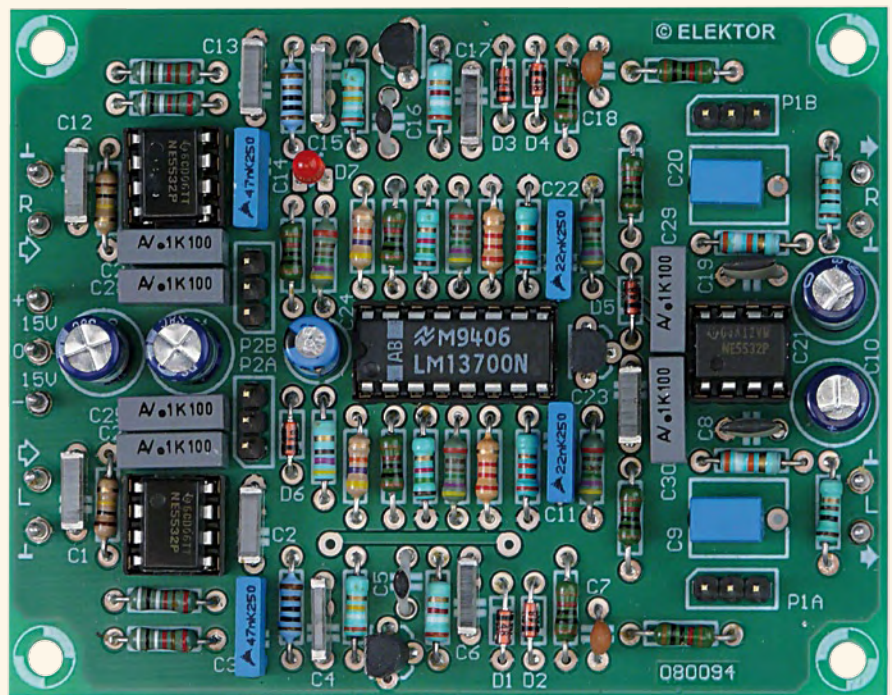


Figure 2. The components are quite close so the circuit will fit on a compact PCB.

voltage, measured at pin 9 of IC<sub>4</sub> (blue). The –10 dB value is also represented in this curve, with the difference that the distortion increases exponentially from that point onwards (this makes sense because the signal is compressed above that value).

This is naturally not a circuit of particular interest for audiophiles. But they probably only use flawless signal sources. For everyone else who would like their sound to be fresher and livelier this booster circuit is a good alternative to an equalizer.

(080094-1)

### Internet Link

[1] [www.elektor.com/080094](http://www.elektor.com/080094)

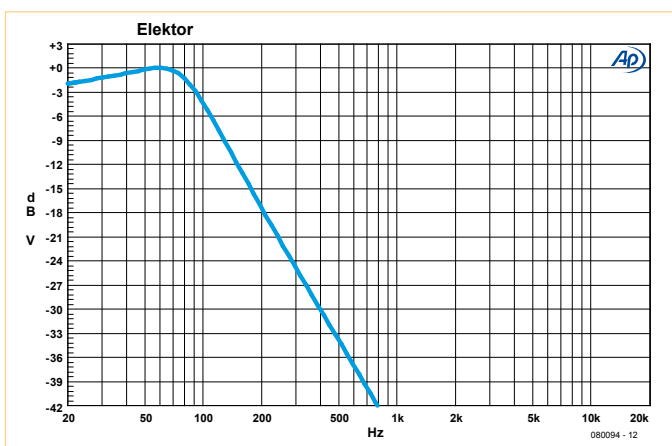


Figure 3. This clearly shows the frequency range of the low frequency part of the circuit.

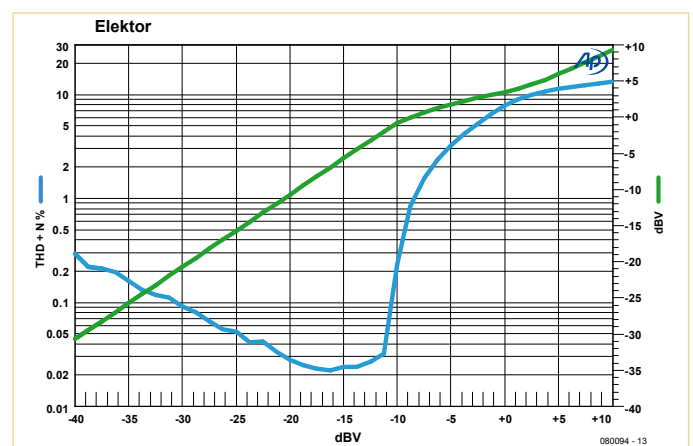


Figure 4. The gain and distortion of the low frequencies depends on the input voltage.

# USB Mouse using R8C/13 Starter Kit

Helmut Posselt (Germany)

The ‘Tom Thumb’ R8C/13 starter kit described in Elektor in February 2006 has proved popular with our readers and has found its way into many applications, as a glance at the Forum on our website will show. The original idea behind the project presented here was to make a friction-free device for measuring linear movement using the R8C/13 and an optical mouse. The advantage of the optical mouse over its mechanical brother is that it has no moving parts that inevitably get dirty and jam.

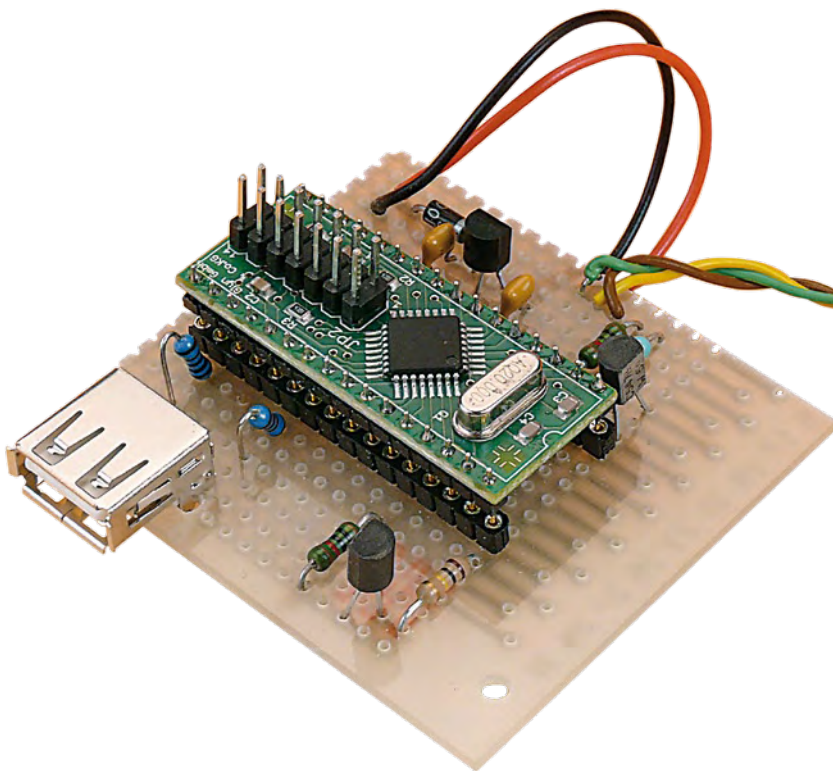


Figure 1. The prototype built and tested in the Elektor labs.

The system consists of a C program running on the R8C and a short terminal program in Visual Basic to display the results on the PC. Early tests showed that the displacement values reported by the optical mouse seem to depend on the speed of the motion: when moved faster over the same distance, the reported total count was considerably smaller. This is not ideal for a measurement application, but the project still provides a useful demonstration of how a mouse can be driven from a microcontroller. No doubt our ingenious readers will find other applications for these very low-cost sensors.



Most USB optical mice come with a USB-to-PS/2 adaptor to allow them to be used on older

PCs via the PS/2 connector. The mouse uses four pins on the connector, as shown in **Figure 1** (and see also [1]). By tapping into a PS/2 extension cable it is possible to look at the data and clock signals that run between mouse and PC using a two-channel oscilloscope. Similarly, the USB connector has four pins (**Figure 2**) and again we can tap into an extension cable to

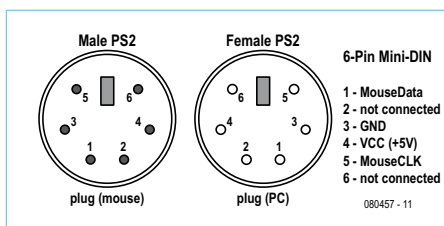


Figure 2. pinout of the PS2-to-mouse connection.

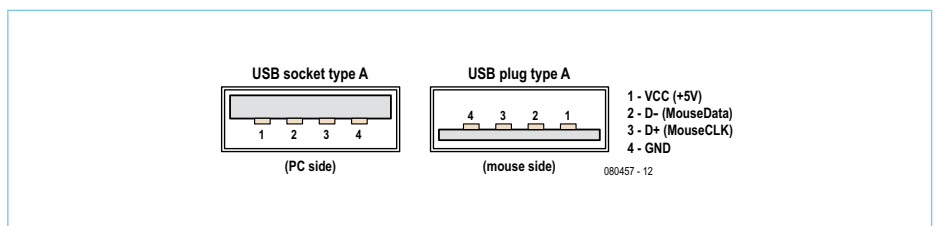


Figure 3. Pinout of a USB mouse with Type-A plug and socket.

monitor the signals. The surprise is that the USB signals are the same as the PS/2 signals! The USB-to-PS/2 adaptor is in fact entirely passive and simply connects the USB signal wires through to the PS/2 connector.

For our experiments with mouse and microcontroller we simply need to obtain a suitable PS/2 or USB socket and connect the two control signals to spare port pins, for example via 1 kΩ resistors on the R8C/13. It is also necessary to connect GND on the mouse connector to GND on the R8C/13, and to supply the mouse with +5 V, which can also be done via the microcontroller board (Figure 3). For test purposes we connect the R8C/13 board to a PC using its RS-232 interface (RXD1 and TXD1). The short terminal program, written in Visual Basic 5, along with 'port.dll' [4], allows command codes to be sent to the R8C/13 at the click of a button; the R8C/13 in turn carries out the desired command. Where necessary, additional data values required for its execution are appended to the command code (for example, in the case of SetSampleRate).

The returned values are sent back to the PC for validation and display. This makes it easy to check that the mouse and the R8C/13 program are running correctly. Figure 4 shows an example of received data when the mouse is 'hot plugged', and at the top of the figure is an oscilloscope trace of the data and clock signals.

Communication between mouse and R8C/13 uses a bidirectional synchronous serial protocol [1], one byte at a time. Each byte is sent as a string of 11 bits, consisting of one start bit (always logic 0), eight data bits (sent LSB first), one parity bit (logic 1 if the number of '1' bits is even, logic 0 otherwise), and one stop bit (always logic 1). When transferring data from the host to the mouse there is an additional acknowledge bit.

The clock signal is always generated by the mouse. However, the R8C/13 can hold the clock signal Low in order to interrupt the mouse. The R8C/13 reads data bits from the mouse on the falling edge of the clock signal, and the mouse reads data bits on the rising edge of the clock.

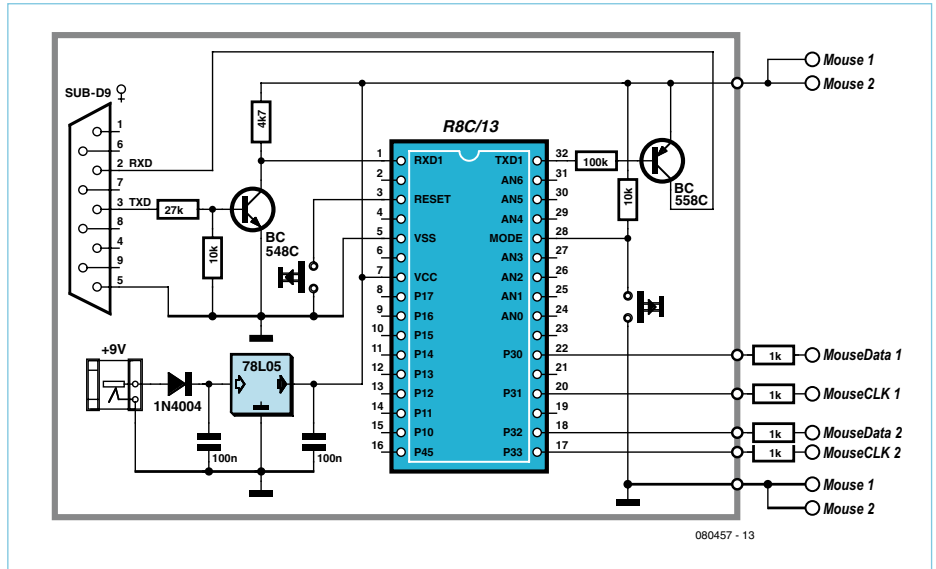


Figure 4. The minimal system with the R8C/13 carrier board complemented with a mouse connection.

At the beginning of a mouse command (see [2] for a more complete description of the commands) the R8C/13 first pulls the clock signal Low for 100 μs, which interrupts any communication from the mouse. The R8C/13 must then take the data signal Low and the clock signal High, forming a 'request to send' instruction to the mouse. The mouse is now permitted to start generating clock pulses.

Figure 5 shows the status information that a Status Request command elicits, and Figure 6 shows the movement and button

information. An example of command execution is shown in Figure 7, where the command 'ReadStreamData' has been sent: one of the movement data packets (containing status, X-movement and Y-movement information: compare with Figure 6) is shown in the figure. Further examples can be found in a PDF file at [5], where software files (including source code) for this project are available for download.

If a standard PS/2 mouse is used, movements in the X and Y axes and the state

	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Byte 1	const. 0	Mode	Enable	Scaling	const. 0	centre button	right button	left button
Byte 2	resolution							
Byte 3	data rate							

080457 - 14

Figure 5. Status register structure and content.

	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Byte 1	Y overflow	X overflow	Y sign bit	X sign bit	const. 1	centre button	right button	left button
Byte 2	X movement							
Byte 3	Y movement							

080457 - 15

Figure 6. Data on movement and switch status.

of the left, right and middle buttons are reported. With certain non-standard PS/2 mice it is also possible to obtain the status of additional buttons and of a scroll wheel. In this project we ignore acknowledge bytes and the overflow bits in the mouse messages, and we do not check parity bits.

**Figure 8** shows the partial support for PS/2 keyboards. In the log the first line shows the keyboard being reset followed by a 'GetDeviceID' command being issued. The 'A' key on the keyboard is then pressed and released.

### The R8C/13 program

In 'main' the program runs in an infinite loop. On each pass through the loop the serial input buffer is checked for data. If a byte has been received from the PC a mouse command is issued. First 'RequestToSendFlag' is set by a call to 'RequestToSend'. This function holds the clock signal Low for at least 100 µs by disabling interrupts and configuring the port pin as an output. Then, after 100 µs, the data signal is taken Low and the clock signal taken High: interrupts are enabled and the port is configured as an input. Finally 'RequestToSendFlag' is cleared.

Negative-going clock edges are detected via INT2. INT3 is used to detect the level of the data signal from the mouse when receiving data from it and to set the data signal to the appropriate level when transmitting. This behaviour is controlled by the subroutine 'mClockLow(i)', which can support two mice or one mouse and one keyboard [3]. The byte counter writes the number of received data bytes into the second byte of the transmit buffer. The first byte in this buffer indicates via a value of 1 or 2 that valid mouse data are available. If a negative-going edge is detected and no mouse command is being sent, then either a 'hot plug' event has occurred (Figure 6)

or a data packet is being received in stream mode (Figure 7).

Flag 'ucModeFlag' is used to control how the transmit buffer is filled with mouse data and with position data accumulated since the last external reset of the X and Y move-

checks whether the value has reached zero. If 'timeout[i]' has reached zero and the first byte of the transmit buffer is 1 or 2, then there is a data packet to send; otherwise the byte 'o' is sent.

### The Visual Basic Terminal Program

This program provides a way to visualise mouse activity. It initialises the mouse and sets its operating mode. The most important part of the program is the form which contains buttons for sending control commands and text fields for displaying data from the mouse. The program defines the following modes: initialisation, test-remote, test-stream, remote and stream. The test modes allow manual retrieval of individual mouse data packets after a mouse state change; otherwise position requests are made periodically using Timer1. Timer1 checks every 50 ms whether a data packet is available (by examining the first byte in buffers 1 and 2). If a packet is available the second byte in the buffer determines how many bytes remain to be received. The current mode is then used to control the display of data in the text boxes.

The 'Mouse ID' button issues a series of consecutive commands which are used to identify the type of mouse connected, for example whether the device is a three-button scroll mouse with ID code 3. (080457-1)

### Sources and Internet links

- [1] [www.computer-engineering.org/ps2protocol/](http://www.computer-engineering.org/ps2protocol/)
- [2] [www.computer-engineering.org/ps2mouse/](http://www.computer-engineering.org/ps2mouse/)
- [3] [www.computer-engineering.org/ps2keyboard/](http://www.computer-engineering.org/ps2keyboard/)
- [4] [www.b-kainka.de/port.zip](http://www.b-kainka.de/port.zip)

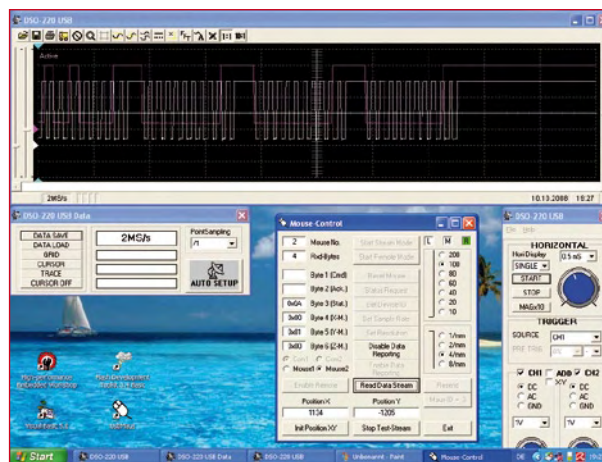


Figure 7. ReadStreamData from a mouse captured on an oscilloscope (above) and in the VB Terminal program (below).

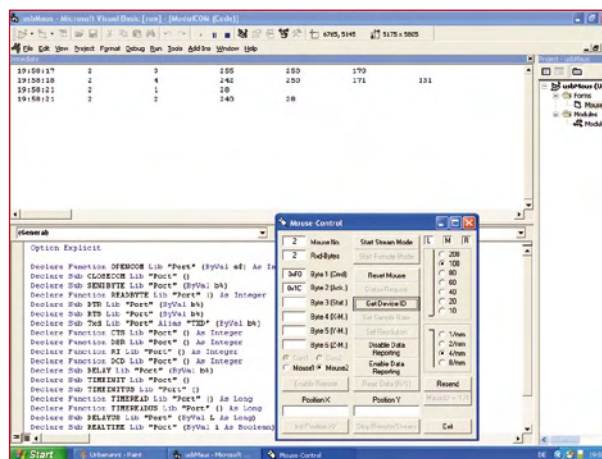
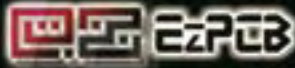


Figure 8. A PS2 keyboard is also partially supported.

ment integrator registers. Variable 'timeout[i]' is set to a positive value on each negative-going clock edge, which is taken as an indicator of mouse activity. TimerY decrements this value once per millisecond, and every 50 ms TimerY





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# Hexadoku

## Puzzle with an electronics touch

Towards the final pages of this November 2009 issue we again print Hexadoku, your monthly dose of puzzle entertainment. Find the comfy chair, concentrate and put an effort into solving what looks like a maze of numbers and letters. Send the numbers in the grey boxes to Elektor and enter a prize draw for an E-blocks Starter Kit Professional and three Elektor Shop vouchers. Have fun!

The instructions for this puzzle are straightforward. In the diagram composed of 16 × 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 4×4 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 the Elektor website.

### Solve Hexadoku and win!

Correct solutions received from the entire Elektor readership automatically enter a prize draw for an

E-blocks Starter Kit Professional worth £ 300 / € 375 (rrp) and three Elektor Electronics SHOP Vouchers worth £ 40.00 / € 50.00.

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

### Participate!

Please send your solution (the numbers in the grey boxes) by email to [hexadoku@elektor.com](mailto:hexadoku@elektor.com) – Subject: **hexadoku 11-2009** (please copy exactly). Include with your solution: full name and street address.

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

The closing date is 1 December 2009.

### Prize winners

The solution of the September 2009 Hexadoku is: **10965**.

The E-blocks Starter Kit Professional goes to: Torsten Clever (Germany).

An Elektor SHOP voucher goes to: J. Kartman (Netherlands), Matthias Rummel (Germany), Pierre Chareyron (France).

Congratulations everybody!

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

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

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

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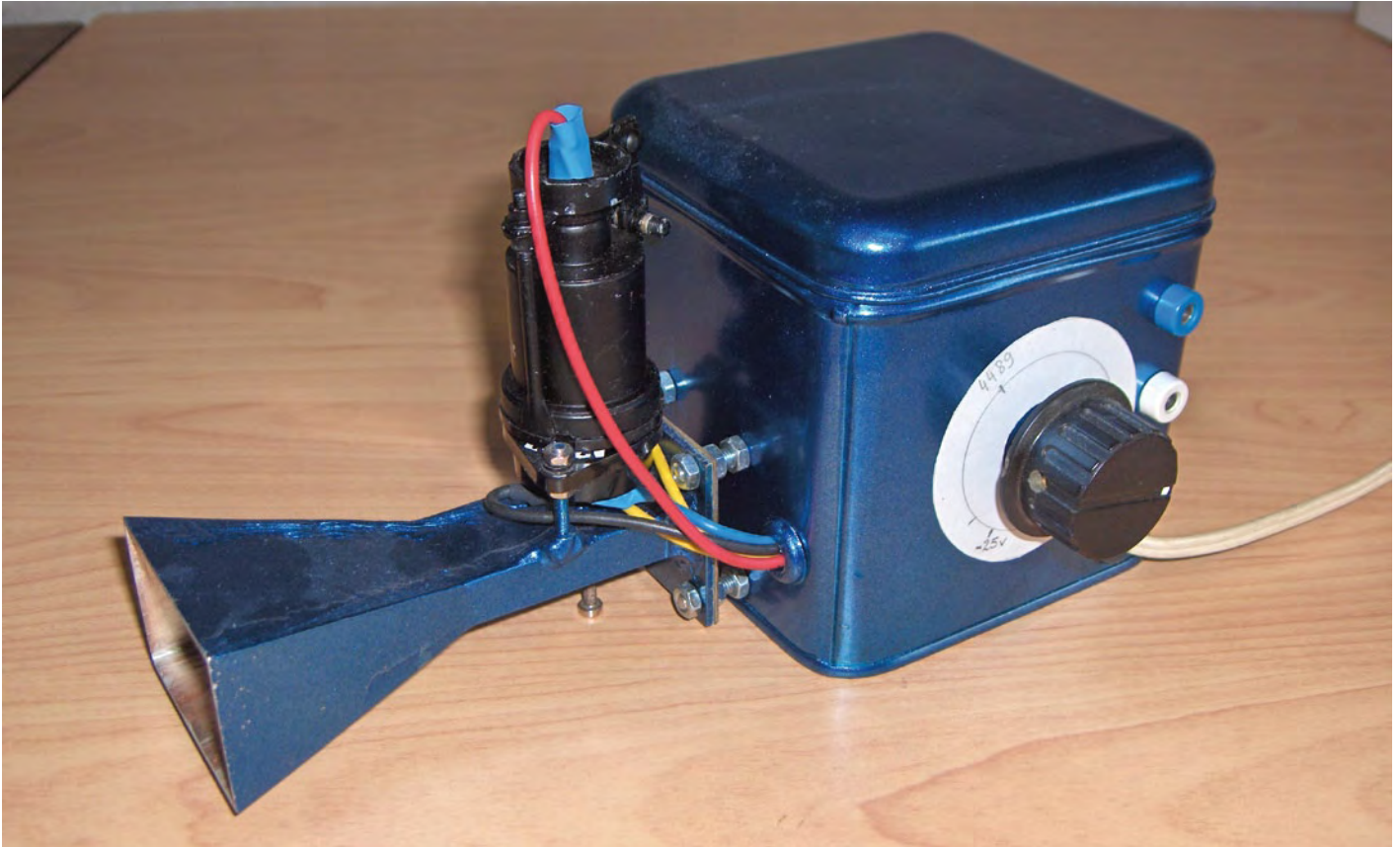
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# Klystrons type 2K25 and 2K56



By Jean Herman (Belgium)

The klystron was invented, and a first prototype constructed, by the brothers Sigurd and Russel Varian working at Stanford University (CA) in 1937. After a paper on the new device appeared in *Journal of Applied Physics* in 1939, radar experts were soon upon the brothers and not surprisingly the klystron was embraced big time by the US military. The klystron's heyday was to last, well, about 50 years.

Several types of klystron exist; one model has two or more cavities centred on an electron beam focused by magnets; the first cavity receives the signal from a local oscillator, it modulates the beam, it acts as a sort of control grid, the second cavity close to a collector (anode) where the signal appears highly amplified. These klystrons exist for all the UHF and microwave bands and all powers, right up to 1 MW and esoteric components as they might appear to the non-initiated, you may have been enjoying its practical use for more hours than you realize simply by watching TV between 1960 and 1995 (roughly).

Another type of klystron is known as 'reflex' (**Figure 1**); this is an oscillator, it only has one cavity centred on the electron beam. The volume of the cavity is slightly adjustable, and hence the resonant frequency too.

It could be thought of as a little like a whistle, except that here the flow tangential to the lips of the cavity is a beam of electrons instead of air.

The speed of the electrons is close (and adjustable) to the variation in the alternating voltage on the two lips of the cavity. With the help of a reflector, the electrons pass and then pass again a second time across the lips of the cavity. When the reflector voltage is just right, the electrons exchange energy with the cavity twice (each time they pass). They finish up on the outside of the cavity or on the metal of the valve envelope.

In an accelerated electron beam, the spectrum of the speed of the electrons is wide. Hence it is important that the median speed is centred on the cavity's resonant frequency. In this way, faster or slower electrons will form distinct packets that will be speeded up or slowed down at the lips of the cavity – in other words, they exchange energy with the cavity. Out of chaos, harmony (and RF power) is born!

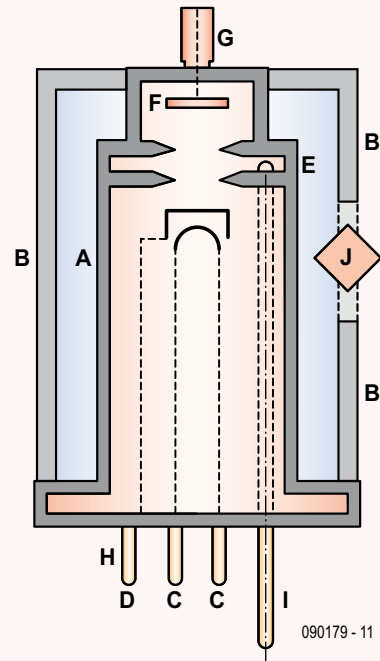
I've had a type 2K56 reflex klystron for 50 odd years. It came from a WW2 bomber radar unit. Getting hold of the specifications [1] was very troublesome, although its sibling the 2K25 is very common. The '56 and the '25 are pin compatible, but their resonant frequencies are very different: the 2K56 oscillates at 4400 MHz (3840–4460 MHz); while the 2K25 oscillates at 9050 MHz (8500–9660 MHz).

Over 30 years ago, I ventured out to build a circuit 'around' the 2K56. In fact it boiled down to a fairly complex power supply for this tube, which was fitted onto a piece of RG52/U waveguide (1" × 0.5"). What a mistake, it should have been fitted to a length of

## Specifications of the 2K25 and 2K56 klystrons

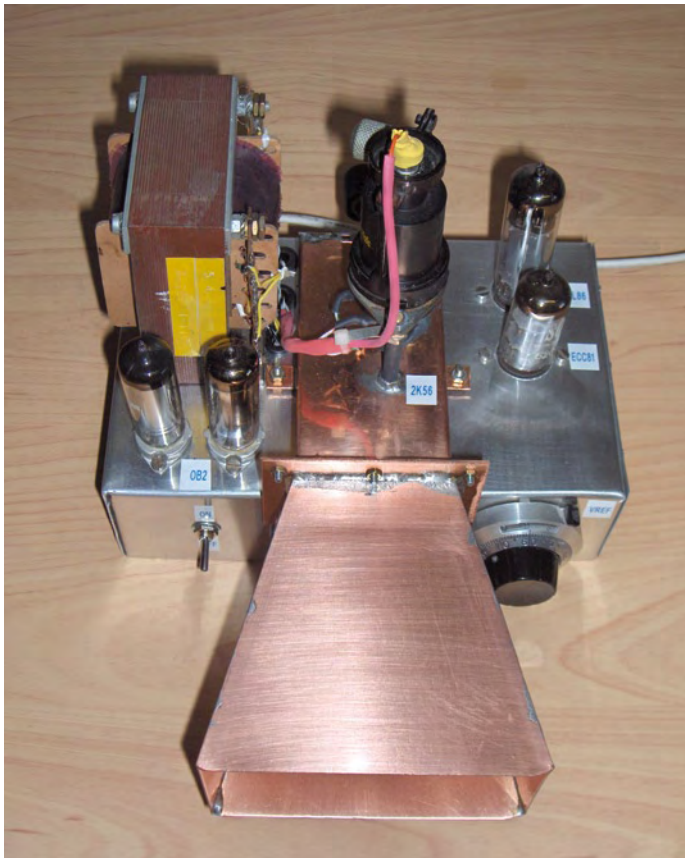
- Nominal cathode/cavity voltage: + 300 V
- Cavity/cathode current: approx. 22 mA
- Reflector/cathode voltage variable from -24V to -180V
- Reflector current: < 7  $\mu$ A
- Reflector resistance must be < 100 k $\Omega$
- Heater voltage: 6.3 V @ 0.44 A.

1



Cutaway representation of a klystron.

A: envelope (anode); B: cavity tuning pillars; C: heater filament terminal; D: cathode terminal; E: RF coupling loop; F: reflector; G: reflector voltage terminal; H: filament and cathode pins; I: antenna; J: frequency adjustment screw.



RG49/U waveguide (2" x 1")! However, when tested, a weak microwave signal was detected; measuring its frequency, I realised that it was too low for this type of waveguide. I then had the idea of fitting a dielectric into the waveguide. Experimenting with a stick of Perspex soon resulted in recovery of about 50 mW of gigahertz RF power from the klystron.

The 2K25 is an old favourite with radio amateurs who command our respect for having pioneered much of today's microwave communication infrastructures (taken for granted by millions of cellphone users unaware of the SHF link systems carrying their conversations). With a few judiciously applied dents in the cavity, an ex-army 2K25 is easily pulled into the 10 GHz (3 cm) amateur radio band.

If you think that the 'cantenna' was invented during the WiFi and WLAN age, you are mistaken. One of the finest and most appealing applications developed for surplus klystrons and widely published by the ARRL in the 1960s was the 'Klystron Polaplexer' [2]. Two suitably tuned Polaplexer units using (US size) bean cans were capable of covering line-of-sight links of tens of miles with just a few milliwatts of RF power in the 9 cm (3.4 GHz) band. Full-duplex (!) wideband FM communication 'on a shoestring' was achieved using a portable VHF

FM radio as the final converter and demodulator. Borrowing a term from today's world of microcontrollers, the Polaplexer/Cantenna design was "easily migrated" to the 3 cm (10 GHz) "platform" simply by fitting the klystron on a piece of WG16 waveguide and adapting the antenna shape and dimensions.

Finally, 2K25 klystrons are by no means difficult obtain, for example, through Ebay.

(090179-1)

*Editor's note:* the author has developed both a tube-based and a transistorised power supply unit (PSU) for the klystrons described here. Scans of his original circuit diagrams may be downloaded free from the Elektor website [3].

## Internet Links

- [1] [www.pmilllett.com/tubedata/HB-3/Transmitting\\_Tubes/2K56.pdf](http://www.pmilllett.com/tubedata/HB-3/Transmitting_Tubes/2K56.pdf)
- [2] [www.ham-radio.com/sbms/sd/ppxrdsn.htm](http://www.ham-radio.com/sbms/sd/ppxrdsn.htm)
- [3] [www.elektor.com/090179](http://www.elektor.com/090179)

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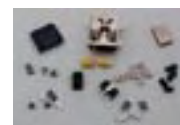


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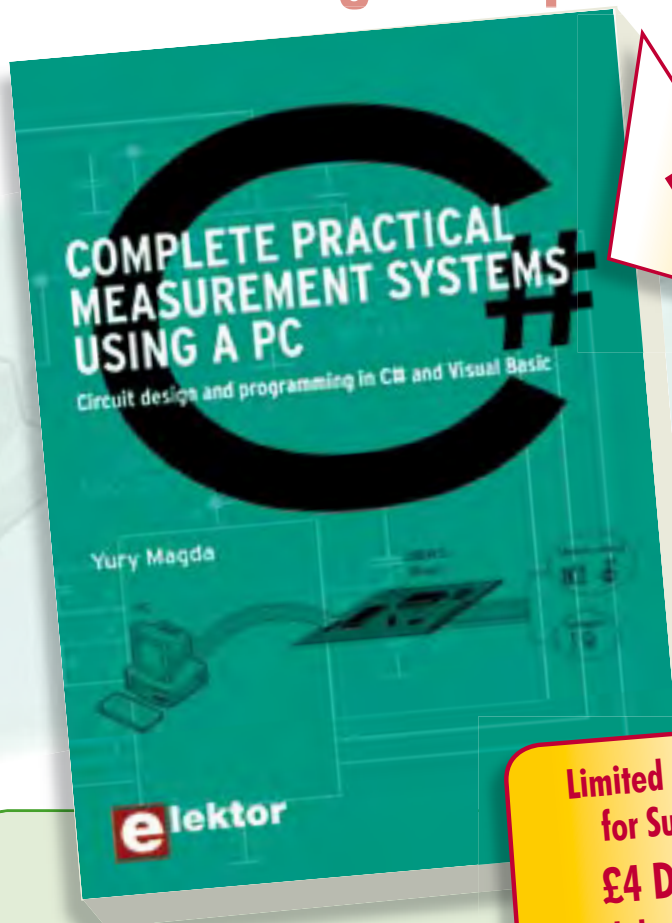
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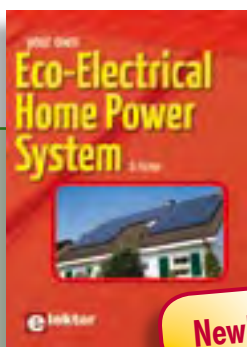
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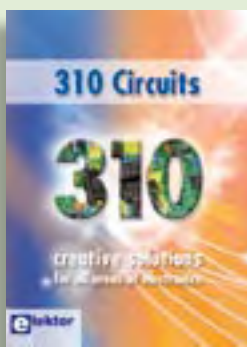
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The program package consists of eight databanks covering ICs, germanium and silicon transistors, FETs, diodes, thyristors, triacs and optocouplers. A further eleven applications cover the calculation of, for example, LED series droppers, zener diode series resistors, voltage regulators and AMVs. A colour band decoder is included for determining resistor and inductor values. ECD 5 gives instant access to data on more than 69,000 components. All databank applications are fully interactive, allowing the user to add, edit and complete component data.

ISBN 978-90-5381-159-7 • £24.90 • US \$39.50



**Bestseller!**

## OBD Analyser NG

(September 2009)

The compact OBD2 Analyser in the June 2007 issue was an enormous success – not surprising for an affordable handheld onboard diagnostics device with automatic protocol recognition and error codes explained in plain language. Now enhanced with a graphical display, Cortex M3 processor and an Open Source user interface, the next generation of Elektor's standalone analyser sets new standards for a DIY OBD2 project. The key advantage of this OBD2 Analyser NG is that it's self-contained and can plug into any OBD diagnostic port.

*Kit of parts including DXM Module, PCB SMD-prefitted, case, mounting materials and cable*

Art.# 090451-71 • £84.00 • US \$135.00



**New!**

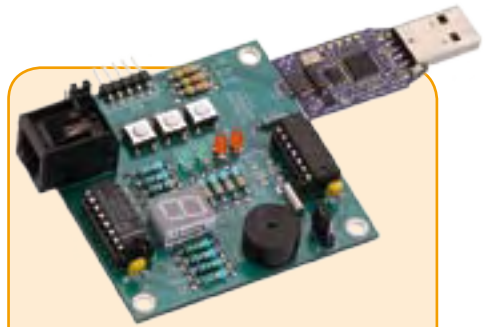
## R32C Application Board

(September 2009)

This R32C Application Board sports push-buttons, LEDs, an I2C interface, an OLED display panel, an SD card interface and a socket for an Ethernet module. There is plenty of space on the board for further expansion.

*Kit of parts incl. application board with SMD parts prefitted, plus all other components*

Art.# 080082-71 • £112.50 • US \$185.00



## Experimenting with the MSP430

(May 2009)

All the big electronics manufacturers supply microcontrollers offering a wide range of functions. Texas Instruments supplies handy USB evaluation sticks with related software for its low-cost MSP430 controllers. Unfortunately the I/O facilities are somewhat limited. These can be substantially enhanced with the help of the Elektor MSP430 board.

*PCB, populated and tested*

Art.# 080558-91 • £35.00 • US \$55.00

*TI eZ430-F2013 Evaluation Kit*

Art.# 080558-92 • £24.50 • US \$35.00



## Automotive CAN controller

(April 2009)

Since cars contain an ever increasing amount of electronics, students learning about motor vehicle technology also need to know more about electronics and microcontrollers. In collaboration with the Timloto o.s. Foundation in the Netherlands, Elektor designed a special controller PCB, which will be used in schools in several countries for teaching students about automotive technologies. But it can also be used for other applications, of course. The heart of this board is an Atmel AT90CAN32 with a fast RISC core.

*Kit of parts, incl. PCB with SMDs prefitted*

Art.# 080671-91 • £52.00 • US \$79.00

<b>November 2009 (No. 395)</b>	£	US \$
+ + + Product Shortlist November: See <a href="http://www.elektor.com">www.elektor.com</a> + + +		
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080444-41 .... PIC18F2423, programmed .....	15.00	24.00
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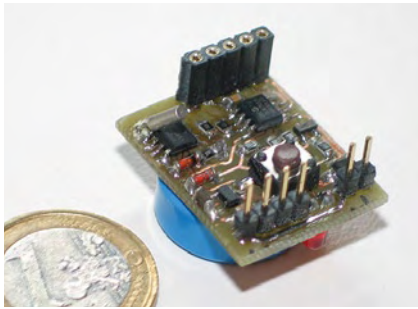
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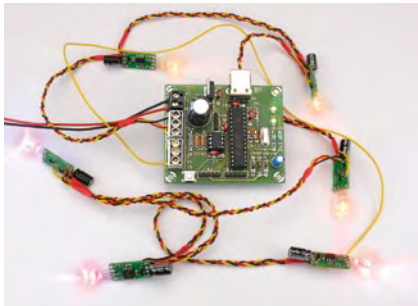


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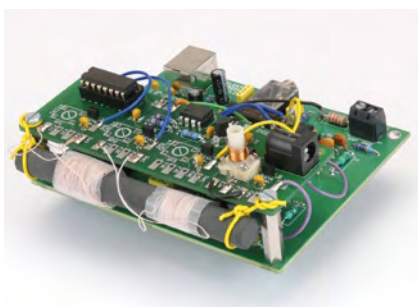
### Cutting down on Energy Consumption

It's not too difficult to trace equipment that's wasteful of electrical energy — in fact we've shown how it can be done in an earlier issue of Elektor. But what to do if you are faced with 6 watts power consumption, compliments of the WiFi router? Pulling the plug if you are not online is unworkable, so let's think up some realistic measures to cut down on electricity wasted on standby power. In the same article we present an ingenious mini switching clock based on a PIC microcontroller, which allows the DC supply of equipment to be switched on and off at user defined times.



### Colourful Party Lights

In time for the Festive Season you can get cracking with this lights pendulum that's sure to provide super light effects. The project consists of 63 modules with RGB LEDs, and a master unit. The LEDs are driven via a 3-wire serial bus, which is fed back to the master to enable it to determine the number of LEDs connected up! The light patterns can be changed by adapting the PIC source code.



### Active Antenna and Preselector for Elektor SDR

The vastly popular Elektor Software Defined Radio (SDR) from the May 2007 issue works quite well with just a ferrite rod or an indoor tuned loop for an antenna. In the December issue we present a small PCB comprising an active antenna and a preselector for up to four LC circuits, each of which is tuned by software and varicap diodes. The control of the DAC supplying the tuning voltage is carried out via the I<sup>2</sup>C bus already present on the Elektor SDR board.

The December 2009 issue comes on sale on Thursday, November 19, 2009 (UK distribution only).  
UK mainland subscribers will receive the issue between November 14 and 17, 2009.

Article titles and magazine contents subject to change; please check the Magazine tab on [www.elektor.com](http://www.elektor.com)

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January 2009

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January 2009

# ElektorWheelie

➔ Elektor's DIY self-balancing vehicle

Everyone agrees; the internal combustion engine is coming to the end of its life cycle. However you don't need to go to the expense of a Prius or Tesla to experience the future of transportation devices. If you would prefer something more personal (and don't mind turning a few heads) why not build the astonishing ElektorWheelie? First take two electric motors, two rechargeable batteries and two sensors, now add two microcontrollers and the ElektorWheelie is ready to transport you in style to your destination.



Demo video on  
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- Weight approximately 35 kg

The kit comprises two 500-watt DC drive motors, two 12-V lead-acid AGM batteries, two 16-inch ABS wheels, casing, control lever and assembled and tested control board with sensor board fitted on top.

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