www.elektor-usa.com JUNE 2009 US $ 7.95 - Canada $ 7.95

elektor

electronics & microcontrollers

••• ELEKTORWHEELIE ••• CAMPSITE AC MONITOR ••• POCKET PWM AMP ••• AIR IONIZER •••

Portable Solar Modules

chargers for the Great Outdoors

True-RMS Meter

for volts & frequency

Profiler Pro

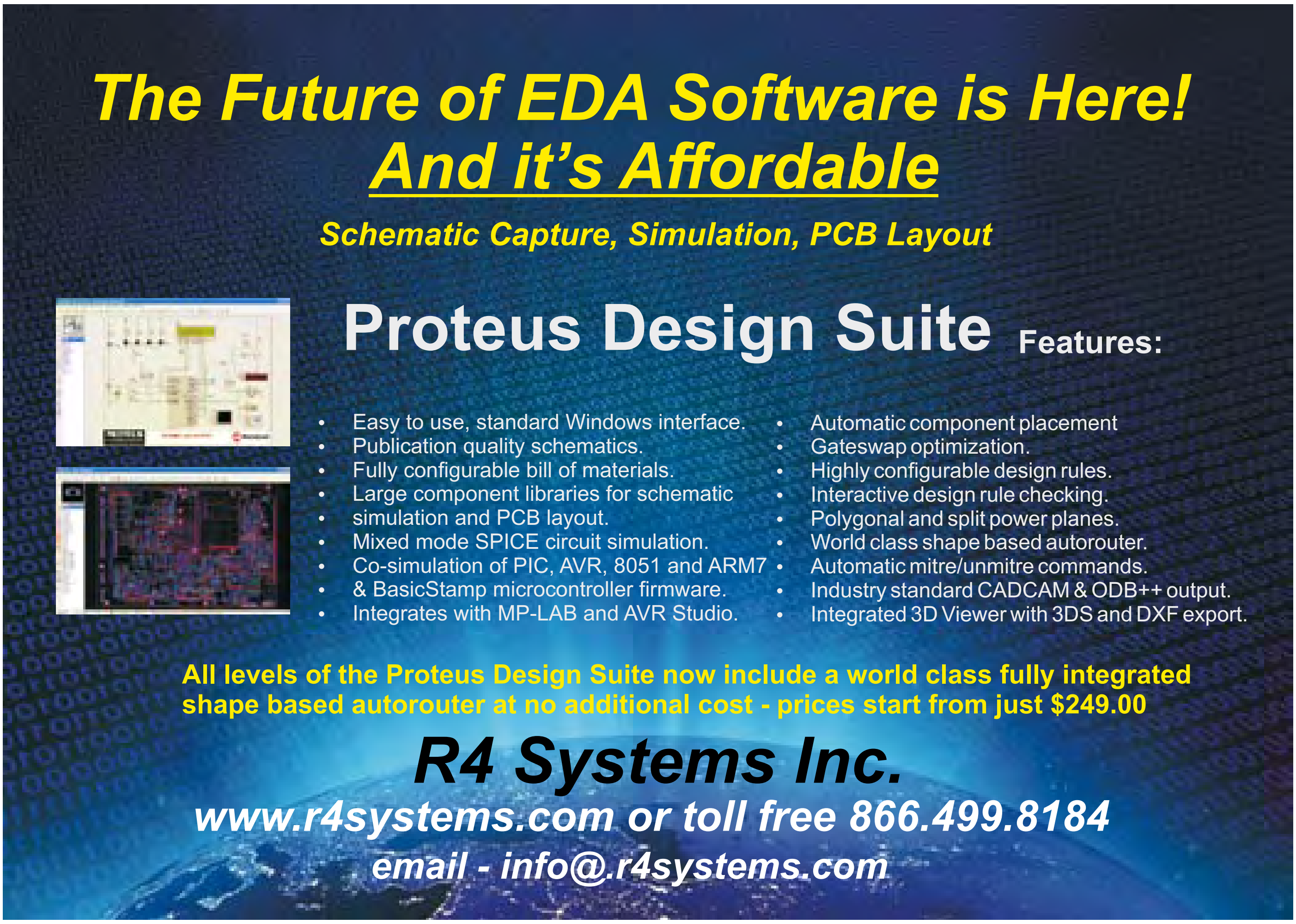
hard- & software upgrades for DIY milling machine

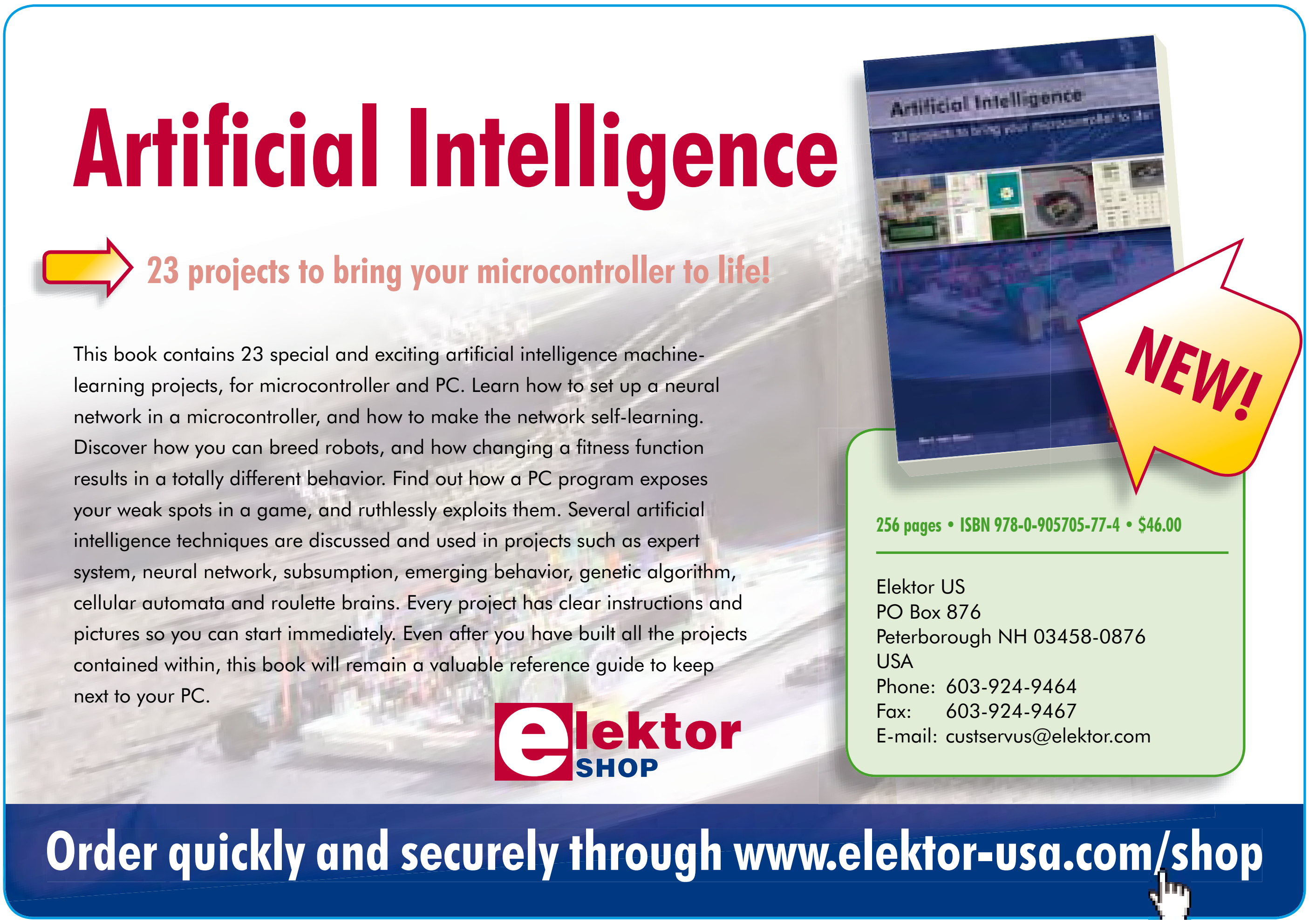
Elektor Wheelie

page 44

06

0 74470 24965 8


The Future of EDA Software is Here!
And it's Affordable
Schematic Capture, Simulation, PCB Layout
Proteus Design Suite
Features:
• Easy to use, standard Windows interface.
• Publication quality schematics.
• Fully configurable bill of materials.
• Large component libraries for schematic
• simulation and PCB layout.
• Mixed mode SPICE circuit simulation.
• Co-simulation of PIC, AVR, 8051 and ARM7
• & BasicStamp microcontroller firmware.
• Integrates with MP-LAB and AVR Studio.
• Automatic component placement
• Gateswap optimization.
• Highly configurable design rules.
• Interactive design rule checking.
• Polygonal and split power planes.
• World class shape based autorouter.
• Automatic mitre/unmitre commands.
• Industry standard CADCAM & ODB++ output.
• Integrated 3D Viewer with 3DS and DXF export.
All levels of the Proteus Design Suite now include a world class fully integrated shape based autorouter at no additional cost - prices start from just $249.00
R4 Systems Inc.
www.r4systems.com or toll free 866.499.8184
email - info@.r4systems.com


Artificial Intelligence
23 projects to bring your microcontroller to life!
This book contains 23 special and exciting artificial intelligence machine-learning projects, for microcontroller and PC. Learn how to set up a neural network in a microcontroller, and how to make the network self-learning. Discover how you can breed robots, and how changing a fitness function results in a totally different behavior. Find out how a PC program exposes your weak spots in a game, and ruthlessly exploits them. Several artificial intelligence techniques are discussed and used in projects such as expert system, neural network, subsumption, emerging behavior, genetic algorithm, cellular automata and roulette brains. Every project has clear instructions and pictures so you can start immediately. Even after you have built all the projects contained within, this book will remain a valuable reference guide to keep next to your PC.
NEW!
256 pages • ISBN 978-0-905705-77-4 • $46.00
Elektor US
PO Box 876
Peterborough NH 03458-0876
USA
Phone: 603-924-9464
Fax: 603-924-9467
E-mail: custservus@elektor.com
elektor SHOP
Order quickly and securely through www.elektor-usa.com/shop

elektor
electronics & microcontrollers

All solar power charged

For the first time in the history of Elektor we have examined the practical use of small solar cells specially designed (it seems) to charge batteries for mobile equipment like cell phones, navigation aids and PDAs. The range of commercially available products is large, and with no sidewalk or power lines in sight for miles around, a solar charger seems to be the only viable alternative to lugging spare batteries over cliffs and mountains. These chargers operate wherever sunlight is plentiful, they do not leave waste behind and do not consume natural resources in use. On the down side, the prices are still high considering what you get terms in terms of watts out, which also tend to drop quickly and dramatically with anything less than full sunshine.

Less known are the practical value and quality of the products available in this relatively new area.

As a positive outcome of tests carried out by the Elektor labs, genuine doubts on our part regarding certain electrical specifications found in the product catalogs were not substantiated. Overall, with the modules tested, the rated output power stated with 100,000 lux worth of sunshine is rarely achieved in our neck of the woods where the skies seem to default to cloudy. Still, the specified data appears to be correct and the output power that can be achieved at realistic light intensity levels can be ‘downsized’ from the rated value with a fair amount of confidence.

This month our editorial focus is on energy (mostly electrical as that is our specialty) and at least two articles in this issue show how electronics can contribute to saving natural resources, especially within the ‘great outdoors’ context: our Campsite AC Monitor on page 62, and ElektorWheelie on the centerfold. Sure, the Air Ionizer mini project on page 74 is for indoor use but it should help to disperse stale air and make you feel healthier at home, too. However, it’s no match for a brisk walk along the cliffs, or an excursion in the woods exploring the trails!

Jan Buiting
Editor

18 Portable Solar

Especially on somewhat longer trips in sun drenched countries, a portable solar panel can come in very handy to ensure that you always have enough power for your mobile phone, iPod, GPS receiver, and even the car battery.

26 True RMS Digital Voltmeter

The module described here displays the frequency and RMS amplitude of a signal on a two-line LCD panel. The circuit can also be used as a stand-alone true RMS voltmeter with frequency measurement.

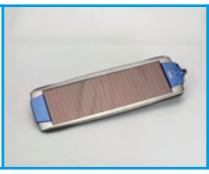
40 Profiler Pro

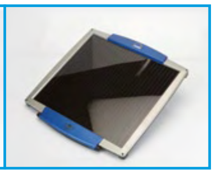
Thanks to a new controller board with a powerful ARM processor and a new, robust Z-axis with floating head you can upgrade your existing Profiler milling machine to a ‘Pro’ version. The software has also been adapted to take advantage of this and has many improvements and new features.

CONTENTS

Volume 1
June 2009
no. 6

Modules

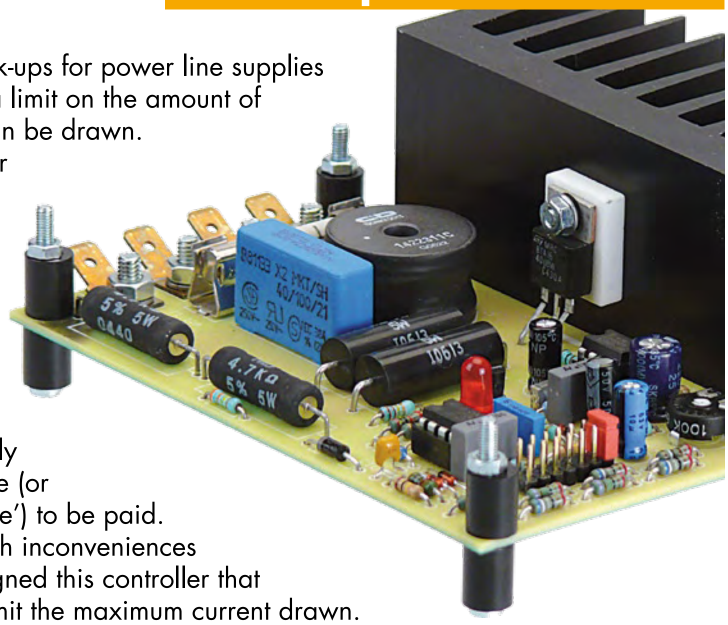



We selected some of the products currently available in this area and checked what they have to offer.

58 Power in the Pocket (1)

Here we present a very compact class-D amplifier that can be powered from four AA batteries and because of its relatively high efficiency can elicit quite a few decibels from a loudspeaker.

62 Campsite AC Monitor



Camping hook-ups for power line supplies usually have a limit on the amount of current that can be drawn. When a larger current is drawn it trips a fuse, which usually has to be reset by the campsite manager and which probably results in a fine (or 'service charge') to be paid. To prevent such inconveniences we have designed this controller that can quickly limit the maximum current drawn.

projects

info & market

infotainment

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. Analog and digital; practical and theoretical; software and hardware.

JUNE 2009 ISSN 1757-0875

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

Publishers:
Elektor US, PO Box 876, Peterborough NH 03458-0876 USA.
Phone: 603-924-9464, Fax: 603-924-9467 www.elektor-usa.com

Elektor USA magazine commenced publication with the January 2009 issue.
Elektor is published 11 times a year with a double issue for July & August.

Elektor is also published in French, Spanish, German and Dutch. Together with franchised editions the magazine is on circulation in more than 50 countries.

International Editor:
Wisse Hettinga (w.hettinga@elektor.com)

Editor: Jan Buiting (editor@elektor-usa.com)

International editorial staff: Harry Baggen, Thijs Beckers, Eduardo Corral, Ernst Krempelsauer, Jens Nickel, Clemens Valens

Design staff: Antoine Authier (Head), Ton Giesberts, Luc Lemmens, Daniel Rodrigues, Jan Visser, Christian Vossen

Graphic design / DTP: Giel Dols, Mart Schroijen

Managing Director / Publisher: Hugo Vanhaecke (h.vanhaecke@elektor.com)

Marketing: Carlo van Nistelrooy, Laurel Humphrey

Customer Services: Sharon LeClair (sales@elektor-usa.com)

Subscriptions:
Elektor US, PO Box 876, Peterborough NH 03458-0876 USA.
Phone: 603-924-9464, Fax: 603-924-9467
Internet: www.elektor-usa.com E-mail: custservus@elektor.com

Experimenting with the MSP430

Low-cost development system with a USB interface

NEW!

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!

Together with Rotterdam's Technical College Elektor developed a low-cost development system that should appeal to those of you just starting out into microcontroller land. The basis of the system is the MSP-eZ430 USB-stick from Texas Instruments, a chip graced by a free development platform and a programming language (C). The associated experimenter's board easily accommodates the hardware for the project examples like a buzzer, a 7-segment display, some LEDs and pushbuttons.

Specifications

- Experimenter's board with several I/O possibilities
- Powerful 16-bit MSP430F2012 controller running at 16 MHz, 2 KB Flash and 128 bytes RAM
- 4 indicator LEDs
- 7-segment display
- Piezo buzzer
- 3 pushbuttons
- I2C/SPI connector
- Powered via the USB stick or an external adapter

Order in the Elektor Shop

PCB, populated and tested

Art. # 080558-91 • $55.00

TI eZ430-F2013 Evaluation Kit

Art. # 080558-92 • $35.00

elektor SHOP

Further information and ordering at www.elektor-usa.com/080558

Head Office:
Elektor International Media b.v.
PO Box 11 NL-6114-ZG Susteren The Netherlands
Telephone: (+31) 46 4389444, Fax: (+31) 46 4370161

US Advertising:
Strategic Media Marketing, Peter Wostrel,
1187 Washington St., Gloucester MA 01930 USA.
Phone: 978-281-7708, Fax: 978-281-7706
E-mail: peter@smmarketing.us
Advertising rates and terms available on request.

Your Professional PCBs

via www.elektorpcbservice.com

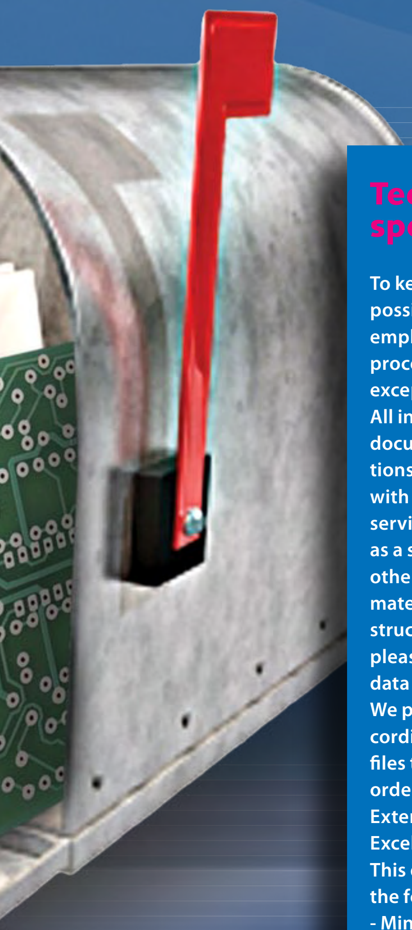
Making printed circuit boards for electronic designs is an art. Many a designer is regularly confronted with the difficulties associated with producing prototype PCBs. To make things easier for our readers and anyone else who may need a PCB for some reason, Elektor has joined forces with Eurocircuits to launch Elektor PCB Service.

Elektor PCB Service is a new service from Elektor. You can have your designs converted into a professional-quality PCBs via the www.elektorpcbservice.com website. Elektor PCB Service is intended for prototype builders and designers who want to have their PCBs made to professional standards, and for users who want customized versions of Elektor PCBs. If you need a couple of 'protos' with fast turnaround or a batch of 5 to 50 units, we can meet your needs at a favorable price. When you place your order, simply send us a WinZip file containing the Extended Gerber files (RS274X format) of your layout. Most layout programs can generate Gerber files in this format.

The advantages at a glance

- Available to private and commercial customers.
- No film charges or start-up charges.
- There is no minimum order quantity or charge for this service, and all prices include handling and shipping charges.
- Choice of double-sided or four-layer PCBs.
- The PCBs are professional quality, finished with an industrial (lead-free) finish with two solder masks and one silkscreen overlay.
- The supplied layout must be in RS274X format. Almost every popular layout program can produce files in this format.
- After your project has been checked and found to be producible (which will be reported to you within four hours), your PCBs are produced after receipt of payment.
- In case of a prototype order, you receive two PCBs sent to you five working days after receipt of payment. In order to supply two PCBs, we make three. If the third board is also good, you receive it as well – free of charge.
- In case of a batch order (any quantity from 5 to 50 boards), your PCBs are shipped ten working days after receipt of payment.
- You can use our online payment module to pay easily, quickly and securely with Visa or MasterCard.

Now available for everybody!



Technical specifications

To keep costs as low as possible, Elektor PCB Service employs a fixed production process. There is no room for exceptions here.

All information in text documents or other instructions that do not comply with the specifications of this service will be ignored (such as a second silkscreen overlay, other solder mask colors, material specifications, construction, etc.). For this reason, please do not send any other data along with your order.

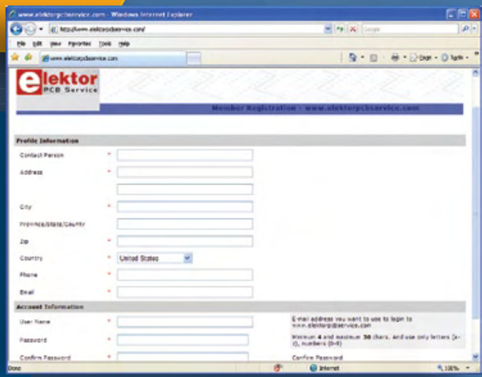
We produce your PCBs according to the data in the files that you send with your order (the layout data in the Extended Gerber files and the Excellon drilling data).

This data must comply with the following specifications:

- Minimum track width and track clearance: 150 µm
- Minimum restring on outer layers: 125 µm
- Minimum restring on inner layers: 175 µm
- Smallest hole (finished): 250 µm
- Two solder masks (green)
- One silkscreen overlay (white)
- Outline and internal milling, to the extent that this can be done with a 2-mm milling cutter
- Lead-free finish (our choice of chemical silver, chemical nickel-gold, or lead-free HAL)
- FR-4 RoHS-compliant material with standard construction
- Minimum dimensions 20 × 20 mm; maximum dimensions 425 × 425 mm

www.elektorpcbservice.com

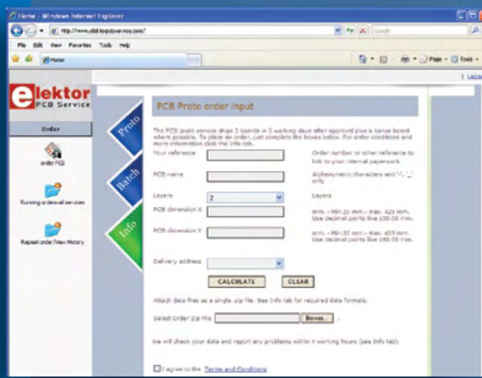
Procedure



1 Create your account

The first step in the procedure is to visit www.elektorpcbservice.com and create your account (note: this site does not use the same accounts as the Elektor magazine website). Be sure to enter your address data correctly. This is essential to ensure that you actually receive your boards!

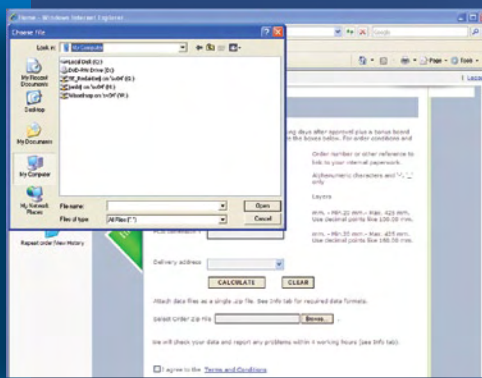
For access to the site, use your e-mail address as your user name together with a password of your own choosing.



2 Place your order

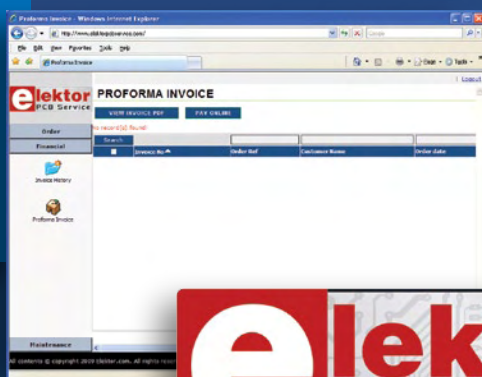
To place an order, click the *Order* button. Click *Order PCBs* to navigate to the order page. Select the Proto tab to order a set of two prototype boards, or select the *Batch* tab to order a batch of PCBs of the same type (5 to 50 (max.) units).

Click the *Calculate* button to see the calculated order price.



3 Your project is checked

For the actual order, you must submit your project files in **Extended Gerber format (RS274X)**. Within four hours, Elektor PCB Service will advise you whether we can produce your project. If we cannot execute your job, you will receive a report stating the reason for our refusal, along with some suggestions for suitable modifications to your data.



4 Payment

Before we process your order, you must pay our pro-forma invoice. You can pay with Visa or MasterCard under *Pro-forma Invoice* by clicking the *Pay Invoice Online* button. After we receive your payment, we schedule your PCBs for production.

elektor PCB Service

5 Your order is shipped

Your prototype boards are shipped to your postal address five working days after receipt of payment. The turn-around time for batch orders is ten working days.

Free BASIC Stamp educator's courses

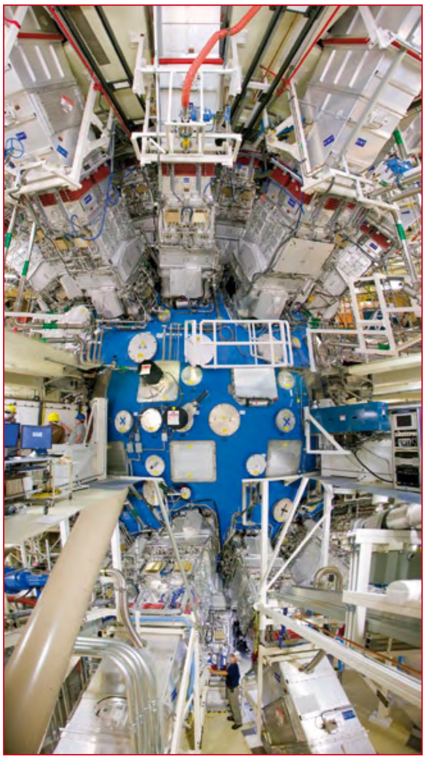
Parallax, Inc., the manufacturer of the BASIC Stamp module and related products, is offering free pilot courses for educators. These courses are designed for teachers who are interested in getting started with or furthering their BASIC Stamp knowledge and skills. Each course can accommodate up to 20 teachers, complete with equipment for hands-on learning. You can learn the basics with "What's a Microcontroller?", pursue more advanced topics using Parallax's smart sensors and applications, or explore robotics applications with the Boe-Bot texts. The courses are held at Parallax's facility in Rocklin, California (near Sacramento).

The BASIC Stamp microcontroller module is a perfect onboard computer for robots and automating student projects. It's also a great resource for STEM curriculum. The BASIC Stamp module is easily programmed using a form of the BASIC programming language called PBASIC. It's called a "Stamp" because it is close to the size of an average postage stamp, except for the BS2p40 model which is much longer due to its additional I/O pins. There are currently eight functional versions of the BASIC Stamp module and thirteen physical versions.

Parallax also offers several other microcontroller products (Propeller, SX, and Javelin Stamp), a variety of robots, a range of components and accessories, and education kits.

www.parallax.com/tabid/733/Default.aspx

(090411-I)



Department of Energy announces completion of world's largest laser

The Department of Energy has announced the completion of the world's largest laser. Housed at the Department of Energy's Lawrence Livermore National Laboratory, the National Ignition Facility (NIF) is expected to allow scientists to achieve fusion ignition in the laboratory, obtaining more energy from the target than is provided by the laser.

The stadium-sized NIF can focus all of its 192 individual beams, each about 40 centimeters square, into a spot about one-half millimeter in diameter at the center of its 10-meter diameter target chamber. The NIF can deliver large amounts of energy with extreme precision in billionths of a second. The NIF has already produced significant results. It is the first fusion laser in the world to break the megajoule barrier by delivering 1.1 million joules of ultraviolet energy to the center of its target chamber - more than 25 times more energy than the previous record.

The NIF is a critical part of the mission of the National Nuclear Security Administration (NNSA) to maintain the safety and reliability of U.S. nuclear deterrents without conducting nuclear testing. With the NIF, scientists will be able to evaluate key scientific assumptions in current computer models, obtain previously unavailable data on how materials behave at temperatures and pressures like those in the center of a star, and help validate NNSA's supercomputer simulations by comparing code predictions with observations from laboratory experiments.

The NIF also has the potential to produce breakthroughs in fields beyond national security. It may help advance fusion energy technology, which could be an element of making the United States energy independent. It could also help scientists better understand the makeup of stars and giant planets, both within and outside our solar system.

https://publicaffairs.llnl.gov/news/news_releases/2009/NR-NNSA-09-03-06.html

(090411-III)

Gumstix releases OMAP35x modules and expansion boards for Overo series

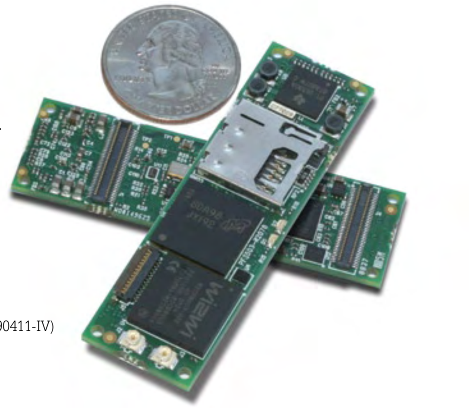
Gumstix has expanded its Overo™ series of miniature computer-on-module (COM) products with the addition of the Overo Fire, Overo Water, and Overo Air. Two new expansion boards were also released to provide the additional options of an LCD with touch screen capability and 10/100baseT Ethernet.

The Overo series consist of four different modules based on Texas Instruments (TI) OMAP35x applications processors with an ARM Cortex™-A8 CPU. Each Overo COM operates at 600 MHz and includes 256 MB RAM, 256 MB NAND Flash and a microSD card slot for additional on-board memory. The tiny modules (17×58×4.2 mm) run Linux kernel 2.6.28 or higher, and developers have access to extensive online software documentation. The Overo modules are pin-compatible, so each expansion board can be used with every Overo.

The popular Overo Earth is based on TI's OMAP3503 Applications Processor, which features an ARM Cortex-A8 CPU. The Overo Air COM provides the same features and function as Overo Earth, plus WLAN and Bluetooth® capabilities with an on-board W2CBW003 module from

Wi2Wi. Overo Water uses the high-performance TI OMAP3530 applications processor instead of the OMAP3503. The OMAP3530 adds the TMS320C64x+ DSP and OpenGL® ES graphics engine to the Cortex CPU to enhance applications with such features as a smart user interfaces and photorealistic graphics. Overo Fire enhances the OMAP3530-driven Overo Water with WLAN and Bluetooth communications using the same Wi2Wi module as in the Overo Air.

Each Overo is a computer-on-module unit and easily expandable, so design engineers can leverage the Overo to get their new product ideas to market much faster than building from scratch. Overo COM units are recommended for integration into commercial products projected to sell up to 50,000 units per year.



www.gumstix.com

(090411-IV)

Popular whip antennas now available in 2.4-GHz versions

Antenna Factor (Merlin, OR) has launched new 2.4-GHz versions of its popular PW and CW series of quarter-wave monopole whip antennas. These durable, classically-styled dipole antennas are well suited for a wide range of industrial, medical, sporting and consumer applications.

Antennas in the PW series are designed for permanent attachment and provide outstanding performance in a rugged, cost-effective package. The antenna is attached by placing its base through a 1/4" hole in the product and securing it with a nut or by threading it into a PEM-style insert. This method of attachment is highly secure and saves the cost of an antenna connector. The antenna is fed through the base with RG-174 coax cable, which may be soldered directly to the board or attached using a 50-ohm connector. The standard cable length is 8.5". Custom lengths and terminations are available by special order.

The CW series antennas deliver outstanding performance and wide bandwidth in a rugged, attractive package. These antennas feature an FCC Part 15 compliant RP-SMA connector. This simplifies packaging and shipment, allowing for easy field replacement while complying with FCC requirements. A wide variety of matching connectors allows for numerous mounting options.

Both versions feature a wide useable bandwidth, low VSWR, and an omni-directional pattern. An internal counterpoise eliminates external ground plane dependence.

The antennas are available from Antenna Factor and distributors worldwide.

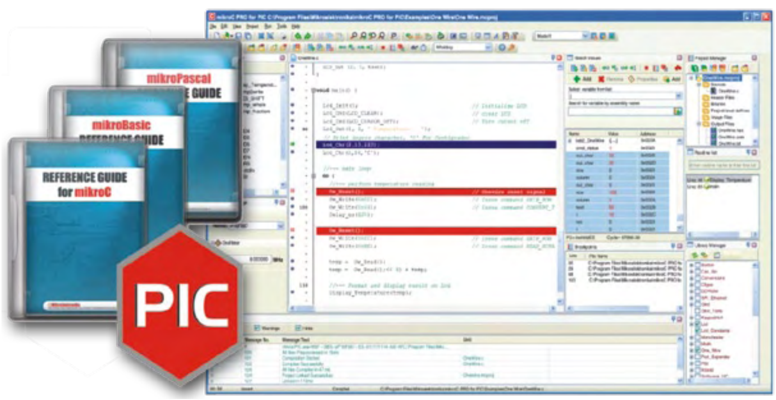
www.antennafactor.com

(090411-II)

Mikroelektronika releases Basic, C and Pascal compilers for PIC microcontrollers

Mikroelektronika has recently released new compilers for the PIC family of microcontrollers: mikroBasic PRO PIC 2009, mikroC PRO PIC 2009, and mikroPascal PRO PIC 2009. Each of them is available as part of a complete IDE that features project-based design and supports an impressive range of PIC microcontrollers.

At the management level, the IDE provides three functions: Project Manager, Code Explorer, and Library Manager. Project Manager helps users manage multiple projects. Several projects in a project group may be open at the same time, with one of them currently active. Code Explorer enables users to monitor variables, functions, procedures and other program items. Library Manager simplifies the handling of the libraries used in a project.The IDE incorporates code editor with a code assistant that saves time when you're writing code and a parameter assistant that helps you complete the parameter fields of functions. There are also many other useful features, such as auto correct, code templates, syntax highlighting, enhanced undo/redo, and more.



mikroBasic PRO, mikroC PRO, and mikroPascal PRO for PIC 2009 include more than 25 libraries to make it easier to use the PIC MCU and its peripheral functions, including libraries for ADC, CAN, SPI, Compact Flash, EEPROM, Ethernet, Flash Memory, Graphic LCD, I²C, Keypad, LCD, Manchester code, MMC/SD Card, One-Wire, Port Expander, PrintOut, PS/2, PWM, RS-485, Sound, SPI, Graphic LCD, UART, USB HID, Standard ANSI C, T6963C GLCD, Miscellaneous, SPI and more. It also includes many practical examples and comprehensive documentation, to get you off to a fast start in PIC programming.

Fully functional demonstration versions (with hex output limited to 2k program words) are available on the mikroElektronika web site. PIC hardware development tools that fully support mikroPascal PRO for PIC 2009 are also available.

www.mikroe.com/en/compilers/

(090411-V)

Operating range of industrial panel PCs extends from -20 °C to +60 °C

The new Intelligent Thermal And Power Supervisor (ITAPS) from Ocular, Inc., a longtime leader in advanced display-centric solutions for embedded computing and communications systems, allows the company's industrial panel PCs to be used over the extended temperature range of -20 °C to +60 °C. ITAPS monitors and manages power and temperature to prevent data corruption, ensuring reliable system operation in extremely harsh conditions.

Until now, most panel PCs were limited to the 0 °C to +50 °C temperature range, so many embedded systems operating in harsh conditions could not take advantage of panel PCs or human-machine interface (HMI) with their ease-of-use features, such as a touch screen interface. ITAPS is available on Ocular's Denali 7000 Industrial Panel PC platform, which features a 7-in. TFT screen, an x86-based processor, and the WinCE operating system. ITAPS will be available on the Denali 1040 Industrial Panel PC with its 10.4-in. TFT display during the second half of 2009. In addition, it can be implemented on any of Ocular's standard embedded processor display platforms, as well as customized panel PCs or HMIs.

By monitoring and managing the panel PC's system voltage and temperature, ITAPS protects the system from damage by low- and high-temperature conditions, under- and over-voltage problems, and brown-out and surge events. For example, when the ambient temperature is low, ITAPS heats the system before it attempts to boot start, ensuring that the panel PC is at a safe operating temperature before it starts. In high temperature conditions, ITAPS prevents the system from starting to avoid circuit and component damage. If the system is running and the temperature exceeds the safe operating range, ITAPS intervenes directly with the operating system to execute an orderly shutdown. In addition, ITAPS constantly monitors the state of any battery connected to the system and charges the battery when necessary. In the event of a brown-out or power failure, the system can be switched immediately and seamlessly to battery power.

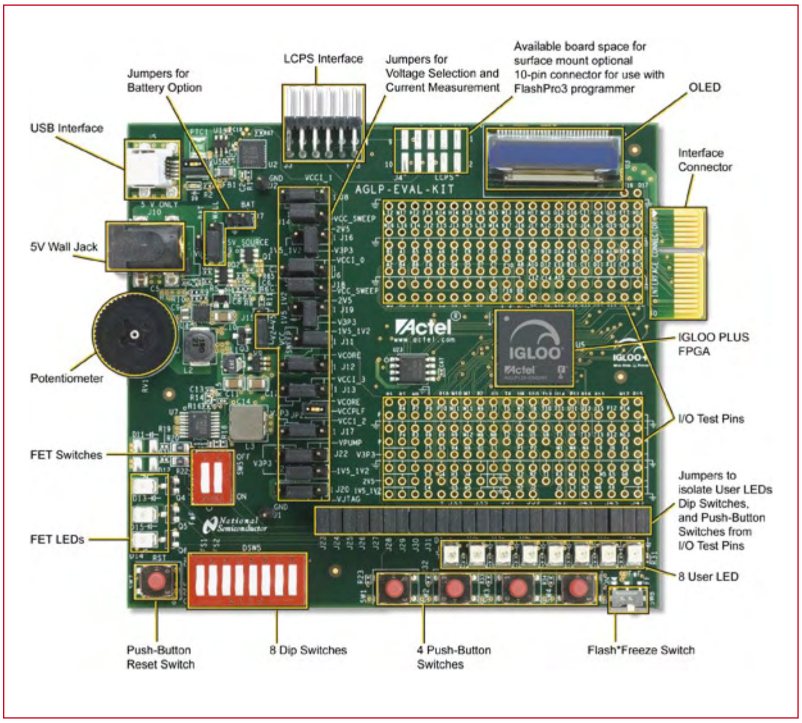
www.OcularDisplaySystems.com

(090411-VI)

New starter kit for IGLOO Plus FPGAs

Actel's new, low-cost IGLOO PLUS Starter Kit supports the IGLOO PLUS family of low-power FPGAs, which are claimed to offer the industry's best power-, area-, logic- and feature-per-I/O ratios in a programmable device. The IGLOO PLUS Starter Kit is fully RoHS-compliant and includes a modular board with the IGLOO PLUS AGLP125 device in a CSG289 package as well as a miniature programming stick, which allows both evaluation and prototyping of your design. Actel IGLOO PLUS devices range from 30,000 to 125,000 gates, and they support independent Schmitt trigger inputs, hot-swapping, and Flash*Freeze bus hold.

User I/O is routed to holes on the board to allow the board to be wired into any extensive system where IGLOO PLUS would potentially be used, enabling you to design it into a typical application without the expense or time of building a dedicated board. The IGLOO PLUS Starter Kit is fitted with the largest IGLOO PLUS die to enable designers to target any device in the IGLOO PLUS family. In addition, the CSG289 package has a common footprint across the AGLP030, AGLP060 and AGLP125 devices, enabling designers to use the IGLOO PLUS kit to develop an application that can be directly targeted at a different device. The included programming stick enables easy experimentation with ISP, device serialization, and FlashLock on-chip system security.



The IGLOO PLUS Starter Kit board has a small form factor of 3.7 x 4 inches and has on-board voltage regulation, enabling you to set some of the I/O bank voltages independently. IGLOO PLUS devices can operate at core voltages ranging from 1.2 V to 1.5 V, and they require the core to be held at 1.5 V during programming. Power analysis can be performed in Libero IDE at 50-mV increments from 1.2 V to 1.5 V.

A regulator circuit for controlling the core voltage is provided on the board. Besides automatic switching to 1.5 V during programming operations, the regulator includes potentiometer adjustment to enable the user to vary the core voltage to simulate a battery failure.

www.actel.com/products/hardware/devkits_boards/iglooplus_starter.aspx

(090411-IX)

ST offers miniature MEMS motion sensor

STMicroelectronics has introduced a high-performance MEMS (micro electro-mechanical system) sensor featuring a three-axis accelerometer with absolute analog output. Operating from a supply voltage of 2.16 to 3.6 V and extremely stable over temperature and time, the LIS352AX is designed for motion-sensing applications in space- and cost-constrained battery-operated devices, including free-fall detection for data-integrity protection in hard-disk drives, vibration monitoring and compensation, remote control, and user motion interfaces in mobile and gaming devices or portable media players.

The three-axis motion sensor is designed to provide acceleration values in the form of absolute analog outputs. Taking advantage of internal regulated voltage, the measurements are insensitive to the typical variations in power-supply voltage that occur in battery-operated devices such as mobile phones and other portable devices. This eliminates the need for a separate voltage regulator and enhances design flexibility.

The LIS352AX features high stability over a wide temperature range for both zero-g offset and sensitivity, with an offset drift (temperature variation) of approximately plus or minus 0.3 mg/°C. It provides accurate output over a full-scale range of +/-2.0 g. The device features as low noise level with minimized power consumption, which is important in battery-operated systems. The accelerometer has high immunity to vibration and shock survivability up to 10,000 g. Built-in self-test capability enables verification of sensor functionality after board assembly.

www.st.com/stonline/products/literature/ds/15530/lis352ax.htm

(090411-VIII)

Driver IC extends operating life of high-power LEDs

Infineon Technologies has introduced a low-cost LED driver IC for general lighting applications. Specifically designed for driving high-power LEDs, the BCR 450 features precise current control, thermal protection, and over-voltage / over-current protection.

The BCR 450 is specifically designed for use with high-wattage LEDs (for example in the 0.5 W, 1 W or 3 W range) in combination with an external transistor. By simply changing the external transistor, manufacturers of LED lighting have the flexibility to adapt output currents from 100 mA to above 1 A.

The BCR 450 does not generate any electromagnetic radiation, which makes it especially suitable for applications sensitive to electromagnetic interference, such as lighting systems in vehicles including buses, ships, trains and aircraft, as well as medical applications using data bus systems. In addition to general lighting systems, the BCR 450 is ideal for architectural and accent lighting, advertising, flashing lights for emergency vehicles, hazard lights, and road safety lights.

The application circuit for the BCR 450 has a low component count and does not need any inductors, capacitors or free-wheeling diodes, resulting in a small PCB footprint. Eliminating electrolytic capacitors enables LED lighting systems to achieve longer service life compared with PWM systems, which typically require electrolytic capacitors. To further ensure the long life of LED lighting systems, Infineon recognized the strong demands for thermal management and integrated an effective thermal shutdown feature, as well as over-voltage and over-current protection.

Uniform brightness of the entire LED chain is crucial in many lighting applications, especially architectural lighting, and human vision is sensitive to shifts in light color.

With its precise output current control (+/-10% variation over the entire operating temperature range), the BCR 450 supports the uniform brightness requirement for LED lighting systems.

www.infineon.com/leddriver

(090411-X)

Linear Hall-effect sensor provides PWM output

The new A1354 from Allegro MicroSystems is a programmable, precision two-wire Hall-effect linear sensor that has a pulse-width modulated (PWM) output with The new A1354 from Allegro MicroSystems is a programmable, precision two-wire Hall-effect linear sensor that has a pulse-width modulated (PWM) output with

duty cycle proportional to the applied magnetic field. It incorporates a voltage regulator, which allows the device to be powered directly from a battery with a supply voltage of 4.5 V to 18 V. The A1354 converts the analogue signal from its internal Hall sensor element to a digitally encoded PWM output signal.

The A1354 is targeted at position sensing applications in the automoduty cycle proportional to the applied magnetic field. It incorporates a voltage regulator, which allows the device to be powered directly from a battery with a supply voltage of 4.5 V to 18 V. The A1354 converts the analogue signal from its internal Hall sensor element to a digitally encoded PWM output signal.

The A1354 is targeted at position sensing applications in the automotive and industrial sectors, particularly where diagnostic capabilities

are required, where there is a limitation on the number of wires to and from a control unit, or where noise immunity over long wires is required. The noise immunity of the digitally encoded PWM output is far superior to the noise immunity of an analogue output signal.
The A1354 incorporates precision temperature-compensating circuitry to reduce the intrinsic sensitivity and offset drift of the Hall element, a small-signal high-gain amplifier, proprietary dynamic offset cancellation circuits, and PWM conversion circuitry. Dynamic offset cancellation reduces the residual offset voltage of the Hall element. High-frequency offset cancellation enables a higher sampling rate, which increases the accuracy of the output signal and enables faster signal processing.
Programmable features include sensitivity, PWM frequency (15 Hz or 120 Hz) and unidirectional or bidirectional sensing. Programmability allows the device to be fine-tuned in the final application for higher system accuracy. Output duty cycle clamps provide short-circuit diagnostic capability, while a start-up test mode allows users to calibrate out the effects of ground potential and threshold variance in use.

www.allegromicro.com

(090411-VII)

IAR releases IDE for Toshiba ARM Cortex-M3

IAR Systems AB have announced the release of a new, low-cost development kit for the ARM Cortex-M3 in partnership with Toshiba Corp.
Toshiba was the first Japanese semiconductor manufacturer to release a 32-bit ARM Cortex-M3 core-based microcontroller with the TMPM330FDFG in late 2008. It uses the Cortex-M3 core to provide a high-performance, low-power general-purpose MCU with a large flash memory, real-time clock, 10-bit analog-to-digital converter, and three-channel SIO/UART, all housed in a compact LQFP package. The TMPM330FDFG is optimized for use in consumer, industrial, security, and general low power applications.

The IAR KickStart Kit for the TMPM330FDFG contains all the hardware and software elements necessary for the design, development, integration and testing of specific applications. It includes a TMPM330-SK evaluation board with a TMPM330FDFG ARM 32-bit Cortex-M3 device, an IAR J-Link for Toshiba's Cortex-M3 family, an IAR PowerPac board support package, a Micrium board support package, and a set of example applications.

The kit's TMPM330-SK evaluation board comes with a JTAG connector (as defined by ARM) for programming and debugging, USB and RS232 drivers, an audio jack (3.5 mm, mono), and a power supply. It has a TFT LCD display and outside extended SDRAM, NAND flash, NOR flash, USB OTG (On-the-Go), a SD/MMC card connector, speaker, and buzzer.

www.iar.com

(090411-XI)

Secure MCU targets financial terminals

Maxim Integrated Products has introduced the MAXQ1850, a high-performance 32-bit RISC microcontroller for financial terminal applications. The MAXQ1850 integrates security supervisory features, advanced encryption acceleration, and 8 KB of nonvolatile memory with a 32-bit MAXQ(r) microcontroller core. The microcontroller has the lowest pin count and smallest footprint available for applications that require a high level of physical and logical security.
The MAXQ1850's security mechanisms protect against both logical and physical attacks. Its encryption engines are resistant to side-channel attacks and cryptanalysis, environmental sensors protect against physical manipulation, and secure tamper triggers offer many options for application-specific tamper-detection circuits. Most important for secret key protection is the MAXQ1850's custom-designed, battery-backed nonvolatile NV SRAM-the best kind of memory for secret storage because it can be erased quickly in response to tampering.
The MAXQ1850 is optimized for use as a system microcontroller in simpler financial terminals, or as a secure coprocessor in complex point-of-sale (POS) terminals. It is the only high-security microcontroller without an external memory bus, so it has an extremely low pin count. The MAXQ1850 drastically reduces the amount of board space taken up by the system microcontroller for applications that need 256 KB of flash and 8 KB of secure NV SRAM.
The MAXQ1850 also provides greater flexibility when used as a secure coprocessor in higher-end financial terminals. By executing all necessary security functions and key management, the microcontroller maintains the security of the financial terminal without having to send the keys from one IC to another.
Evaluation kits and software libraries are available.

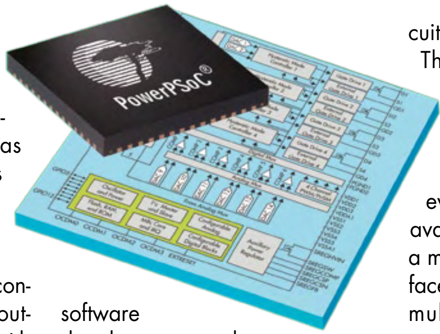
www.maxim-ic.com/MAXQ1850-Micro

(090411-XII)

PowerPSoC single-chip solution for integrated LED driver and controller

The PowerPSoC family of integrated embedded power controllers from Cypress Semiconductor provide a single-chip solution for controlling and driving high-power LEDs. This family of devices integrates four constant-current regulators and four 32-V, 1-A MOSFETs with the company's PSoC programmable system-on-chip (SoC), which includes a microcontroller, programmable analog and digital blocks, and memory. The result is an end system with fewer components, faster design cycles, lower power consumption, and higher reliability.

The PSoC architecture consists of an 8-bit MCU, eight programmable digital blocks to serve as timers, counters, PWMs or UARTs, six programmable analog blocks for functions such as amplifiers, ADCs, DACs, filters and comparators, and 16 KB of flash memory.



Other features include up to four programmable hysteretic controllers for controlled current output, four low-side gate drivers with programmable drive strength, a 2-MHz switching frequency, and an auxiliary power regulator that enables the chip to operate from a single supply voltage.

PSoC Designer , the companion software development tool for the PowerPSoC, lets designers quickly and efficiently program the controllers for different lighting and power options. It also allows changes late in the design cycle without having to change the circuit board layout.

The CY3268 demonstration kit drives four LEDs in a 2.5- by 3.5-in form factor with basic reprogramming and debugging capability. A PowerPSoC evaluation kit (CY3267) is also available for prototyping. It offers a modular approach with an interface for daughter cards to support multiple applications, multiple protocols, and customer-specific daughter cards.

www.cypress.com/psoc

(090411-XIV)

Optimized LED is 15 percent brighter

The Advanced Power TopLED Plus from Osram Opto Semiconductors is specifically designed for architectural and sales lighting applications. It combines impressive brightness with high luminous efficacy of up to 90 lm/W. It is the light source of choice for all applications that call for bright light but offer very little space, such as highlighting edges and contours or illuminating surfaces with uniform brightness. It combines remarkable brightness with low power consumption and small dimensions.

The new Advanced Power TopLED Plus has a luminous flux of up to 27 lm (100 mA / 5700 K). Not only is it on average 15% brighter than the standard version, it is also available in color temperatures from 2700 to 6500 K. This means that different white-light tones ranging from warm white to cold white can be achieved, and all requirements of applications ranging from linear lighting to strip lighting and surface illumination can be met. The LED is ideal for illuminating building facades and outlines, and it is perfect for applications in retail outlets, such as in freezer cases.

The LED has a typical beam angle of 140° and a uniform white color from every viewing angle. Its small dimensions enable light to be mixed in the smallest of spaces. A large number of small LEDs produce more homogenous illumination on a surface than a few large LEDs. Designers are thus free to create new lighting solutions, limited only by their imagination. The Advanced Power TopLED Plus is rated at up to 0.5 W dissipation. Heat is efficiently dissipated to the PC board via gull-wing connections to the lead frame, eliminating the need for expensive thermal management.

www.osram-os.com

(090411-XIII)

Fanless embedded box computer boasts compact size

Axiomtek has introduced an extremely small fanless embedded box computer, the eBOX530-820-FL, which measures only 130 x 95.4 x 47.1 mm - smaller than an adult hand. The eBOX530-820-FL is based on an ultra low-power Intel Atom processor and operates at up to 1.6 GHz with the Intel US15W system controller hub. The integrated Intel Graphics Media Accelerator 500 delivers advanced graphics and 3-D performance. The eBOX530-820-FL targets embedded market segments such as DSA, car PCs, healthcare, entry-level gaming, and in-flight infotainment.

Housed in a rugged compact aluminum chassis, the eBOX530-820-FL provides a full set of I/O features including Gigabit Ethernet, four USB 2.0 ports, two COM ports, a VGA connector, an audio connector, and PS/2 ports. This durable embedded computer also supports one 2.5 SATA HDD drive bay and a CompactFlash card for high-capacity storage. The computer uses DDR2 memory with a capacity of up to 2 GB and requires only +5 V power input. For installation flexibility, the eBOX530-820-FL can be fitted stand-alone, wall-mounted, or DIN-rail mounted. A watchdog timer is available to monitor the system.

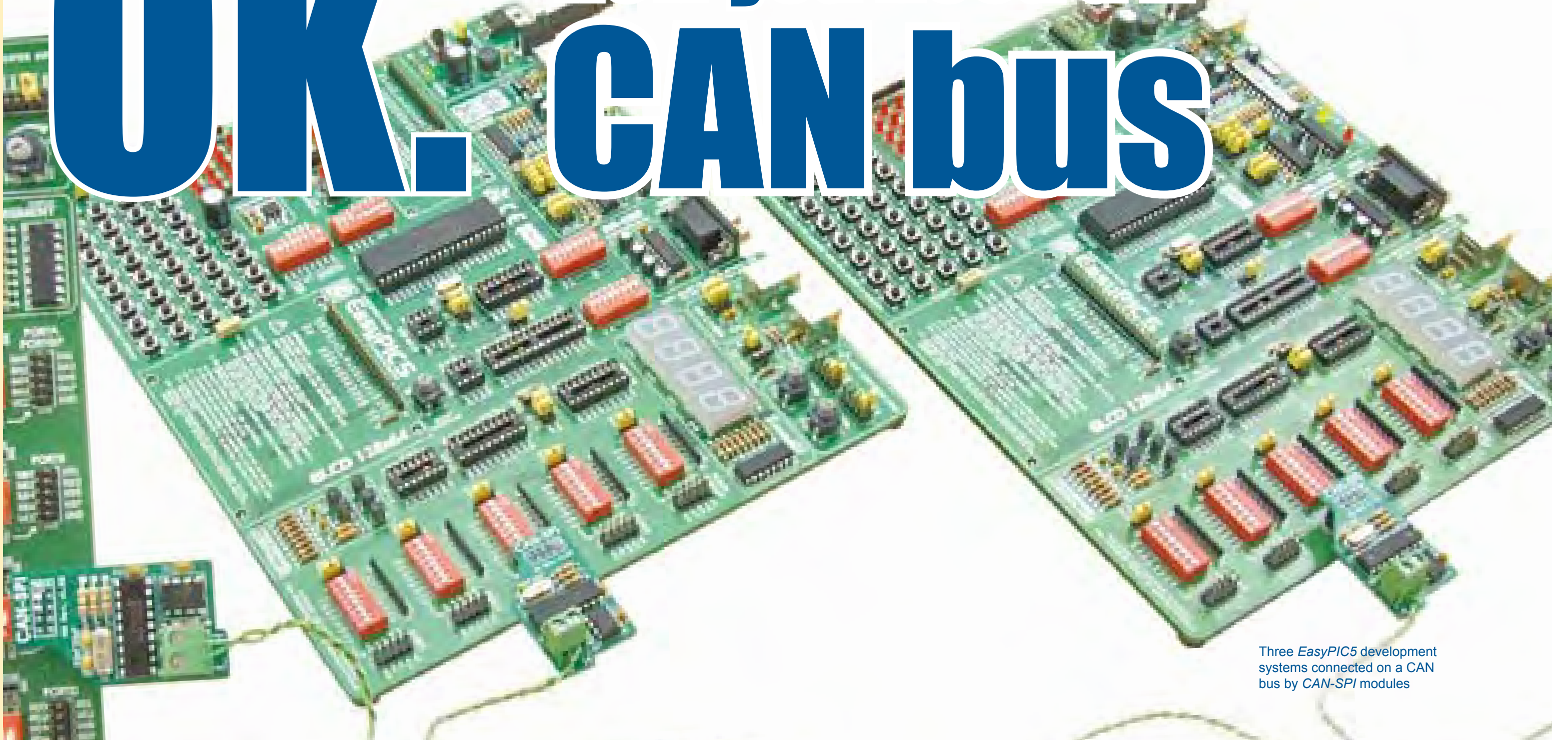
The fanless design and a unique thermal solution enable the eBOX530-820-FL to operate without silently in critical environments at temperature from 0 to 50 °C. It also offers excellent vibration resistance up to 1 g rms.

www.axiomtek.com/products/ViewProduct.asp?view=701

(090411-XV)

MikroElektronika
DEVELOPMENT TOOLS | COMPILERS | BOOKS

OK. Now you need a ... CAN bus



Three *EasyPIC5* development systems connected on a CAN bus by *CAN-SPI* modules

It is often necessary to have several microcontrollers performing different operations integrated in one system in order to make them function as a whole. Here we show how to connect three microcontrollers to a CAN and how to use filters in CAN nodes for the purpose of filtering messages.

By Zoran Ristic
MikroElektronika - Software Department

Whenever several peripheral units share the same data bus, it is necessary to define how the bus is accessed. The CAN protocol accurately describes all the details on connecting several devices to a network and as such it is widely used in the industry. The protocol primarily defines the precedence of bus implementation and solves the problem of 'collision' within the hardware in the event that several peripheral units start to communicate at the same time.

Hardware

In this example, a CAN bus will be configured so that the first device sends messages consisting of 0x10 and 0x11 as their ID, while the second and third device send messages consisting of IDs 0x12 and 0x13, respectively. We will also configure the CAN nodes so that the second node responds to incoming messages containing ID 0x10 only, while the third one responds only to those containing the 0x11 ID. Accordingly, the first device is configured to receive messages containing a 0x12 and 0x13 ID (Figure 2). Message filtering is easily implemented by calling the CANSPISetFilter routine which will also handle all the necessary settings of the microcontroller registers and CAN SPI board.

In general, the CAN protocol doesn't require a Master device to be present on the bus. However, to make this example easy to understand while still keeping it general-purpose, we will set the first device only, to initiate communication on the network and another two devices to respond to individual calls.

Software

When sending a message, the Master node leaves enough time for the called node to respond. In the event that a remote node doesn't respond within the time required, the Master reports an error in the current message and proceeds with calling other nodes (Figure 3). In the event that a peripheral CAN node responds at the same time as another node, a 'collision' will occur on the CAN bus. However, the device address priority and CAN alone prescribe that in this case the node transmitting the lower priority message withdraws from the bus, thus enabling the node transmitting the higher priority message to proceed with transmission immediately.

As mentioned before, we will use an internal SPI module of the microcontroller to transfer data onto the CAN bus. Some of the advantages of using the microcontroller's internal SPI module are: the possibility of generating an interrupt when sending and receiving data; the SPI module operates independently of other peripherals and has a simple configuration. The CAN SPI library enables you to set the operating mode of the CAN and node filters, read data from the CAN SPI board buffer, etc.

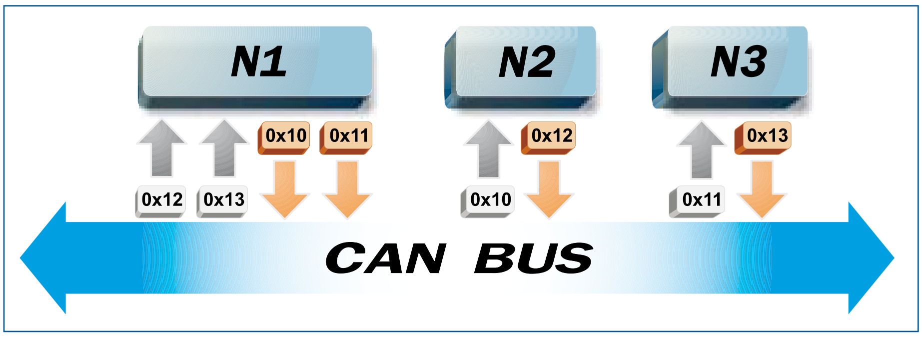
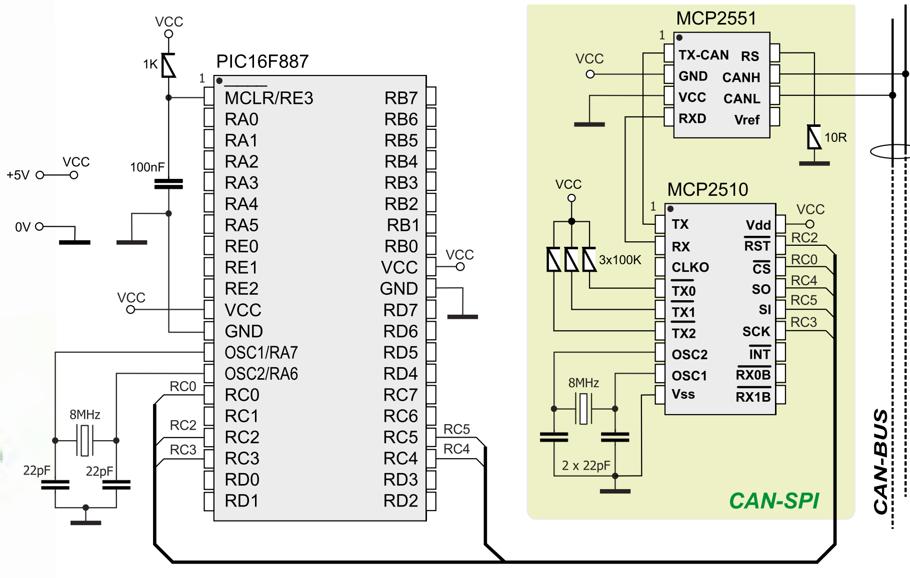


Figure 1. Message filtering



Schematic 1. Connecting the *CAN-SPI* module to a PIC16F887

This example also includes LEDs on the microcontroller pins indicating that the network operates properly. When node 2 responds to node 1's call, the PORTB LEDs will be automatically turned on. If node 3 responds to the call, the PORTD LEDs will be turned on. The source code for all three nodes in the network is provided with this example. In order to create a HEX file for each of these nodes individually, it is necessary to write only one DEFINE directive in the example header.

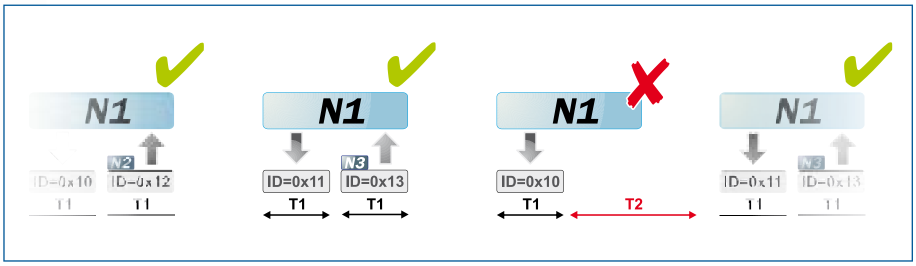
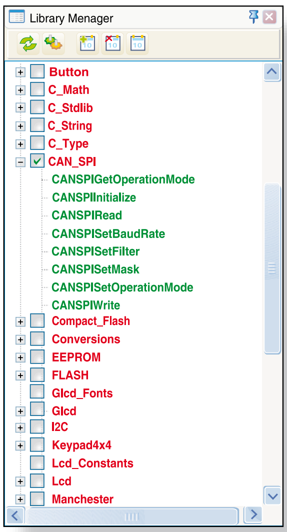


Figure 2. Communication example

In summary, here we have described one way of connecting microcontrollers to the CAN bus. We have also described how to detect errors by means of a communication protocol in the event that a remote node doesn't respond as expected, how to filter messages using CAN filters, as well as how to perform communication in general on the CAN bus.

mikroC PRO for PIC® library editor with ready to use libraries such as: CAN_SPI, GLCD, Ethernet etc.



Functions used in the program

CANSPIGetOperationMode()	Current operation mode
CANSPIInitialize()*	Initialize the CANSPI module
CANIRead()*	Read message
CANSPISetBaudRate()	Set the CANSPI baud rate
CANSPISetFilter()*	Configure message filter
CANSPISetMask()*	Advanced filtering configuration
CANSPISet OperationMode()*	Current operation mode
CANSPIWrite()*	Write message

*** CANSPI library functions used in the program**

Other *mikroC PRO for PIC* functions used in the program:
Delay_us()
SPI1_init()
SPI1_read()

GO TO The program for this example written for PIC® microcontrollers in C, Basic and Pascal as well as the programs written for dsPIC® and AVR® microcontrollers may be found on our web site: **www.mikroe.com/en/article/**

Program to demonstrate the operation of a *CAN bus*

```
#define NODE1    // Uncomment this line to build HEX for Node 1
//#define NODE2 // Uncomment this line to build HEX for Node 2
//#define NODE3 // Uncomment this line to build HEX for Node 3
char Can_Init_Flags, Can_Send_Flags, Can_Rcv_Flags; // Can flags
char Rx_Data_Len;           // Received data length in bytes
char RxTx_Data[8];          // Can rx/tx data buffer
char Msg_Rcvd;              // Reception flag
long Tx_ID, Rx_ID;          // Can rx and tx ID
char ErrorCount;
// CANSPI module connections
sbit CanSpi_CS at RC0_bit;   // Chip select (CS) pin for CANSPI board
sbit CanSpi_CS_Direction at TRISC0_bit; // Direction register for
CS pin
sbit CanSpi_Rst at RC2_bit; // Reset pin for CANSPI board
sbit CanSpi_Rst_Direction at TRISC2_bit;   // Direction register for
Reset pin
// End CANSPI module connections
void main(){
ANSEL  = 0; ANSELH = 0;      // Configure analog pins as digital I/O
PORTB  = 0; TRISB  = 0;      // Initialize ports
PORTD  = 0; TRISD  = 0;
ErrorCount     = 0;          // Error flag
Can_Init_Flags = 0; Can_Send_Flags = 0; Can_Rcv_Flags = 0;// Clear flags

Can_Send_Flags = _CANSPI_TX_PRIORITY_0 &  // Form value to be used
                 _CANSPI_TX_XTD_FRAME &   //   with CANSPIWrite
                 _CANSPI_TX_NO_RTR_FRAME;

Can_Init_Flags = _CANSPI_CONFIG_SAMPLE_THRICE &  // Form value to
be used
                 _CANSPI_CONFIG_PHSEG2_PRG_ON &  //   with CANSPIInit
                 _CANSPI_CONFIG_XTD_MSG &
                 _CANSPI_CONFIG_DBL_BUFFER_ON &
                 _CANSPI_CONFIG_VALID_XTD_MSG;

SPI1_Init();                 // Initialize SPI module
CANSPIInitialize(1, 3, 3, 3, 1, Can_Init_Flags);
// Initialize external CANSPI module
CANSPISetOperationMode(_CANSPI_MODE_CONFIG, 0xFF);
// Set CONFIGURATION mode
CANSPISetMask(_CANSPI_MASK_B1, -1, _CANSPI_CONFIG_XTD_MSG);
// Set all mask1 bits to ones
CANSPISetMask(_CANSPI_MASK_B2, -1, _CANSPI_CONFIG_XTD_MSG);
// Set all mask2 bits to ones
#ifdef NODE1
CANSPISetFilter(_CANSPI_FILTER_B2_F4, 0x12, _CANSPI_CONFIG_XTD_MSG);
// Node1 accepts messages with ID 0x12
CANSPISetFilter(_CANSPI_FILTER_B1_F1, 0x13, _CANSPI_CONFIG_XTD_MSG);
// Node1 accepts messages with ID 0x13
#else
CANSPISetFilter(_CANSPI_FILTER_B2_F2, 0x10, _CANSPI_CONFIG_XTD_MSG);
// Node2 and Node3 accept messages with ID 0x10
CANSPISetFilter(_CANSPI_FILTER_B1_F2, 0x11, _CANSPI_CONFIG_XTD_MSG);
// Node2 and Node3 accept messages with ID 0x11
#endif
CANSPISetOperationMode(_CANSPI_MODE_NORMAL,0xFF);  // Set NORMAL mode
RxTx_Data[0] = 0x40;      // Set initial data to be sent
#ifdef NODE1
Tx_ID = 0x10;             // Set transmit ID for CAN message
#endif
#ifdef NODE2
Tx_ID = 0x12;             // set transmit ID for CAN message
#endif
#ifdef NODE3
Tx_ID = 0x13;             // Set transmit ID for CAN message
#endif
#ifdef NODE1
CANSPIWrite(Tx_ID, &RxTx_Data, 1, Can_Send_Flags);
// Node1 sends initial message
#endif
while (1)                 // Endless loop
    {
Msg_Rcvd = CANSPIRead(&Rx_ID, &RxTx_Data, &Rx_Data_Len, &Can_Rcv_Flags);
// Attempt receive message
if (Msg_Rcvd) {           // If message is received then check id
#ifdef NODE1
if (Rx_ID == 0x12)        // Check ID
PORTB = RxTx_Data[0];     // Output data at PORTB
else
PORTD = RxTx_Data[0];     // Output data at PORTD
delay_ms(50);             // Wait for a while between messages
CANSPIWrite(Tx_ID, &RxTx_Data, 1, Can_Send_Flags);  // Send one byte
Tx_ID++;                  // Switch to next message
if (Tx_ID > 0x11) Tx_ID = 0x10;          // Check overflow
#endif
#ifdef NODE2
if (Rx_ID == 0x10) {      // Check if this is our message
PORTB = RxTx_Data[0];     // Display incoming data on PORTB
RxTx_Data[0] = RxTx_Data[0] << 1; // Prepare data for sending back
if (RxTx_Data[0] == 0) RxTx_Data[0] = 1;   // Reinitialize if
                                           // maximum reached
Delay_ms(10);             // Wait for a while
CANSPIWrite(Tx_ID, &RxTx_Data, 1, Can_Send_Flags);   // Send one byte
                                                     // of data back
         }
#endif
#ifdef NODE3
if (Rx_ID == 0x11){       // Check if this is our message
PORTD = RxTx_Data[0];     // Display incoming data on PORTD
RxTx_Data[0] = RxTx_Data[0] >> 1;  // Prepare data for sending back
if (RxTx_Data[0] == 0) RxTx_Data[0] = 128; // Reinitialize if
                                           //maximum reached
Delay_ms(10);             // Wait for a while
CANSPIWrite(Tx_ID, &RxTx_Data, 1, Can_Send_Flags); // Send one byte
                                                   //of data back
        }
#endif
       }
else {                    // An error occured, wait for a while
#ifdef NODE1
ErrorCount++;             // Increment error indicator
Delay_ms(10);             // Wait for 100ms
if (ErrorCount > 10) {    // Timeout expired - process errors
ErrorCount = 0;           // Reset error counter
Tx_ID++;                  // Switch to another message
if (Tx_ID > 0x11) Tx_ID = 0x10;       // Check overflow
CANSPIWrite(Tx_ID, &RxTx_Data, 1, Can_Send_Flags);
// Send new message
        }
#endif
       }
    }
}
```

Written in compiler **mikroC PRO for PIC**

Portable Solar Mo

Portable power for people on the go

Harry Baggen (Elektor Netherlands Editorial)

With the summer coming up, many of us are again making preparations for recreational trips in the great outdoors. Especially with somewhat longer trips, a portable solar panel can come in very handy to ensure that you always have enough power for your cell phone, iPod, GPS receiver, and even the car battery. We selected some of the products currently available in this area, and here we describe what they have to offer.

We all lead very busy lives these days. When we're not stressing ourselves out at work, we're busy with projects at home, sports, or attending local club meetings.
It's thus no wonder that many people look for a chance to relax and restore their balance when they have a few days off. For many people, this means spending a day hiking, or even going hiking for several days, with only a backpack and the bare essentials.

In many cases, during your trip you often discover that it's not so easy to do without all the conveniences of modern life. It can be very handy to occasionally call someone with your cell phone or check your GPS receiver to see where you are. During long trips, this can lead to problems with your collection of battery-powered devices, because their battery life is often relatively short. The solution in such cases is to take along some spare batteries, or perhaps a portable solar panel.

Figure 1. Many portable solar panels come with an extensive set of adapters.

If you choose the latter option, you can also choose from a variety of portable solar panels presently available. There are even small solar panels that can be placed behind the window of a trailer or the windshield of a car to maintain the battery charge while the vehicle is parked. We chose several models of both types and subjected them to closer examination. We wanted to see what they can do and how useful they are in practice.

Types

The available solar panels can be roughly divided into a few categories.
For instance, there are fixed panels that are intended to be used for topping up a car battery in a car or trailer. In most cases, you can simply put a panel of this type behind a window and connect the included cable directly to the battery or plug it into the cigarette lighter socket. Depending on its dimensions, a panel of this type can supply a current of 100 to 1000 mA. These panels are reasonably priced, and the smaller models are well suited to powering a small stand-alone circuit or a home-made garden lamp.

Another category consists of portable solar panels. These models are specifically designed to be easy to take along on a trip, such as a hiking trip. Folding and roll-up panels are available, with or without an integrated battery pack. The battery pack (often a rechargeable lithium-ion battery) has a built-in charging regulator and can be connected directly to the solar panel. When the battery pack is fully

dules

charged, it can be used to charge or power other devices, such as a cell phone. For this purpose, many of these chargers come with a broad selection of adapters for connection to the most popular types of portable devices.
Various adapters are also included with the models that do not include a battery pack, so that external devices can be connected directly to the solar panel. In this case, you should pay careful attention to the required supply voltage.

Technology

Most of the solar panels examined for this article are fitted with thin-film solar cells fabricated using vapor-deposition technology. The manufacturing cost of this type of solar cell is relatively low, but it has lower efficiency than monocrystalline or polycrystalline solar cells. The advantage of thin-film solar cells is that they are relatively flexible, which makes them quite suitable for use in foldable and roll-up panels.
Every solar panel consists of a group of solar cells connected in series to obtain the desired output voltage, such as eight cells for an output voltage of approximately 4.8 V (each cell has an output voltage of 0.6 V). The maximum output current depends on the size of the individual cells.
Most panels intended to be used in or on a car or trailer are made from a large sheet of glass or transparent plastic that forms the base for the solar cells. With portable solar panels, the solar cells are laminated between plastic sheets and fitted in a frame made from nylon or a similar material, with the connections formed such that they can bend with the frame.

How well do they work?

How much power can a solar panel supply? Can you use it to charge a car battery, cell phone or iPod, or even to power a laptop computer? This depends primarily on the size of the panel and the amount of sunlight available. The surface area of the solar panel in many small battery chargers is very small, so the time required to charge a pair of penlight cells can be rather long.

Solar panels are usually specified in terms of the amount of power they supply. For this article, we generally limited our attention to panels rated at less than around 10 W (with a few exceptions) to keep everything reasonably comprehensible, but much larger panels are also available.
The panel power specified by the manufacturer is usually achieved with illumination corresponding to a specified standard spectrum and a light intensity of 100,000 lux. At

Figure 2.
A light meter calibrated in lux is indispensable for measuring light intensity. For our measurements, we used a Voltcraft LX-1108 provided by Conrad Netherlands.

central to northerly European latitudes, this requires a bright summer day with a cloud-free sky, which means that the panel will supply much less power under "normal" weather conditions. To give you an idea, on a sunny day with a light overcast the supplied power can easily decline to 50–70% of the rated value. With partially cloudy weather, it drops to 20–40%, and with full cloud cover and no direct sunlight it decreases considerably more to around 2–10%. These are very rough values, but they give you an approximate idea of what you can expect in terms of power yield. If you go to Africa for your vacation, you can draw a lot of power from your solar panel, but if you spend your vacation close to home, you may have to make do with much less power (but of course, in the Netherlands you can find a power outlet on almost every street corner).
In practice, this means that a solar panel rated at a few watts will unquestionably have to lie in full sunlight for several hours in order to charge a small battery. You are thus forced to stay put during this period. A handy alternative here is a backpack with a built-in solar panel, and we examined one example of this sort of solution.
A solar panel with a matching battery pack is a good combination. This configuration often includes a charging regulator to optimize the use of the available power. Although these combined packages are a good deal more expensive, you can unfold or unroll the solar panel while you take a break without having to connect your cell phone or other device directly to the panel. In the evening, you can then use the battery pack to charge your cell phone or GPS receiver at your leisure.

Practical experience

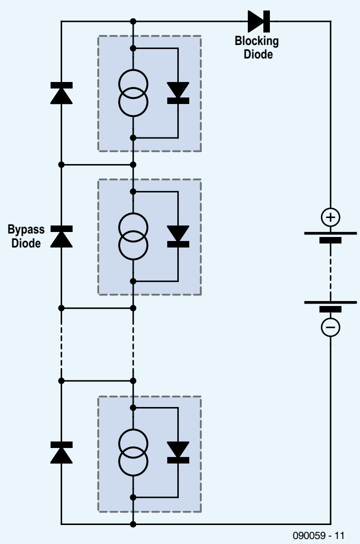
To get an idea of how well the various panels work, we tested them outdoors on a bright blue spring day (light intensity approximately 75,000 lux) with various loads. Under these conditions, most of the panels managed to deliver around 75 to 90% of their rated power. In particular, the roll-up panel from Powerfilm, the foldable 6.5-watt panel from ME2, and the solar panel case from ELV scored very high. The "car panels" also performed reasonably well. Unfortunately, the two Solar products proved to be under-achievers, with a maximum output of around 70% of their rated power. They obviously need to spend more time in the sun.
We made all these measurements on a bright spring day. The results are not nearly as nice on a cloudy day, when the output can easily drop to around a tenth of the rated power. This is something that you have to bear in mind.

Prices

Is a portable solar panel a reasonable investment? The prices of standard panels are fairly attractive, with small models rated at around 2 watts available for around 40 dollars and up. However, the practical utility of such models is questionable. Foldable and roll-up models are generally a good deal more expensive due to their construction, with prices ranging from 140 to 800 dollars.
When selecting a panel of this type, you should primarily consider your intended use. In many cases, the main issue is not the price, but instead how urgently you need electrical power in a remote area. If you spend a month in Tibet, it's nice to be able to use a solar panel to charge your camera or cell phone

Solar cells

Jens Nickel (Elektor Germany Editorial)

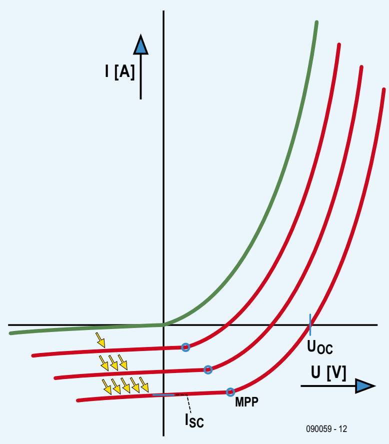


All solar cells are made from at least two different materials, often in the form of two thin, adjacent layers. One of the materials must act as an electron donor under illumination, while the other material must act as an electron acceptor. If there is some sort of electron barrier between the two materials, the result is an electrical potential. If each of these materials is now provided with an electrode made from an electrically conductive material and the two electrodes are connected to an external load, the electrons will follow this path.

The most commonly used solar cells are made from thin wafers of polycrystalline silicon (polycrystalline cells have a typical "frosty" appearance after sawing and polishing). The silicon is very pure, but it contains an extremely small amount of boron as a dopant (an intentionally introduced impurity), and it has a thin surface layer doped with phosphorus. This creates a PN junction in the cell, exactly the same as in a diode. When the cell is exposed to light, electrons are released and holes (positive charge carriers) are generated. The holes can recombine with the electrons. The charge carriers are kept apart by the electrical field of the PN junction, which partially prevents the direct recombination of electrons and holes.

The electrical potential between the electrodes on the top and bottom of the cell is approximately 0.6 V. The maximum current (short-circuit current) is proportional to the surface area of the cell, the impinging light energy, and the efficiency. Higher voltages and currents are obtained by connecting cells in series to form strings and connecting these strings of cells in parallel to form modules.

The maximum efficiency achieved by polycrystalline cells is 17%, while monocrystalline cells can achieve up to 22%, although the overall efficiency is lower if the total module area is taken into



now and then. You should carefully estimate how much power you need and how much sunshine you can expect at your intended destination, and then make your choice on this basis. It's better to choose a panel that is somewhat larger than what you absolutely need, since the available power decreases considerably when the sun is obscured by cloud.

On the following pages, we provide an overview of several modules to give you an idea of what types are available and what they have to offer.

(070798-I)

Brand	Type	RRP	Importer/supplier
Voltaic www.voltaicsystems.com	Backpack Solar-power backpack	$300	Ecotopia www.ecotopia.co.uk The Electronic Zone www.electroniczone.co.uk
Solar www.solarmio.com	Supra survival kit	$800	ME2: www.selectsolar.co.uk/pics/6.5W%20Sunlinq%20E-Sun.php
Solar	Mio 31	$185	
ME² www.mobile-energy2.com	Foldable solar panel 6.5 W max.	$230	
Sunforce www.sunforceproducts.com	Battery trickle charger 5 W	$120	
Sunsei www.sunsei.com	SE400 Order no. 857032-89	$140	Sunsei: www.conrad-int.com Sunforce: www.selectsolar.co.uk
Sunsei	SE135 Order no. 857030-89	$50	
SunForce	Solar-powered battery maintenance charger 1.8 W Order no. 853784 - 89	$45	
	Mobile solar power case TPS-936 Order no. 68-693-25	$120	www.towsure.com
PowerFilm www.powerfilmsolar.com	R15-600	$340	www.selectsolar.co.uk/pics/rollable.php

account. On a sunny day in central Europe, the available solar energy is approximately 1000 W/m², and around 150 W/m² of this can be converted into electrical energy with currently available solar cells.

Cells made from selenium, gallium arsenide, or other compounds can achieve even higher efficiency, but they are more expensive and are only used in special applications, such as space travel. There are also other approaches that are aimed primarily at reducing costs instead of increasing efficiency. The objective of such approaches is to considerably reduce the amount of pure silicon that has to be used or eliminate its use entirely. One example is thin-film solar cells made from amorphous silicon, which have an efficiency of 8 to 10% and a good price/performance ratio. The silicon can be applied to a glass sheet or plastic film in the form of a thin layer. This thin-film technology is quite suitable for the production of robust, flexible modules, such as the examples described in this article.

Battery charging

From an electrical viewpoint, an ideal solar cell consists of a pure current source in parallel with a diode (the outlined components in the accompanying schematic diagram). When the solar cell is illuminated, the typical U/I characteristic of the diode shifts downward (see the drawing, which also shows the open-circuit voltage U_{OC} and the short-circuit current I_{SC}). The panel supplies maximum power when the load corresponds to the points marked "MPP" (maximum power point) in the drawing. The power rating of a cell or panel specified by the manufacturer usually refers to operation at the MPP with a light intensity of 100,000 lux and a temperature of 25 °C. The power decreases by approximately 0.2 to 0.5 %/°C as the temperature increases.

A battery can be charged directly from a panel without any problems if the open-circuit voltage of the panel is higher than the nominal voltage of the battery. No voltage divider is necessary, even if the battery voltage is only 3 V and the nominal voltage of the solar panel is 12 V. This is because a solar cell always acts as a current source instead of a voltage source.

If the battery is connected directly to the solar panel, a small leakage current will flow through the solar panel when it is not illuminated. The can be prevented by adding a blocking diode to the circuit (see the schematic). Many portable solar modules have a built-in blocking diode (check the manufacturer's specifications).

This simple arrangement is adequate if the maximum current from the solar panel is less than the maximum allowable overcharging current of the battery. NiMH cells can be overcharged for up to 100 hours if the charging current (in A) is less than one-tenth of their rated capacity in Ah. This means that a panel with a rated current of 2 A can be connected directly to a 20-Ah battery without any problems. However, under these conditions the battery must be fully discharged by a load from time to time.

Practical matters

When positioning a solar panel, you should ensure that no part of the panel is in the shade, as otherwise the voltage will decrease markedly, with a good chance that no current will flow into the connected battery.

Most modules have integrated bypass diodes connected in reverse parallel with the solar cells. These diodes prevent reverse polarization of any cells that are not exposed to sunlight, so the current from the other cells flows through the diodes, which can cause overheating and damage to the cells. To reduce costs, it is common practice to fit only one diode to a group of cells instead of providing a separate diode for each cell.

ME^2 Solar Foldable 650

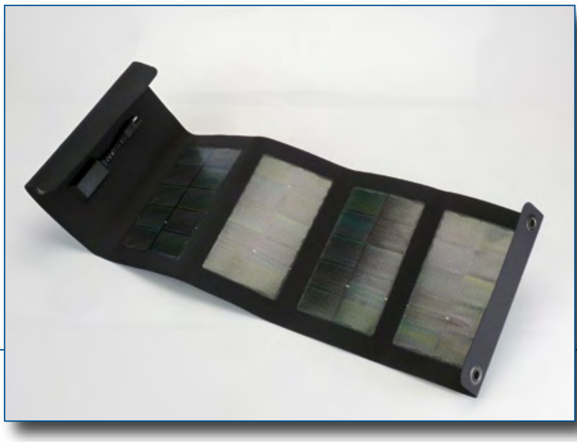
This foldable panel is made from very sturdy nylon fabric. The manufacturer uses c-CGIS cells, which according to the manufacturer have higher efficiency than the commonly used amorphous cells. The panel is weather-resistant, and on closer examination we see that the cells are integrated almost seamlessly into the nylon fabric, so the structure can indeed tolerate a certain amount of rain.

The included accessories consist of a variety of adapter cables with a cigarette-lighter plug and matching socket, a 5-mm power plug, an extension cable, and two battery clips.

A sound product with impressive cell efficiency and outstanding finish.

Voltage/current: 12 V / 0.433 A

Dimensions: 23 × 12 cm folded; 75 × 12 cm unfolded



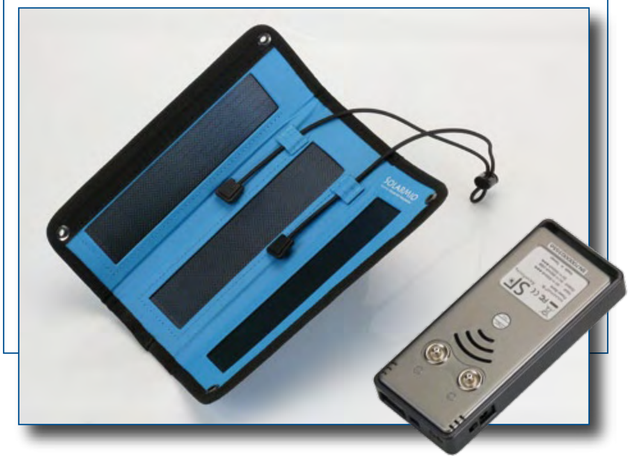
Solar Mio 31

This small foldable panel with a striking color can be folded into a compact package. It has a fairly low output voltage of 6 V, and it is intended to be used for charging portable devices. A bracket with an included box is fitted on the back, and the box contains a lithium polymer battery with an integrated charging regulator. You can charge this battery during the day and then use it whenever desired to charge another device. A USB connector (5 V) and a 2.5-mm power plug are included for this purpose. An extensive set of adapters allows a wide variety of devices to be connected to the battery. An AC power line adapter and a car adapter are also included for charging the battery without the solar panel.

A handy kit, but it's a pity that the battery capacity isn't a bit larger.

Voltage/current: solar panel 6 V / 0.42 A; battery 5–6 V / 0.5 A

Dimensions: 23 × 8 cm folded; 235 × 23 cm unfolded



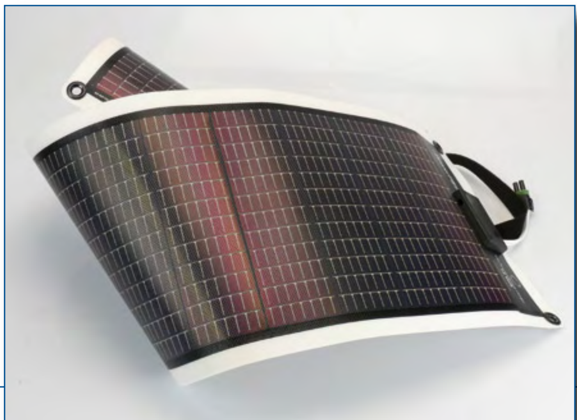
PowerFilm R15-600

This rather unusual panel is the only roll-up model in our overview. The solar cells of this panel are fitted between two layers of tough plastic that can handle a certain amount of abuse and is weatherproof and UV-resistant. This type of flexible solar panel is often used on boats, among other applications. The price of a model with a power rating of 10 W (around $330) may seem high compared with the other panels, but for this price you have a robust panel that can withstand a bit of rough treatment and poor weather conditions. This panel can be secured using four grommets in the corners. It can be connected directly a 12-V battery with the included cable. The best way to connect relatively small devices is to use a 12-V battery charger for in-car use.

An outstanding panel, primarily suitable for special applications due to its unusual features.

Voltage/current: 15.4 V / 0.6 A

Dimensions: 23 long by 11 cm diameter rolled up; 97 × 29 cm unrolled



Voltaic Backpack

A few companies, such as Ecosolar and Voltaic, produce backpacks with integrated solar panels. We chose the popular Backpack model for this overview.

The sturdy, comfortable backpack with a capacity of 30 liters has a three-section panel of monocrystalline solar cells, which can collectively charge an included lithium-ion battery rated at 7.2 V / 2.2 A. An AC adapter for charging the battery from a power outlet and a large number of adapter plugs are also included.

The main advantage of this backpack is that you can walk all day with it, with the battery being charged while you are underway. The other panels have to be laid out somewhere while in use, which means you have to stay put for the duration.

An excellent choice for frequent hikers.

Voltage/current: 10.2 V / 0.4 A

Dimensions: 51 × 25–38 × 18–25 mm; weight: 1.6 kg

Solar Supra Survival Kit

The foldable panel of this especially luxurious but rather expensive set has 16 large triple-junction cells that can collectively supply a maximum power of nearly 13.5 W. The nylon case into which the panels are fitted is very sturdy and also has space for the included battery and charging regulator. This "powerbase" contains a hefty rechargeable battery (probably a lithium type) that can supply 50 W. The actual capacity is not stated, but the manufacturer does say that it can power a notebook computer for several hours. This the best battery pack of all the ones we have seen in this overview. The output voltage of the internal DC/DC converter can be adjusted in steps over a range of 5 to 19 V, and its capacity is indeed reasonably large.

This is one of the best combinations we have seen, with numerous accessories.

Voltage/current: 8 V / 1.68 A

Dimensions: 23 × 15 × 9 cm folded; 49 × 46 cm unfolded

Battery pack: 50 W / 5–19 V

TPS936 mobile solar panel

This solar panel is actually out of place in this overview in terms of dimensions and portability, but in light of the attractive price for such a large panel we considered it worthwhile to include it in the selection.

This a sort of small case in approximately European A3 format, which can be opened up to expose large solar panels on the two inner surfaces. Although the efficiency of the amorphous cells used here is not especially high, this unit delivers 13 W and is thus ideal for topping up the battery of a car or trailer. You can also use the included adapters and clips to connect the cable in the case to a wide variety of other devices.

The case is fairly heavy, but this does not matter for use with a car or trailer. With a price of around $120, it's a real bargain.

Voltage/current: 15 V / 0.88 A

Dimensions: 34 × 52 cm closed; 68 × 52 cm open

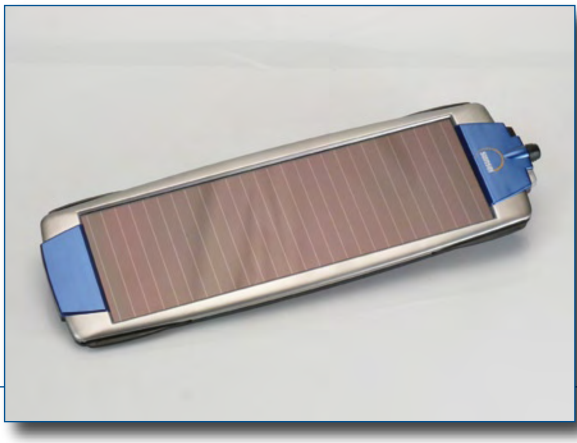
Sunsei Solar Charger 135

This panel is designed for use in or on a car, boat, or trailer, and it can be connected to the battery with the included cables and clips. This is a fairly small panel with a rated power of 1.5 W, so it has to be used as a trickle charger.

The panel has four fold-out supports that can be used to attaché it to a car window with the included suction cups. After this, you can simply leave the panel where it is. The finishing is good, and the unit is made to be weather-resistant. It has a button and blue LED for checking whether the panel is working.

Voltage/current: 15 V / 0.135 A

Dimensions: 38 × 13 cm



Sunsei Solar Charger 400

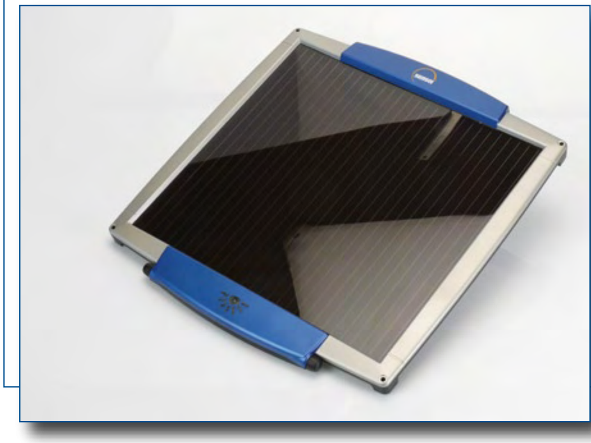
This panel is a larger version of the Solar Charger 135 (there are four different models in this series). Here again the panel can easily be connected directly to the battery with the included cables and clips. The panel is nicely finished, and the connectors have protective caps with silicone washers, all of which makes a reasonably weatherproof impression. Several panels can be connected together in a daisy-chain arrangement.

There is sun-pattern button for checking whether the panel is supplying current. A blue LED lights up if it is working.

A special pivoting bracket is available for easy installation of the panel.

Voltage/current: 15 V / 0.4 A

Dimensions: 36 × 37 cm



Sunforce Battery Maintainer

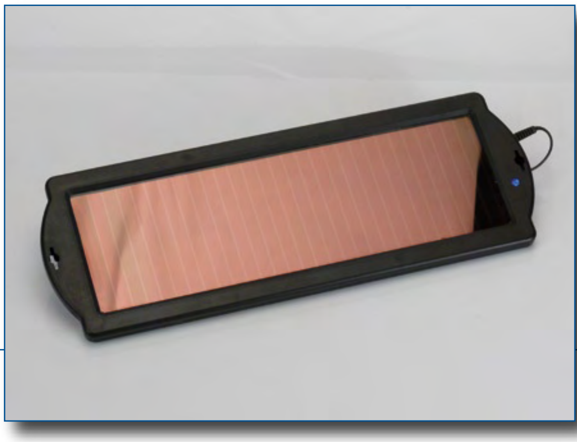
This panel as also intended to be used to maintain the charge of a car battery. The current output is low, and you shouldn't expect too much from a panel of this size.

It can be connected to the battery with the included cable and clips. A built-in blue LED blinks when the panel is supplying power. The LED is constantly connected to a portion of the solar panel, with the result that the voltage decreases considerably in cloudy weather and the battery can't take advantage of the panel's full capacity.

The panel has the same surface area and dimensions as the Solar Charger 135, and nearly the same price. It has openings at the top and bottom for attachment to a window. A few suction cups are included for installation, but they are rather small.

Voltage/current: 15 V / 0.125 A

Dimensions: 35 × 13 cm



Sunforce Battery Trickle Charger

This panel is similar to the large Sunsei panel. It has nearly the same dimensions and nearly the same power rating.

This panel has a permanently attached cable that can be connected to the car battery with the aid of a few adapters and clips or via the cigarette lighter socket. In contrast to the other car panels, it does not have an indicator LED (which is not necessarily a drawback).

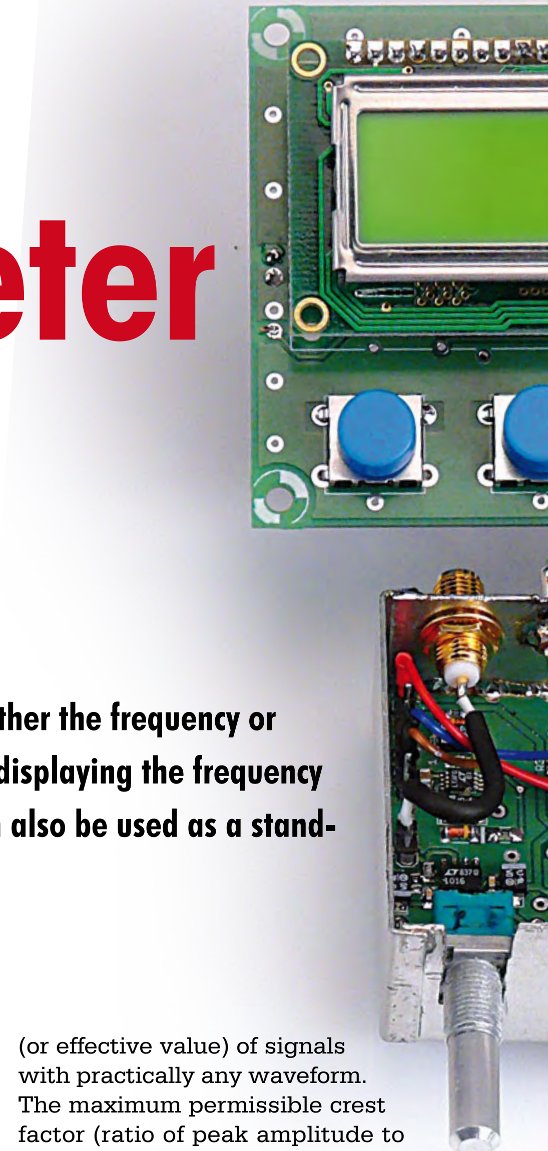
The dimensions and weight of this panel make it more suitable for fixed installation somewhere. You can use the four mounting holes and the included screws to make your on bracket for this purpose.

Voltage/current: 15 V / 0.35 A

Dimensions: 35 × 34 cm

True RMS Digital Voltmeter

with frequency counter



Kai Riedel (Germany)

Many simple function generators do not offer the facility to measure either the frequency or the amplitude of the output. The module described here fills that gap, displaying the frequency and RMS amplitude of a signal on a two-line LCD panel. The circuit can also be used as a stand-alone true RMS voltmeter with frequency measurement.

A wide range of frequency counter designs has been published in Elektor [1]. None of these, however, has offered the ability to measure the amplitude of the input signal. Measuring the RMS (root mean square) amplitude properly is more than matter of applying full-wave rectification, averaging, and multiplying by a suitable magic constant, the method used in low-cost multimeters. The magic multiplication factor used in these meters is correct if the input waveform is a pure sine wave, but the error in the reported value increases as the input waveform deviates from the pure sinusoidal shape. Table 1 shows the degree of error for a few example waveforms. The instrument described here can determine the true RMS amplitude [2] (or effective value) of signals with practically any waveform. The maximum permissible crest factor (ratio of peak amplitude to RMS amplitude) is a way of specifying for what kinds of waveforms can have their RMS value measured with sufficient accuracy. For the true RMS converter used here, the maximum crest factor (for an overall accuracy of 1%) is 4.

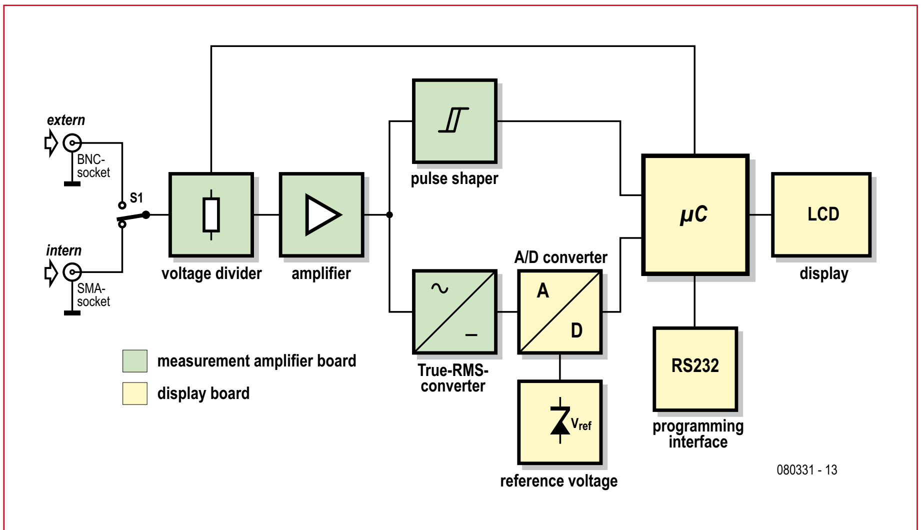


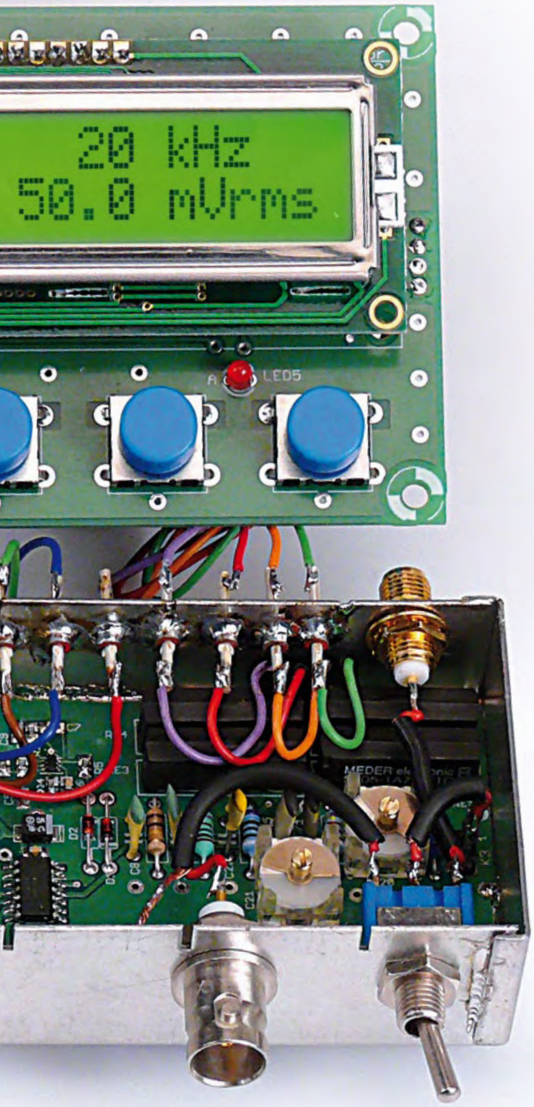
Figure 1. Block diagram of the meter.

The circuit

The operating principle of the circuit can be understood using the block diagram (**Figure 1**). The system is divided into two main modules: the input amplifier and the display board.

The input circuitry consists of a switchable voltage divider with subsequent amplifier and a true RMS converter. Alongside this is a pulse shaper used in measuring the signal frequency. The amplifier is needed because the error in the output of the true RMS converter increases noticeably at input levels of 5 mV or less.

The display module includes the processing circuit, consisting of a micro-



Main Characteristics

- **Four measurement ranges: 0.1 V, 1 V, 10 V, 100 V**
- **Voltmeter bandwidth: 20 Hz to 1 MHz (basic accuracy ±1.0% of full scale)**
- **Frequency counter bandwidth: 1 Hz to 10 MHz (typ.), 25 MHz (max.) (± timebase error)**
- **Minimum input voltage for counter: approximately 50 mVRMS**
- **Input impedance: ≥ 1 MΩ || ≤ 50 pF**
- **Counter timebase: 100 ms, 1 s**
- **Adjustable trigger level: approximately ±0.15 V**
- **Autoranging (may be disabled)**
- **Offset correction and calibration facility**
- **Automatic scaling of frequency display**
- **Voltage displayed as RMS value or peak-to-peak value (for sinusoidal input)**
- **Crest factor: ≤ 4**
- **Two measurement inputs**

Table 1. Mean absolute value versus RMS

We assume a mean signal amplitude of 1 V. 'SCR' stands for Silicon Controlled Rectifier, or thyristor: we use this as shorthand for the waveforms found in AC phase angle control circuits.

Wave shape	Crest factor	True RMS value [V]	Error in using mean absolute value [%]
Sine	1.414	0.707	0
Square, 50%	1.0	1.0	+11.0
Triangle	1.73	0.577	–3.8
SCR, 50%	2	0.495	–28
SCR, 25%	4.7	0.212	–30

controller, LCD panel, analogue-to-digital converter and an RS-232 interface.

Figure 2 shows the circuit diagram of the input amplifier module, where the parts of the block diagram can clearly be seen. As the input voltage is AC, a frequency-compensated voltage divider is used. Without this, the voltage divider would form a low-pass filter with the input capacitance of the subsequent circuit, which would severely limit the maximum operating frequency. To avoid various potential problems associated with matching and with high input voltages, relays are used to switch the voltage divider. The output of the divider is matched to the amplifier by a classical impedance conversion stage using a dual field-effect transistor. This guarantees good stability down to DC (see [3]).
To enable operation up to high frequencies, the main amplification is carried out in three stages. The amplifier used here, an ADA4862-3 [4], has internal frequency compensation and consists of three opamps, which, connected in series, deliver an overall gain of 8. A particular feature of this device is its very good linearity: the gain variation is within 0.1 dB up to 65 MHz.

The output of the amplifier feeds IC3, an RMS-to-DC converter [5][6], and IC4, a high-speed comparator [7]. Potentiometer P1 allows the switching threshold of the comparator to be adjusted slightly. If it is desired to process signals with a greater DC component, we recommend adding a series high-voltage capacitor of (for example) 330 nF before the input amplifier circuit.
According to its datasheet, the Linear Technology LTC1968 RMS-to-DC converter has a 3 dB bandwidth of 15 MHz. The arrangement in our circuit broadly follows the manufacturer's recommendations. Capacitor C15 allows the response time of the converter to be set. A smaller value can be used to reduce the response time, but this will increase the error in the result at frequencies below 100 Hz. C14 ensures that only the AC component of the signal is processed.

Display module using R8C

The display module is based on the popular Renesas R8C/13 microcontroller (see **Figure 4**). The wiring of the microcontroller (with programming via the RS-232 interface, crystal and LCD panel) follows the circuits from the R8C series published in Elektor from February 2006 [8][9]. IC2 is an external 20-bit analog-to-digital (A/D) converter [10]. It uses the delta-sigma conversion technique and can effectively suppress the ripple that appears superimposed on the output of the RMS-to-DC converter. To simplify the necessary calculations, the A/D converter is provided

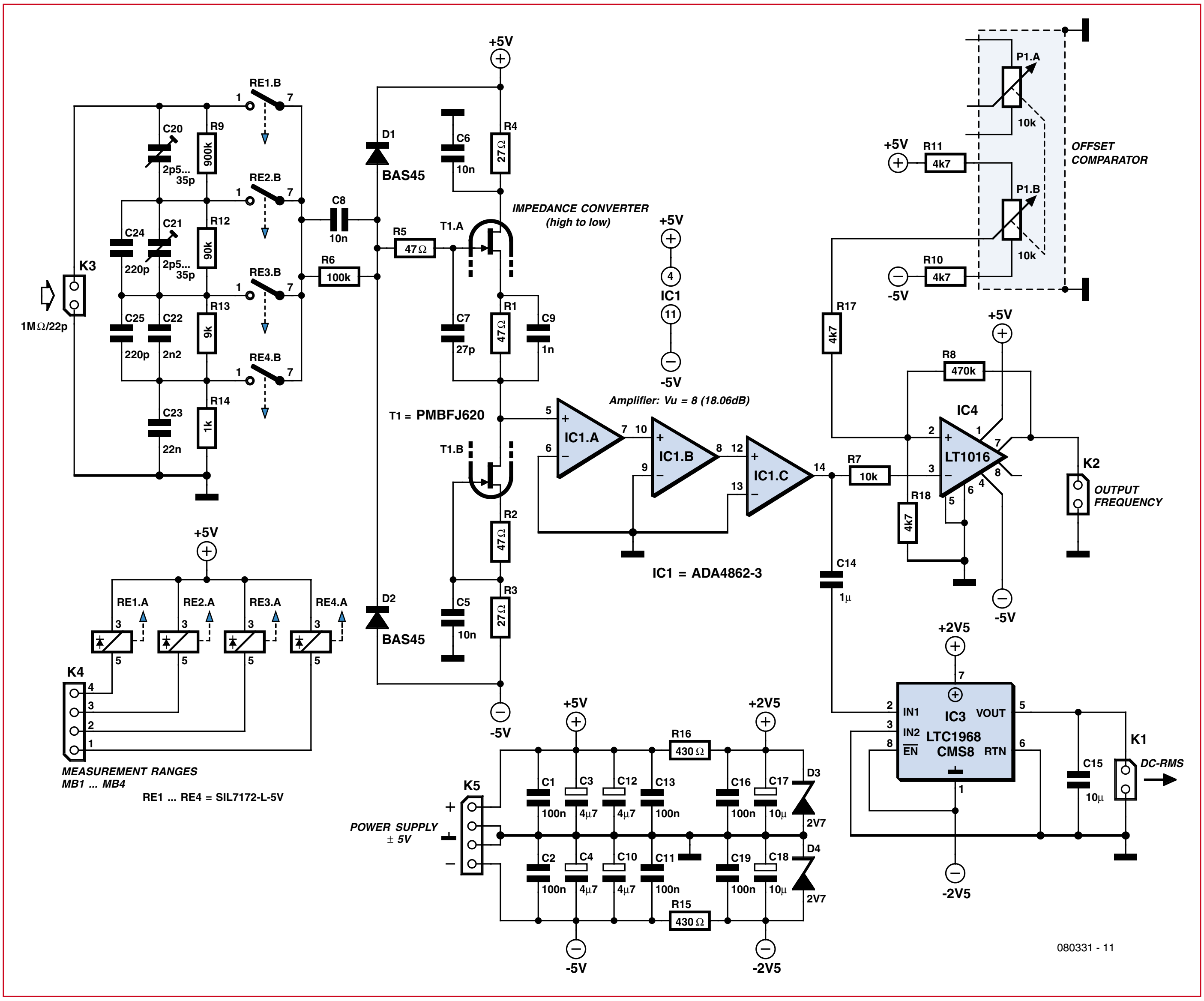


Figure 2. Circuit diagram of the amplifier module, including voltage divider, amplifier and RMS-to-DC converter.

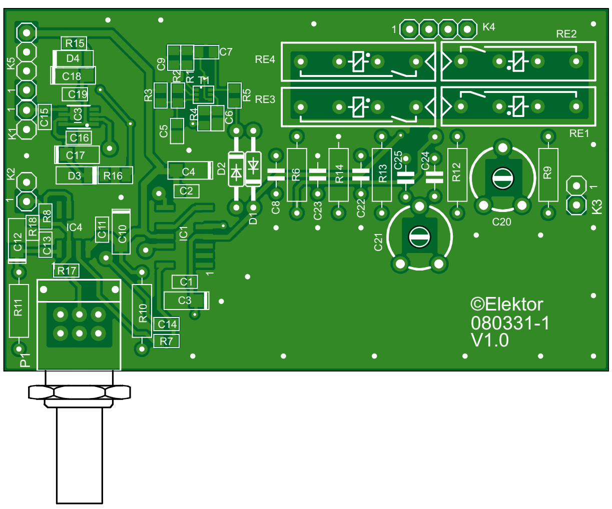


Figure 3. Printed circuit board for the amplifier.

COMPONENT LIST

Measurement Amplifier

Resistors

R1,R2, R5 = 47Ω (SMD 0805)
R3,R4 = 27Ω (SMD 0805)
R6 = 100kΩ
R7 = 10k (SMD 0805)
R8 = 470kΩ (SMD 0805)
R9 = 900kΩ 0.1%
R10,R11 = 4kΩ7
R12 = 90kΩ 0.1%
R13 = 9kΩ 0.1%
R14 = 1kΩ 0.1%
R15 = 430Ω (SMD 0805)
R16 = 430Ω (SMD 1206)
R17 = 4kΩ7 (SMD 0805)
R18 = 4kΩ7 (SMD 0805)

Two ways to calibrate

Method 1:

1. Connect an oscilloscope to the output of IC1 in the amplifier module, using a 10:1 probe.
2. Connect K4.1 to ground: this sets the highest voltage division ratio.
3. Apply a symmetrical square wave with an amplitude of around 1 V to the junction of resistors R12 and R13. This can be obtained, for example, from the calibration output of the oscilloscope.
4. Now the value of C25 must be selected to obtain as accurate as possible a square wave on the oscilloscope screen. The value given in the circuit diagram is a good starting point. One approach is to fit a 100 pF capacitor for C25 and then try adding 100 pF or 220 pF capacitors in parallel. If you have good eyesight and a steady hand, you can solder them as SMDs on the reverse of the board; this makes it easier to change them later.
5. Enable the next measurement range by grounding K4.2.
6. Apply the square-wave signal to the junction of R9 and R12.
7. Adjust trimmer C21 appropriately. Repeat for C20.

Method 2:

Follow steps 1 and 2 above and then apply a symmetrical square wave to the amplifier module input. Now adjust C25, C20 and C21 until an accurate square wave appears at the output of IC1. Since the values of C25, C20 and C21 jointly affect the response in each measurement range, considerably more trial and error is required than with the "textbook" approach described above. Nevertheless, the author has found that it can quickly lead to good results.

It is of course possible to start using method 1 and then use method 2 to make final fine adjustments.

with a 2.048 V reference voltage (IC3). An important factor is the temperature coefficient of this device: at 10 ppm/°C, we have a variation in the reference voltage of 0.02048 mV/°C.
The A/D converter outputs its conversion results to the R8C over an SPI port. Frequency measurement is carried out by feeding pulses into the CNTR0 counter input of the microcontroller. For this to work, the pulse width must be at least 40 ns and the period at least 100 ns. This means that we can measure frequencies of up to 10 MHz without a prescaler.
Four pushbuttons are provided for the user interface. Pressing S1 switches to manual ranging mode (automatic ranging then remains disabled until the next reset). S2 switches the timebase (and hence the sample rate) between 1 s and 100 ms. The current state is indicated by an LED. An extended press on S3 will perform an offset correction, while S4 switches the readout to peak-to-peak amplitude for sinusoidal signals.
Pin P01 on the microcontroller is connected to test point TP1, which is used in calibrating the module.

P1 = 10kΩ (Alps type 290061)

Capacitors
C1,C2,C11,C13,C16,C19 = 100nF (SMD 0805)
C3,C4,C10,C12 = 4µF7 10V (293D/A)
C5,C6 = 10nF (SMD 0805)
C7 = 27pF (SMD 0805)
C8 = 10nF
C9 = 1nF (SMD 0805)
C14 = 1µF 10V (SMD 0805)
C15 = 10µF 10V (SMD 0805)
C17,C18 = 10µF 10V (293D/A)
C20,C21 = 2.5-35pF trimmer (C-TRIMM808-7.5)
C22 = 2nF2
C23 = 22nF
C24,C25 = 220pF

Semiconductors
IC1= ADA4862-3 (SMD)
IC3 = LTC1968CMS8 (MSOP-8)
IC4 = LT1016CS8 (SO-8)
D1,D2 = BAS45 (1N4148)
D3,D4 = BZW55-2.7 (SMD)
T1 = Dual FET PMBFJ620 (NXP)

Miscellaneous
Re1–Re4 = SIL7271-L 5V or MEDER SIL05-IA72-7ID
K1,K2,K3 = 2-way pinheader
K4,K5 = 4-way pinheader
2x SMA case socket
Metal case e.g. TEKO # 372
BNC case socket
Miniature rocker switch
7x 1nF feedthrough capacitor
PCB # 080331-1, see www.elektor-usa.com/shop

Construction

The overall construction of the unit is shown in the wiring diagram (**Figure 6**) and the picture of the prototype (main photograph). Observe correct polarity on the relays (the "+" symbol on the package and the dot on the printed circuit board). The dual FET is fitted correctly when the dot on its package (indicating pin 1) is next to the dot on the board.

The circuit should be built in a metal enclosure to minimise interference (**Figure 7**). The DC signals are connected to the input amplifier via feedthrough capacitors, and the signals being measured are connected using SMA or BNC connectors. The output of the comparator (which is a square wave) is also taken via an SMA connector. If the module is to be built inside a function generator, the generator's output should be connected to the SMA input of the module using a screened cable.

The LCD, the four pushbuttons and the timebase indicator LED are all mounted on the front side of the display board, with all the other components on the back. This allows the board to be mounted in an enclosure as a self-contained module.

Software

We will only describe the structure of the software in broad outline here. Further details can be found in the source code itself and in the file 'Dokumentation_Software.chm' (created using the free software tool Doxygen). Source, hex and help files are of course available for free download from the website for the project [11].

The software makes use of various timers and interrupts (timers X, Y and Z, and the key input interrupt). If a calibration sequence has already been performed at some point, the first thing the software does when power

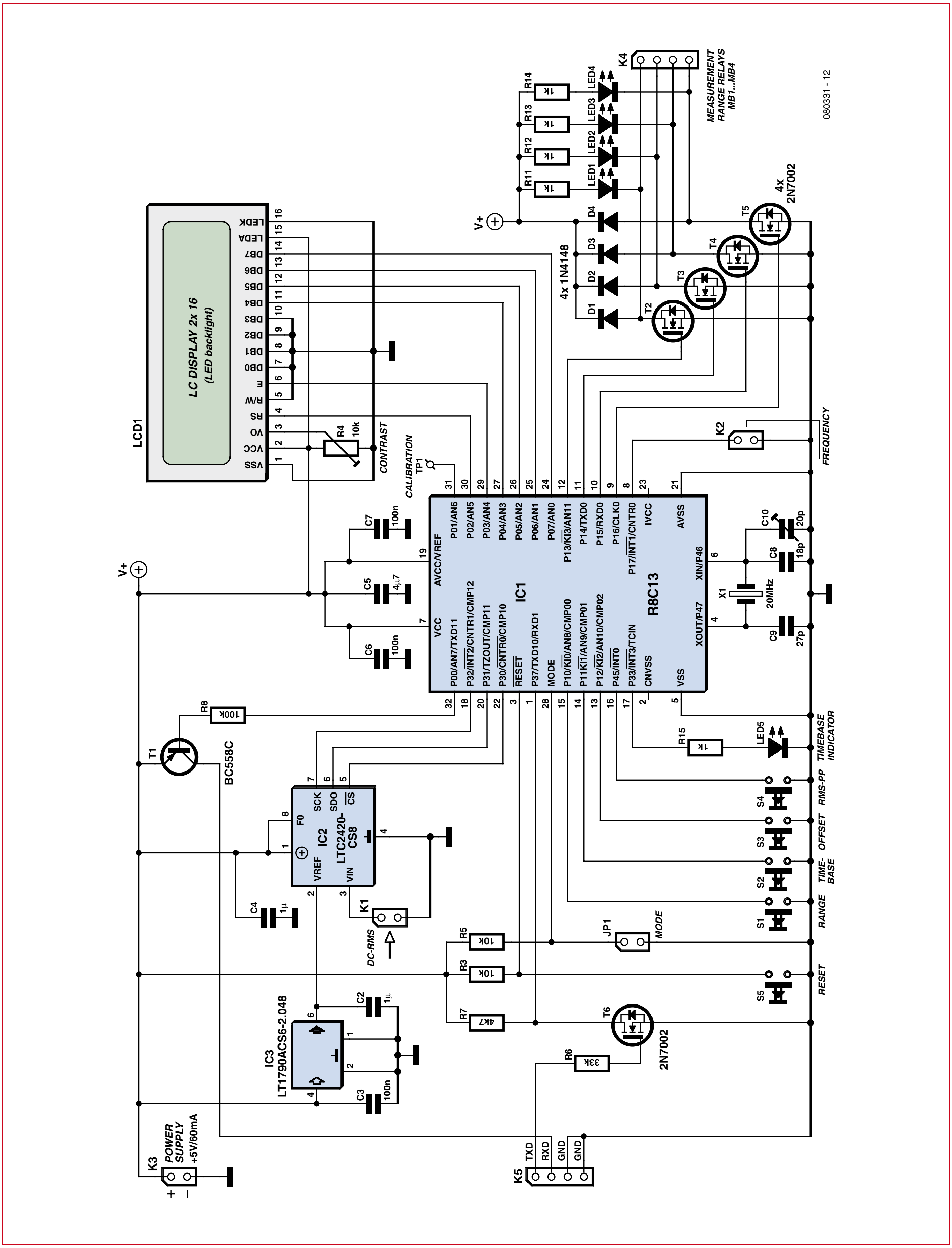


Figure 4. Circuit diagram of the display board with microcontroller, display, A/D converter IC2 and voltage reference IC3.

is applied is to load calibration and offset values from the microcontroller's flash memory; otherwise default values are loaded (and the display shows "LOAD DEFAULTS"). The microcontroller then goes into an idle mode. TimerX is configured in event counter mode and counts the pulses on the CNTR0 input. An interrupt is triggered when the counter overflows. The interrupt routine that gets called then increments a counter variable. When the TimerZ interrupt is triggered (this depends on the timebase setting, and can be every 100 ms or every 1 s) the frequency and voltage values are calculated and output.

Calculation of the frequency takes into account the values of the counter variable, TimerX, and the TimerX prescaler. The voltage is determined by reading the A/D converter via the SPI port. Twelve of the possible twenty bits of the A/D converter resolution are enough for the calculation, which automatically takes into account the gain of the amplifier and the measurement range.

Because of the lag in the RMS-to-DC converter, automatically finding the optimal measurement range takes a few seconds, during which the display shows "Busy". If an overrange occurs, the module will automatically switch to the next higher range for safety reasons, and the display will show "Overflow". This automatic switch happens also in manual mode, although the unit will remain in manual mode after the range change.

The finishing touches

We shall discuss setting up the amplifier and the display board separately. Programming the microcontroller for the display board is described briefly in the "Programming" inset.
Calibrating the amplifier is a somewhat more involved task (see inset). An oscilloscope, a digital voltmeter (ideally one that can make true RMS readings) and a sinewave generator are required.

First make a simple check that the RMS-to-DC converter and the comparator are working correctly. Then connect the two modules together as shown in **Figure 6**. With the input short-circuited, pressing S3 will store the currently displayed value as the calibrated offset voltage (and the display will show "OFFSET SAVED", followed by "0.0 mV").

Now apply a sinewave with an RMS value of 100 mV to the input. Connect test point TP1 to ground and the voltage readings for the lowest measurement range will be calibrated (with display "CALIBRATION OK"). The frequency of the sinewave signal should be chosen to obtain best accuracy from the voltmeter being used for comparison.

Calibration is now complete, and the unit can be put into service.

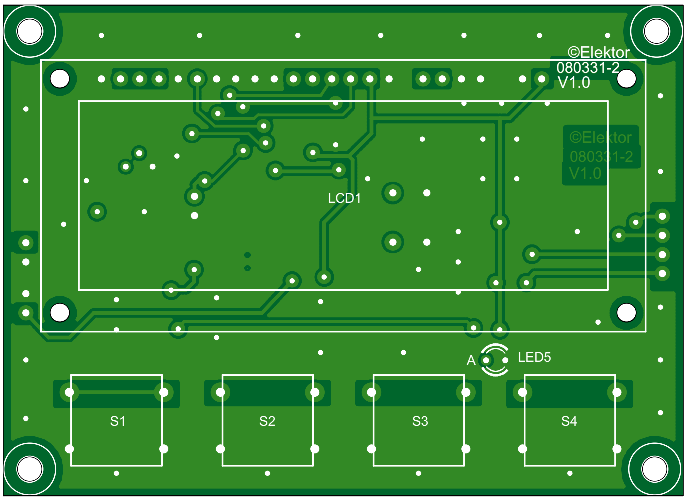


Figure 5. Printed circuit board for the display.

COMPONENT LIST
Display board

Resistors
R3,R5 = 10kΩ (SMD 0603)
R4 = 10k
R6 = 33k (SMD 0603)
R7 = 4kΩ7 (SMD 0603)
R8 = 100kΩ (SMD 0603)
R11,R12,R13,R14 = 1kΩ (SMD 0805)
R15 = 1kΩ (SMD 0603)

Capacitors
C2,C4 = 1µF 10V (SMD 0603)
C3,C6,C7 = 100nF (SMD 0603)
C5 = 4µF7 10V (SMD 0603)
C8 = 18pF (SMD 0603)
C9 = 27pF (SMD 0603)
C10= 20pF trimmer (C-TRIMMCTZ3)

Semiconductors
IC1 = R8C13 (R5F21134FP, LQFP32)
IC2 = LTC2420CS8 (SO-8)
IC3 = LT1790ACS6-2.048 (SOT23-6)
D1..D4 = 1N4148 (SOD-323)
T1 = BC558C (SOT-23)
T2–T6 = 2N7002 (SOT-23)
LED1–LED4 = LED, green (SMD 1206)
LED5 = LED, 3mm

Miscellaneous
LCD1 = LCD 2×16
JP1 = 2-way pinheader and jumper
K1,K2,K3 = 2-way pinheader
K4,K5 = 4-way pinheader
X1 = 20MHz quartz crystal, HC-49US12SMD
S1-S4 = pushbutton (Schurter # 1241.1614)
S5 = pushbutton (6mm)
PCB # 080331-2, see www.elektor-usa.com/shop

Programming

1. Connect the RS-232 interface to a PC.
2. Fit mode jumper JP1.
3. Briefly press the reset button once: this activates the microcontroller's boot loader.
4. Load the program "FreqCounter.mot" [11] into the microcontroller using the Renesas Flash Development Toolkit in "Basic" mode.
5. Remove the mode jumper.
6. Briefly press the reset button. The program will then start up using default parameter values.

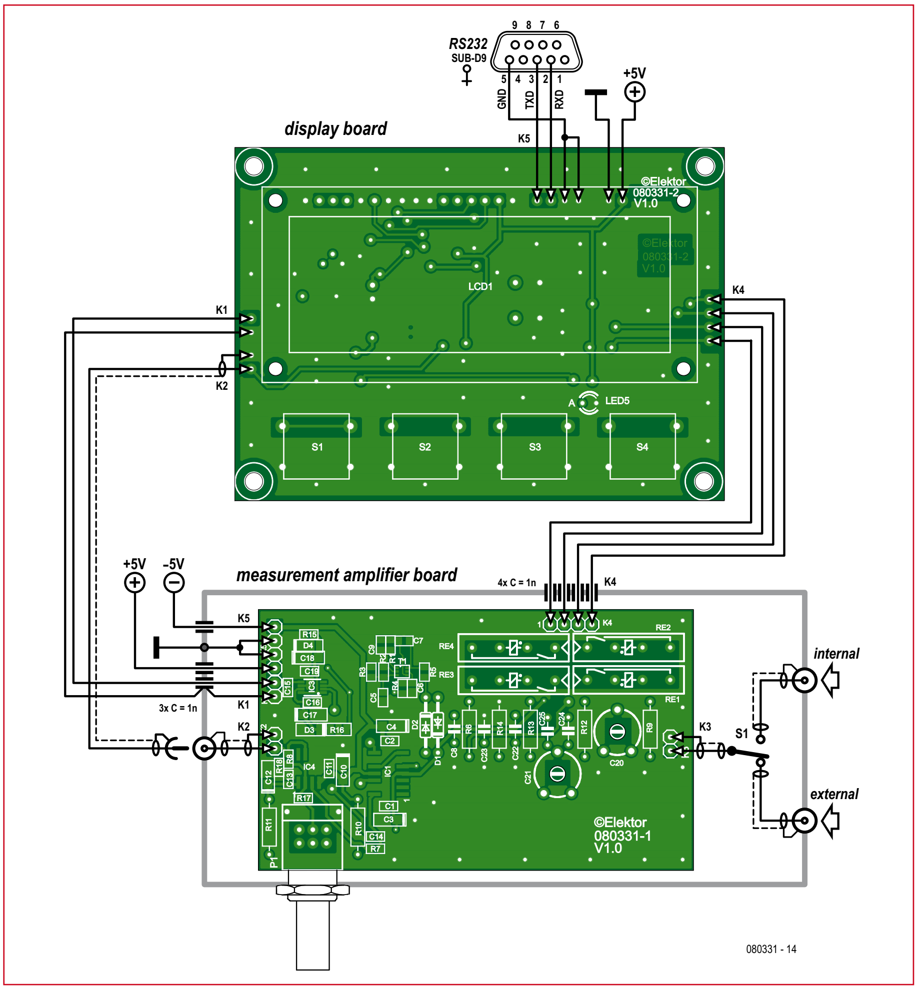


Figure 6. Overall wiring diagram.

Other possibilities

The module can be constructed in the form of a stand-alone voltmeter, or it can be built into a function generator. In the latter case, the synchronisation output of the generator can be connected directly to the microcontroller instead of going via the input amplifier circuit. The measured frequency can be used to access a stored table to enable correction for the frequency response of the instrument.

Another possibility would be to arrange for the software to output readings over the RS-232 port for further processing.

The microcontroller has 16 KB of program memory, of which around 5 KB is used. This gives plenty of room to implement new features. Readers are welcome to contact the author [12] or Elektor with their ideas.

(080331-I)

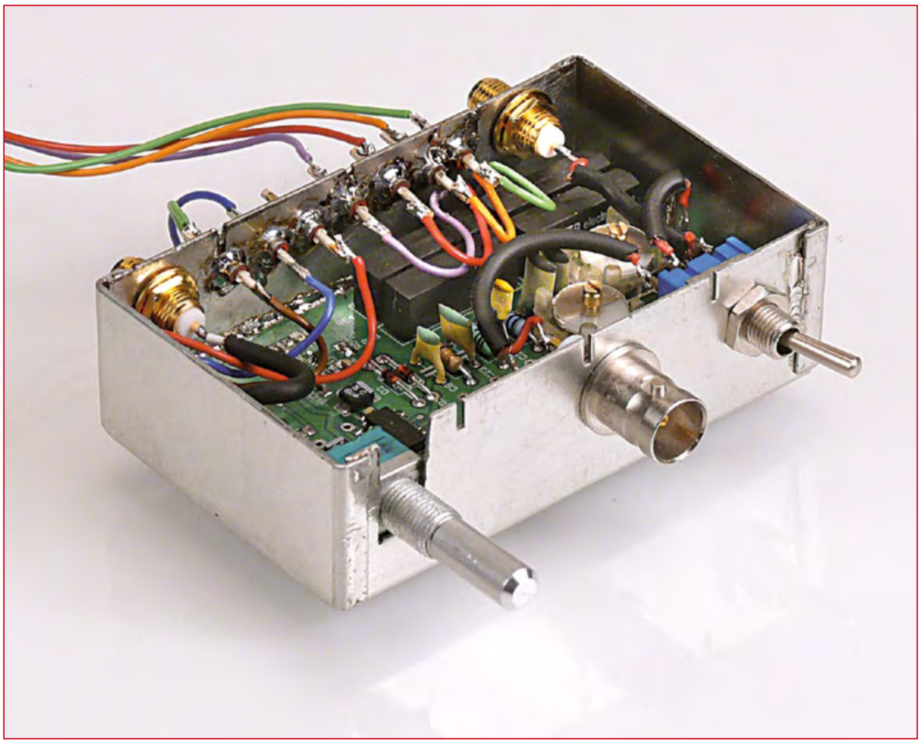


Figure 7. The measurement amplifier should be built into a metal enclosdure.

Internet links

[1] http://www.elektor-usa.com/070954-I

[2] http://en.wikipedia.org/wiki/Root_mean_square

[3] http://tietze-schenk.com/tsbook.htm

[4] http://www.analog.com/en/audiovideo-products/video-ampsbuffersfilters/ada4862-3/products/product.html

[5] http://www.linear.com/pc/productDetail.jsp?navId=H0,C1,C1154,C1086,P7526

[6] http://www.linear.com/pc/downloadDocument.do?navId=H0,C1,C1154,C1086,P1701,D24931

[7] http://www.linear.com/pc/productDetail.jsp?navId=H0,C1,C1154,C1004,C1012,P1225

[8] http://www.elektor-usa.com/050179-2

[9] http://www.elektor-usa.com/050179-3

[10] http://www.linear.com/pc/productDetail.jsp?navIdhttp://www.elektor-usa.com/080331=H0,C1,C1155,C1001,C1152,P1823

[11] http://www.elektor-usa.com/080331

[12] kairiedel@yahoo.de

Automatic Running-in Bench

for internal combustion engines

Part 3: application software

Michel Kuenemann (France)

Our series of three articles on the running-in bench for model i/c engines begun in April concludes this month with a presentation of the automatic running-in software.

In order to take full advantage of the software (*CBRMrunning-in.hex*, [1]) described here, you'll need the following equipment:

- A built and tested CBRM board and a GMMI pocket terminal (described in the April 2009 issue of Elektor [2]);
- A test bench fitted with all its detectors and actuators, as described in the May 2009 issue of Elektor [3]. You will already have carefully checked that the bench works properly, using the *CBRMtest_sensors.hex* [3] software and an engine that's already been run in;
- A model i/c engine that's already been run in, fitted with a suitable twin-bladed propeller;
- An engine to be run in with its twin-bladed prop;

● Some fuel, and a means of starting the engine.

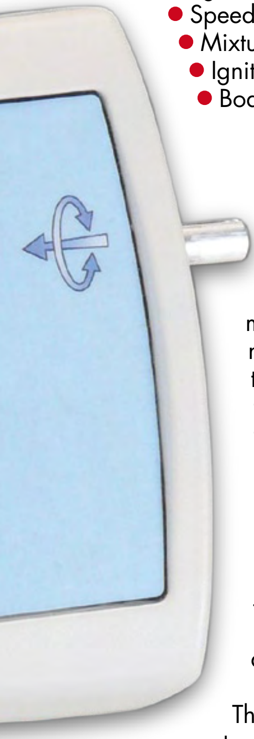
If you have a laptop PC running Windows 2000/XP/Vista, you can if you wish install the *CBRMmonitor* [1] software on it and connect it to the bench via a USB link. As its name indicates, this software will let you monitor all the bench parameters on your computer screen in real time as they change during the running-in process.

Moving on to the nitty-gritty…

Rather than systematically describing all the menus in the application, without more ado we're going to go through a try-out operation – preferably using an already run-in engine.

Flash the *CBRMrunning-in.hex* software as per the procedure given in the April 2009 article, and check that the application runs; the pocket terminal should give three short beeps and the screen should display the welcome message (**Figure 1**). This display soon changes to the manual mode screen (**Figure 2**), which summarizes seven vital parameters of engine operation:

- Throttle (abbreviated to Thr.);
- Engine (Tmp.) and ambient (Amb.) temperatures;
- Speed (Rpm.);
- Mixture richness ("Ned." for needle);
- Ignition battery condition and voltage (Ign.);
- Board supply voltage (Sup.)



Richness setting

The asterisk in the first column on the third line indicates that richness adjustment is enabled. Temporarily loosen the mechanical coupling between the stepper motor and the richness screw. Screw the richness screw all the way in lightly by hand, then retighten the coupling appropriately so that the link shaft cannot slip. If you now turn the encoder knob counterclockwise ("unscrewing"), you'll see that the stepper motor slowly and carefully opens the richness screw in response. Choose a rich setting, i.e. open by around two or three turns (this is only by way of an indication – the exact value depends on your particular installation and engine). The display will appear as in **Figure 3**.

The leftmost number on the "richness" line indicates your set value. In the center of the line, an animated propeller turns when the engine is running. Check that the richness needle closes fully when you go back to zero turns. The mechanical coupling should be able to rotate freely, so the motor won't miss any steps. If it does, the needle opening indication will be incorrect!

The richness screw setting is retained as long as the board has not been re-booted using the reset or emergency stop button or powered down.

Starting the engine

Now press the button next to the first line. An asterisk appears in the first position on the first line, indicating

Figure 1. The bench's welcome screen.

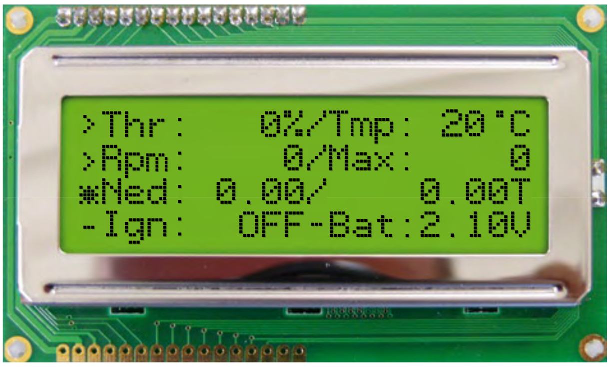


Figure 2. The manual mode screen.

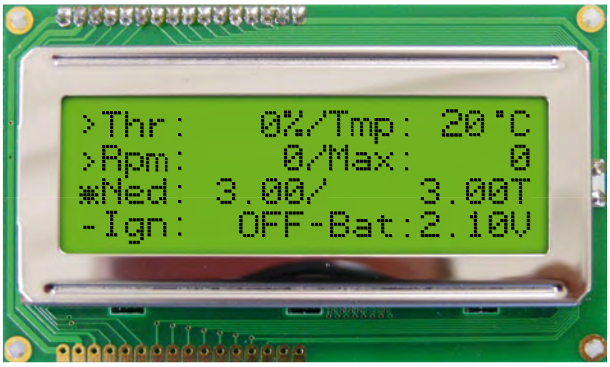


Figure 3. The asterisk indicates the parameter whose value can be adjusted with the encoder knob.

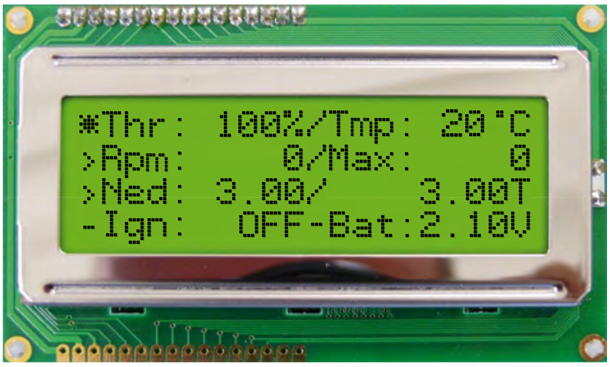


Figure 4. Full throttle!

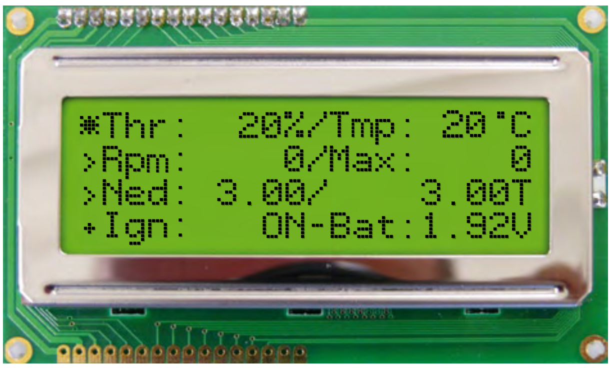


Figure 5. Ignition is on. Watch out for your fingers!

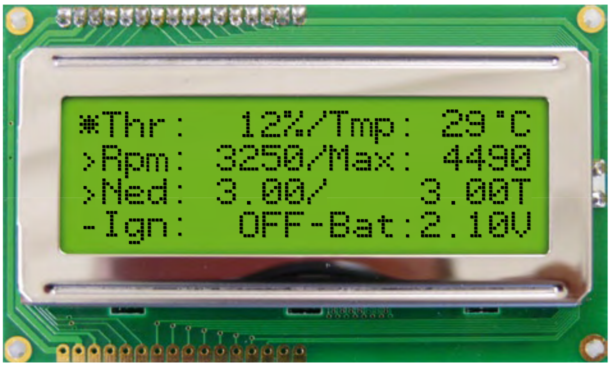


Figure 6. The engine is running and the ignition can be turned off.

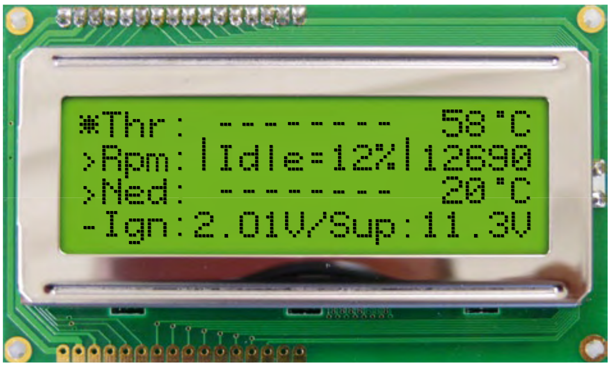


Figure 7. Press the encoder knob to store the servo position in idle.

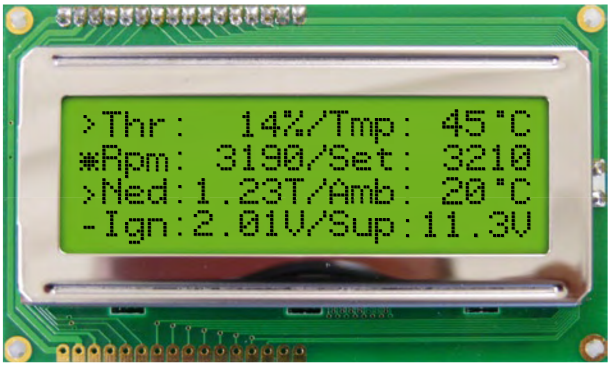


Figure 8. This screen lets you set the engine speed.

Figure 9. The CBRMmonitor software for PC shows the key engine parameters live as they change.

that the throttle control is enabled. To check this, turn the encoder knob counterclockwise. The servo should turn in the direction to increase the throttle – if this is not the case, you'll need to alter the bench parameters. Set it to 100%: full throttle! (**Figure 4**).

Important safety note: if the throttle control is not working satisfactorily, check and adjust the throttle control setting ("Parameters" menu – see below) before continuing.

Now prime your engine as usual, then reduce the throttle to around 10 to 20%. Turn the propeller a few more turns to finish priming the engine, then briefly press the button next to the fourth line (**Figure 5**).
The "+" sign at the start of the fourth line indicates that the glow plug is enabled. You should also clearly hear the beeping from the pocket terminal sounder. This indicates that the ignition is enabled and that the engine is ready to start at the next attempt. **From now on, keep your fingers well away from the propeller!**

Start the engine, then adjust the idling speed using the throttle control. Turn off the power to the glow-plug by pressing the button on the fourth line again. The sounder will stop and the display will appear as in **Figure 6**.

Now increase the throttle to 100%. Since the mixture was set to "rich", the engine will not reach its maximum speed, the peak. To adjust this, press the button on the third line and gradually close the richness screw by turning the encoder knob slowly clockwise until peak speed is reached, just as you would do if operating the mixture needle manually. Take care not to weaken the mixture too much. As the setting resolution is 1/100 of a turn, this setting can be made very accurately. Then go back to idling by pressing the first line button and turning the encoder knob clockwise.

When you are satisfied with the idling speed, you can store the corresponding servo setting (Idle) by briefly pressing the encoder knob (**Figure 7**). When you do this, a pop-up window will appear for one second, confirming that this value has been saved in non-volatile memory.

Speed setting…

… comes into operation when you press the button on the second line (**Figure 8**).
By turning the encoder knob, you can alter the engine speed set point (Set). You'll see that the engine speed will automatically adjust to this value and remain there. To avoid abrupt changes in speed, the set point automatically adopts the engine speeding setting at the time when the adjustment is enabled. In the same way, when returning to manual throttle control the servo maintains the same position as when the controller exits the "speed control" mode.
If you have a (portable) PC, you can now connect it to the bench, run the CBRMmonitor software, and see the parameters on the screen as they change (**Figure 9**).

In the event of a problem with the bench, don't panic! Quickly hit the emergency stop button to stop the engine at once.

The functions provided by the manual mode let you run in an engine in a "controlled" way. The speed adjustment lets you ensure that the engine runs fast enough to run it in properly, while avoiding any risk of damaging it with excessive speeds. The "automatic running-in" mode lets you control the process even better, but before we get to that, we need to go back to the main menu and enter a few safety limits and other parameters.

The main menu…

…is displayed by a pressing the button on the first line twice (**Figure 10**). Press the button on the fourth line to modify the safety limits.

The safety limits…

… define three parameters that are vital for the safety of the bench in operation. These are:

- Maximum permitted engine speed;
- Maximum permitted engine temperature;
- Minimum board supply voltage (to protect your batteries from deep discharge).

The values for these parameters can be modified in the screen shown in **Figure 11**.

Select the parameter to be modified by pressing the corresponding button. Confirm the entered data by pressing the encoder knob. The parameter is then saved in non-volatile memory and will not need to be entered again next time the bench is turned on. Now go back to the main menu by pressing the first button twice, then select the "Parameters" menu.

The parameters…

…that can be adjusted are:

- Servo travel;
- Number of propeller blades (Pro.);
- DSC (Direct Servo Control) throttle channel.

The values for these parameters can be modified in the screen shown in **Figure 12**.
The key servo travel adjustment is done in three steps:

1. Press the second line button twice to position the cursor in the neutral position (marked "N" on the third line), then adjust the throttle servo mechanism so that the rod is perpendicular to the throttle lever. If necessary, adjust the value slightly using the encoder knob, then confirm the entered data.

2. Put the cursor into the "throttle closed" position (marked "Closed"), then adjust the throttle control linkage so that the throttle flap is closed when it is set to the –100% position. If the servo moves in the wrong direction, turn the encoder knob until a value of +100% is displayed. Save the entered data.

3. Set the servo to the "full throttle" position (marked "Full") and check that the throttle flap is fully open. If the servo moves the wrong way, turn the encoder knob until a value of –100% is displayed. Save the entered data.

These adjustments have to be made each time the engine is changed or if there is any modification to the servo installation.
Before proceeding, go back to Manual mode (via the main menu of Figure 10) and check that turning the encoder knob

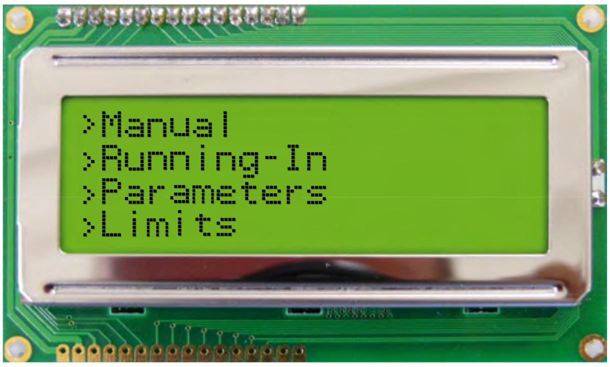


Figure 10.
The main menu.

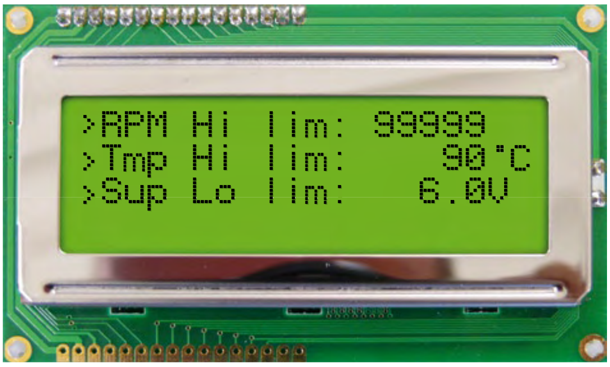


Figure 11.
Don't forget to enter the limits for these three parameters, which are vital for safe operation of the run-in bench.

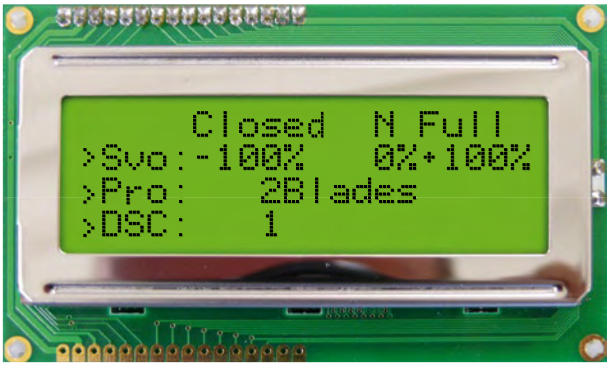


Figure 12.
The adjustments to be made each time the engine is changed or if there is any modification to the servo installation.

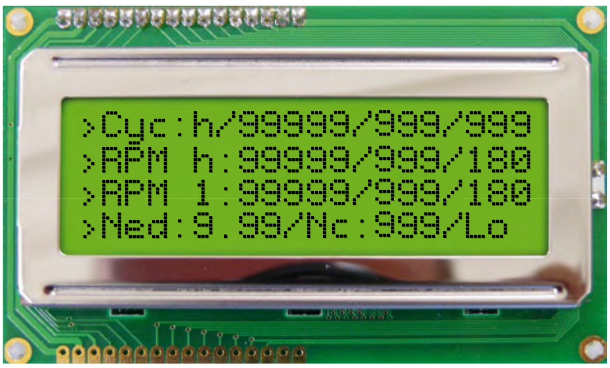


Figure 13.
On this screen, you can define just how automatic running-in is performed.

counterclockwise ("unscrewing") increases the throttle setting. Check too that the throttle flap moves over its full range of travel from 0% to 100%. Tweak the setting until you get the proper travel for the servo.

Important safety note: it is absolutely vital that the throttle adjustment operates in the correct sense. If not, going into "speed control" mode will make the engine race! What's more, pressing the emergency stop will not stop it – quite the reverse, the engine will be set to full throttle!

It's also very important to enter the number of propeller blades correctly, as this factor is used for measuring the speed. Confirm and save the value by pressing the encoder knob.

Lastly, the DSC parameter allows you to define the channel number associated with the throttle control. Once the parameter has been entered and saved, go back to manual mode, connect your transmitter to the DSC socket, and check that the throttle control drives the servo correctly. The servo also has to be adjusted in the transmitter (direction and travel).

Now go back to the main menu and select "Automatic Running-In" mode.

Automatic running-in…

…consists of carrying out successive acceleration/deceleration cycles with a fuel-rich mixture. Running-in occurs during the high-speed phase, but the engine temperature can have a tendency to rise dangerously. It is therefore necessary to lower the speed every now and then to allows the engine to cool down. This cycle has to be repeated several times, while gradually increasing the length of the high-speed interval and reducing the richness of the mixture. All of these parameters depend on the type of engine, the manufacturer's recommendations, and your own habits.

The second line of the automatic mode parameters (**Figure 13**) lets you define the high-speed settings. The first parameter on this line is the speed for this phase, and the second parameter is its duration in seconds. At the end of the line, you'll find the maximum temperature reached during the current cycle. The third line lets you define the low-speed settings. The first parameter on this line is the speed for this phase, and the second parameter is its duration in seconds. At the end of the line, the software indicates the minimum temperature reached during the current cycle. Move between the different fields on the line using the relevant button, and store the parameters using the encoder knob. The fourth line lets you adjust the richness, specify the number of cycles to be performed, and choose the way the bench behaves at the end of the cycle. If you select the number of cycles as zero, the bench won't stop of its own accord. At the end of the cycle, you can choose between stopping the engine (St.), running it at idling speed (Id.), or leaving it running at low speed (Lo.) Lastly, the first line indicates, from left to right, the current phase ("h" or "l"), the current engine speed, the number of seconds left in this phase, and the number of cycles remaining to be performed.

By way of conclusion…

Now you are the proud owner of an original, comprehensive automatic running-in bench. We hope you have a lot of fun using it safely!

(090250-I)

References and web links

[1] www.elektor-usa.com/090250

[2] www.elektor-usa.com/080253, Elektor April 2009

[3] www.elektor-usa.com/081187, Elektor May 2009

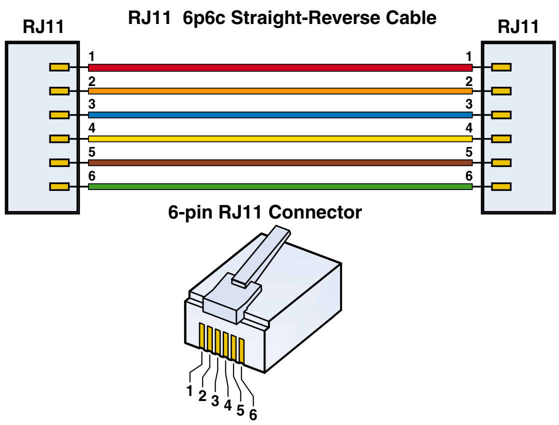
[4] breakinbench.free.fr

[5] author's e-mail address: breakinbench@free.fr

Corrections

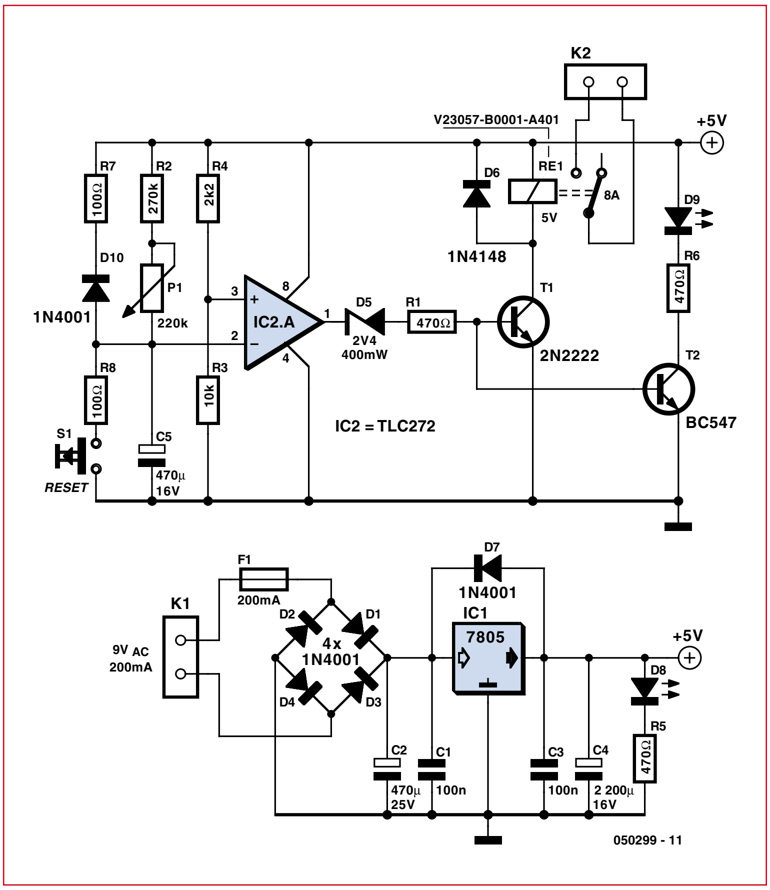
The first part of this series was published two months ago [2], and since then we have found a few small points that deserve special attention:

- The speed detection circuit uses a stabistor diode (D4), which is like a Zener diode but for voltages under 3 V. Unlike the Zener diode marked on the 080253-1 PCB, a stabistor diode is mounted like an ordinary diode. This means that D4 must be fitted "backwards", with its cathode to ground. The 080253-71 kit contains the stabistor diode, so take care!
- If you can't obtain the stabistor diode for D4, you can replace it with a 3-mm red LED. Fit the LED with its cathode to ground; it should light up when the board is powered.
- The speed detector may be lacking in sensitivity. If this is the case, you can increase the value of R40 up to 22 kΩ.
- There are some minor typos in the pocket terminal components list and circuit: T1 should be a ZXM61P02F.
- The value of D10 in Figure 3 (April 2009, page 45) should be 3V3 instead of 5V6. The component list gives the correct value.
- At the start of the paragraph "Testing the pocket terminal" (April 2009, page 49) you are told to fit jumper JP8. This is wrong; it is JP6 that has to be fitted, as otherwise the pocket terminal won't be powered.
- If you've taken a close look at the circuit, you will have already realized that a straight-through (non-crossed) cable must be used to connect the pocket terminal to the controller board, as shown in the figure below:



Electrical Protection
for Well and Tank Pumps

Michaël Gaudin



The function of this pump protection, as its name suggests, is to stop a pump from operating continuously when a problem occurs, thereby preventing (expensive) damage. This protection for a well pump is installed on equipment composed of a water pump with switch control and the switch proper being controlled by a pressure sensor. Using the drop in pressure, the sensor signals when the water tank is empty.

The principle of operation is based on the fact that a water tank with a capacity of 45 gallons must be filled in less than 5 minutes, even if a shower or a bath is already running. Consequently, if the tank is not full within this 5-minute interval, there is a fault somewhere as far as the water supply is concerned (the well is dry, leak at the tank level, problem in the water output pipes, leak anywhere in the pipe system).

The entire circuit actually creates a sort of timer responsible for closing a contact for 5 critical minutes and then opening it.

We propose to use a mains adaptor supplying 9 VAC at a minimum of 200 mA, and connet its output to the terminal b block K1.

When the system is powered, the contact in relay Re1 automatically closes (thus applying power to the contactor coil of the pump motor which closes the secondary contact of the pump by excitation and then begins functioning).

After a certain period *t*, according to the formula

$t = 2 \times C5 \times (P1+R2)$,

the Re1 contact is no longer open; the pump motor stops being powered and turns off.

Depending on the tolerance of the components used, this period may vary from 4 to just over 8 minutes. If this period seems too short to you, you may make it longer by increasing the value of R2, P1 or C5.

The presence of the power line voltage is visualized by green LED D8 coming on. Closing of the well contact K2 is visualized by a yellow-colored LED, D9.

The Reset pushbutton is used to force pump operation by causing capacitor C5 to discharge.

When the power supply is cut off (sensor no longer controlling), C5 is rapidly discharged through resistor R7 whose value is only 100 Ω.

The operation depends on the comparator. When the power supply is on, we have a voltage level of +5 V at the output of regulator IC1. The + input (pin 3) is at +4 V, the – input (pin 2) is at 0V. In these conditions, the output of the comparator goes to +5 V, causing transistor T1 to start conducting. This, in turn, causes both relay Re1 and the pump power supply to make contact, as explained above.

When V+ is above V–, the output (pin 1 of IC2) is at 5 V, transistor T1 is saturated, relay Re1 is in an open position, transistor T2 is also saturated, and the yellow LED is lit.

When V– is above V+, the IC2 output is at 0 V, transistors T1 and T2 are blocked, relay Re1 is idle, the yellow LED is out, and contact K2 is open.

When capacitor C5 is charged (–input is at 5 V, +input at 4 V, output of IC2 comparator is therefore at 0), transistor T1 is blocked (the pump is no longer being powered, LED D9 goes out, the pump is stopped).

The role of the zener diode D5 is to avoid any instability while the system is establishing its +5 V power supply voltage. This has the effect of a small 'firing delay'.

What to do in case of problems?

If the green LED is out (no power supply voltage), verify that you have 9 V_{eff} on K1, and 5 VDC at the output of regulator IC1. If that is the case, there are a few other options: the polarity of the green LED is wrong, or either the LED or resistor R5 is defective.

You should obtain about 4 V on pin 3 of IC2, the voltage on pin 2 of the TLC272 varies between 0 and 5 V.

(050299-1)

Profiler Pro

New processor board, increased software capabilities and mechanical upgrades

Harry Baggen (Elektor Netherlands Editorial) and Frank Jacops (Colinbus, Belgium)

3D workpieces, G-code, milling printed circuit boards: thanks to a new controller board with a powerful ARM processor and a new, robust Z axis with a floating head, you can upgrade your existing Profiler milling machine to the "Pro" version. The software has also been upgraded to take advantage of this and has many improvements and new features.

About two and a half years ago, when Elektor and Belgium-based manufacturer Colinbus thought of putting together a simple, handy and (importantly) affordable milling machine for use in the home workshop, none of the company representatives involved in the discussions had any idea about the runaway success their joint project was to become. The Elektor/Colinbus Profiler turned out to be a hit, and an enormous number of kit sets for this machine were sold. Very quickly an active community formed whose members would analyze the machine down to the tiniest of details. Equally quickly there were modifications and suggestions for improvements. The users and the manufacturer actively continued to explore all possibilities of further improving the Profiler.

The designers at Colinbus have spent a considerable amount of time improving and advancing the development of the Profiler, and the developments have now reached a point that allows us to publish the various new features. In particular the combination of all these new features (a new processor board, modified software and several mechanical upgrades) results in a revolutionary improvement.
Not every user will have a need for these improvements. It depends entirely on what you expect from your Profiler and the types of jobs you want to have it perform. If you only want to mill 2D shapes from relatively lightweight materials and don't have any special demands, the existing machine will work very well for you. For these users, the existing Profiler already caters to the most complex shapes, much faster and more accurately than before.

But other users demand more and often have been actively exploring various solutions and possibilities for themselves. We listened carefully to all these wishes, and Colinbus has attempted to steer further development accordingly. By offering the parts described here we hope to have met the most important requests. With these changes the Profiler becomes a more professional machine with many new capabilities.

What's new?

As already mentioned, there are quite a few new developments. The most important ones are introduced in this article.

- Requested by many and now available: the **new 3D controller**! A new processor board has been developed, fitted with a state-of-the-art 32-bit RISC processor. Just like the original controller PCB, it has all logic on board. This new board can simply be fitted on the driver board, in place of the original board.

- **ColiDrive**, the Colinbus control software, has been expanded with quite a few new options. The program can now import G-code and is more user-friendly and more powerful in combination with the new controller.
- A new **Z axis** is available. It's more stable and easier to mount and calibrate.
- And the most important new option: a **floating head**, an accessory that is indispensable for high-quality engraving work.
- With the new Z axis and floating head now available, an **engraving head** for the Profiler is now also offered.

New 3D controller

Ex factory the Profiler is fitted with a 2.5D controller. This somewhat older controller is used in thousands of machines and works well. With a little effort it can also be used for milling 3D objects, but when doing this you will have to take into account that the computing power of the controller is only enough to control two axes at a time. When creating 3D workpieces you actually need a real (more powerful) 3D controller. The end result will be much nicer and the time it takes to complete a milling job will be much shorter. The FPGA- and DSP-based controllers used by Colinbus in their bigger machines are too expensive and not suitable for the Profiler. They thus decided to build a new, inexpensive, but nevertheless powerful CNC controller board. It is now available and will be included in a special version of the Profiler.

The new controller board is built around an ARM7 32-bit RISC processor, which because it uses pipeline technology is eminently suitable for use as a CNC controller. There is not enough space is this article to elaborate on this, but if you are interested you can consult the datasheet from NXP for more details (www.nxp.com/acrobat_download/datasheets/LPC2212_2214_4.pdf).

Even with a state-of-the-art processor, all the cleverness is of course in the embedded software, which represents four years of development effort. 3D circular and collinear interpolation, adjustable exponential acceleration curves, and adaptive corner speeds are only a few of the many new features that make the new controller board so fast and attractive.

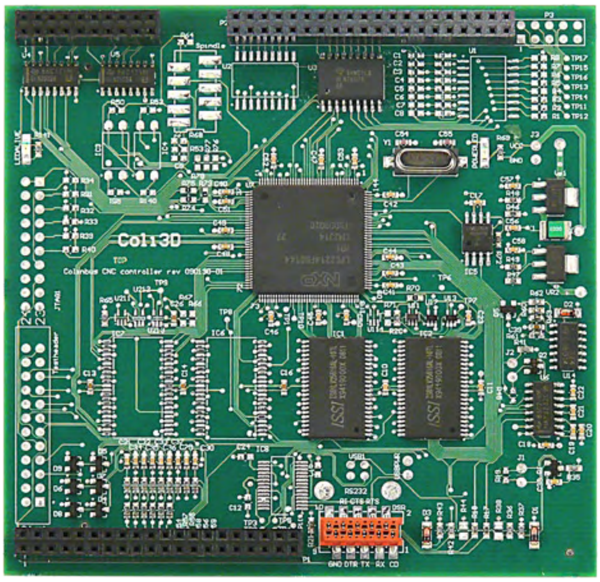


Figure 1. The new PB3D controller board uses an ARM7 processor made by NXP.

What makes the new PB3D controller unique is its price. This is because it works in ways you will only encounter in systems that are considerably more expensive. All other controllers in this price range make the attached PC carry out the necessary calculations. Such a PC has much more computing power than an embedded controller, and simultaneous interpolation of multiple axes requires a significant amount of computing power. Writing the software for a PC is therefore much simpler and cheaper. But as is often the case, the easiest solution is not always the best, and there are a few disadvantages with this approach. The most important disadvantage is the PC itself. Its operating system (typically Windows) is never completely dedicated to the CNC machine, but instead carries out all sorts of other tasks in the meantime as well. This strongly reduces reliability. In addition, writing your own control software is practically impossible because the software is not open source and the producer does not want to reveal all the control details. The option of working in a Linux or Mac environment is usually not available or desired.

With the PB3D controller board, all the intelligence resides in the controller itself. The PB3D is actually a small computer capable of operating completely independently thanks to its powerful embedded software. If desired, users can write application software themselves – you only have to

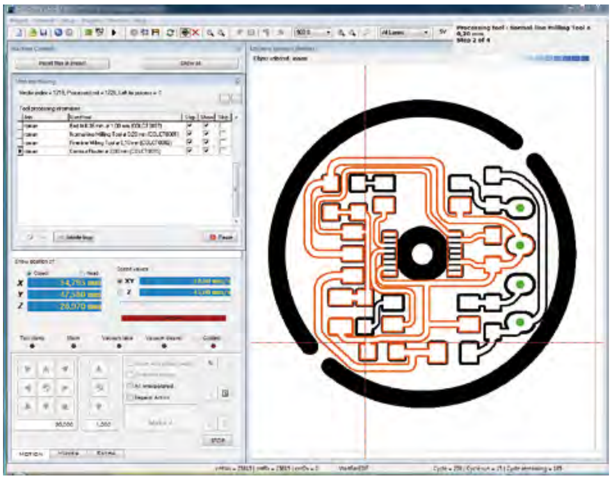


Figure 2. The new version of ColiDrive has quite a few changes and improvements to offer.

Figure 3. The new Z axis is more stable and much easier to adjust than its predecessor. In addition, it has a floating head. Here the IAC500 motor from Colinbus is mounted on the Z axis.

send the correct commands to the Profiler. On the Colinbus website you can find extensive documentation for this (www.colinbus.com/download.htm).

Because of the great computing power of the ARM controller, it is possible to work with much more complex routines, resulting in better dynamic performance from the machine. In combination with the Colinbus software, you have access to a number of additional powerful features. These features are only available with the new board. They are also related to the processor speed and the new processor technology. And finally – we nearly forgot to mention it – you can convert your existing Profiler into a real 3D machine simply by plugging in the PB3D controller board.

New version of ColiDrive

The latest version of ColiDrive is available to all Profiler users. We strongly recommend that you download this software because there are quite a few changes and improvements.
Note that there are now two versions: one for the original Profiler with the 2.5D controller called Robby, and one for the PB3D, the new 3D controller. The latter version has more features simply because the powerful 32-bit RISC processor fitted on the PB3D has more features.

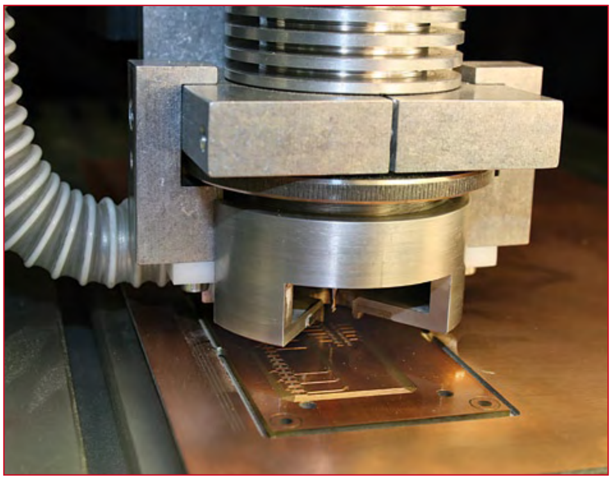


Figure 4. This engraving head follows the surface of the material accurately to ensure constant depth.

What follows is an overview of the new features, where we also indicate which functions are only available in the 3D version.

- Import: this is what many users were waiting for. The latest version of ColiDrive can import and process G-code directly (with automatic detection of positive and negative Z coordinates).
- Plug-in: milling or engraving of text in any size. This uses any of the True Type fonts that are available on the PC.
- Direct milling or engraving of circles and squares without the need to use a CAM package. The user can select a tool and indicate whether to mill inside, outside or on the line. The software calculates the offset.
- Support for a series of new drill functions:
  - drilling
  - counter boring
  - peck drilling
  - boring
- New improved tool library with tool life calculation.
- Calculation of the expected processing time and costing.
- Complete 3D support (*only with PB3D controller*).
- The progress of the operation can now be followed in real time on the screen (*only with PB3D controller*).
- Every milling depth has its own color (*only with PB3D controller*).
- Pause function: you can interrupt the machine at any time, perform some other action, and then resume (*only with PB3D controller*).
- Obstacle database: enables the user to mark an obstacle on the screen. The milling head will not go to that location. In this way you can protect objects. Obstacles can be stored and reused at any time (*only with PB3D controller*).
- ColiDrive now has Undo and Redo functions (5 levels deep).
- The Project Explorer keeps track of all data for a loaded file. This gives you a complete overview of all the operations that have been carried out on loaded files.
- New positioning options for jumping to a corner or the center of an object.
- Aligning different files above or next to each other has become much easier. Alignment can be done using different reference points such as bottom left, from file center point, and from calculated file center.
- Modern user interface with active icons. These appear only when required, which makes the software a lot more user friendly.
- Many time-saving features such as optimized down movement. This makes the head move downwards at full speed up to a preset distance above the workpiece and then change to the working speed. This function can reduce the processing time by up to 65%.
- Slow retract feed: this function allows you to have independent up and down speeds – very useful when drilling deep holes.
- Support for tool length measurement in a very simple manner (*only with PB3D controller*).
- In the event of a problem, Colinbus Support can, with your agreement, make log on to your machine. This avoids telephone calls and exchanging strings of e-mails (*only with PB3D controller*).

The above is a limited overview of the most significant changes. As you can see, it is certainly worth the effort to download the update. You will also receive an update of ColiLiner, which also includes a number of improvements.

New Z axis

Most buyers of the original Profiler kit had little trouble with the assembly of the machine. When there was trouble, it was almost always related to the Z axis. Adjusting the guide wheels was indeed not that simple. When a number of Profilers are set up next to one another – for example at a training session – you may notice that there is some play in the Z axis of some of the machines, and this naturally leads to poor milling results. While this can be solved with a small adjustment, it is not so easy to do because of the way the Z axis is constructed. The Z axis is actually the weakest part of the Profiler – it's more than adequate for light-duty milling, but unsuitable for heavier spindle motors.

This is why Colinbus has designed an entirely new Z axis for the Profiler, which is not only stronger but also more accurate than the first one. Assembly and mounting are a breeze, and the fact that this Z axis also has a floating function is the icing on the cake. All these improvements come at a price however: the new Z axis is more expensive than the previous one and is therefore mainly intended for Profiler users who need heavier milling capability or more accurate results.

Since many users use the Profiler for milling printed circuit boards and engraving front panels, a decision was made to provide this new Z axis with a floating head. If you need to do heavier milling work, you can lock this function.

A nice feature of this is that ColiDrive has a number of provisions to make optimum use of this engraving function. For example, it is no longer necessary for you to set the Z reference point ("zero") when milling printed circuit boards. ColiDrive saves all the parameters in a database, so milling identical materials (such as PCBs) is much easier.

Engraving head

For quality engraving work you need, in the first place, a head which will follow the surface of the material. You also need a mechanism that sets the milling depth. The engraving head now offered with the Profiler comes from the professional machines produced by Colinbus and is made especially for the milling of printed circuit boards. With this head the milling depth can be set very accurately. On the side there is a facility for attaching a vacuum cleaner. This is important because otherwise the head will slide over the top of the accumulated dust and the milling depth will no longer be correct. This milling head can currently only be used in combination with a high-frequency motor.

Figure 5. A few 3D workpieces made using a Profiler Pro machine.

If engraving text is the only thing you want to do, you can also make an engraving head yourself, because the professional engraving head is quite expensive. The only objective is to maintain a constant distance between the material and the tool. A few construction drawings for this are available on the Colinbus website. Certainly of interest is the file 'graveerhet.doc', which clearly explains the how and why of engraving (see www.colinbus.com/freehowto.htm).

Finally

By simply plugging another controller board into your Profiler, you will obtain an entirely different machine. The new PB3D controller makes the machine faster, increases the number of features, and enables you to make real 3D workpieces. The new and improved ColiDrive software is supplied free.

Users who want a more robust and more accurate Profiler can fit a new Z axis.
On the Elektor website you'll find a short video which shows the new configuration in operation: www.elektor-usa.com/profilerpro.
Elsewhere in this issue you will find more information on prices and ordering options for the upgrades described here.

(090163-I)

ElektorWheelie
Elektor's DIY self-balancing vehicle

Everyone agrees that 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, then add two microcontrollers, and the ElektorWheelie is ready to transport you in style to your destination.

The power train

Two sturdy 24 V DC electric motors power the ElektorWheelie up to a maximum speed of 12 km/h (7.5 mph). A combined power of up to 1 kW is delivered to the two axles via a reduction gearbox (ratio approximately 1:6). Two 16-inch pneumatic road wheels ensure good ride comfort and stability for both indoor and outdoor use.

Power source

Power for the personal transporter is supplied by two 12 V rechargeable lead-acid gel cells from CTM in China. Our prototype uses the 9 Ah version, but cells with 7 Ah capacity also give an acceptable range. The range depends on your driving style and the road gradient. With a full battery you can expect 1 to 1.5 hours of use before you need to recharge from a power outlet.

Full construction details of the ElektorWheelie will be included in the next two issues (Elektor July/August 2009 and September 2009). What we can say now is that Elektor will be offering this project as a kit that will have you up and running after just a few hours assembly time!

Control

This vehicle, which effectively has a single axle, can almost automatically maintain its balance. A 3-axis acceleration sensor from Analog Devices and a gyro from Invensense are the only sensors necessary to provide attitude information to the controller. An ATmega32 samples the sensor outputs approximately 100 times a second and continuously supplies commands to the motors to maintain the correct inclination of the ElektorWheelie.

It also reads signals from the control lever. Control is quite intuitive; a light forward pressure sets the ElektorWheelie gliding ahead, while pulling back moves it backwards. Left or right pressure changes the direction of travel correspondingly. If you don't mind wasting a bit of energy, rotating on the spot is also no problem!

Software

Calculation of the vehicle's attitude and motor control are managed by an ATmega32, while the drive motor supply current is monitored by an ATtiny25 microcontroller. Both are programmed in BASCOM. Despite the software sophistication, the program size ensures that its complexity is quite manageable: altogether there are just 800 lines of code.

Construction

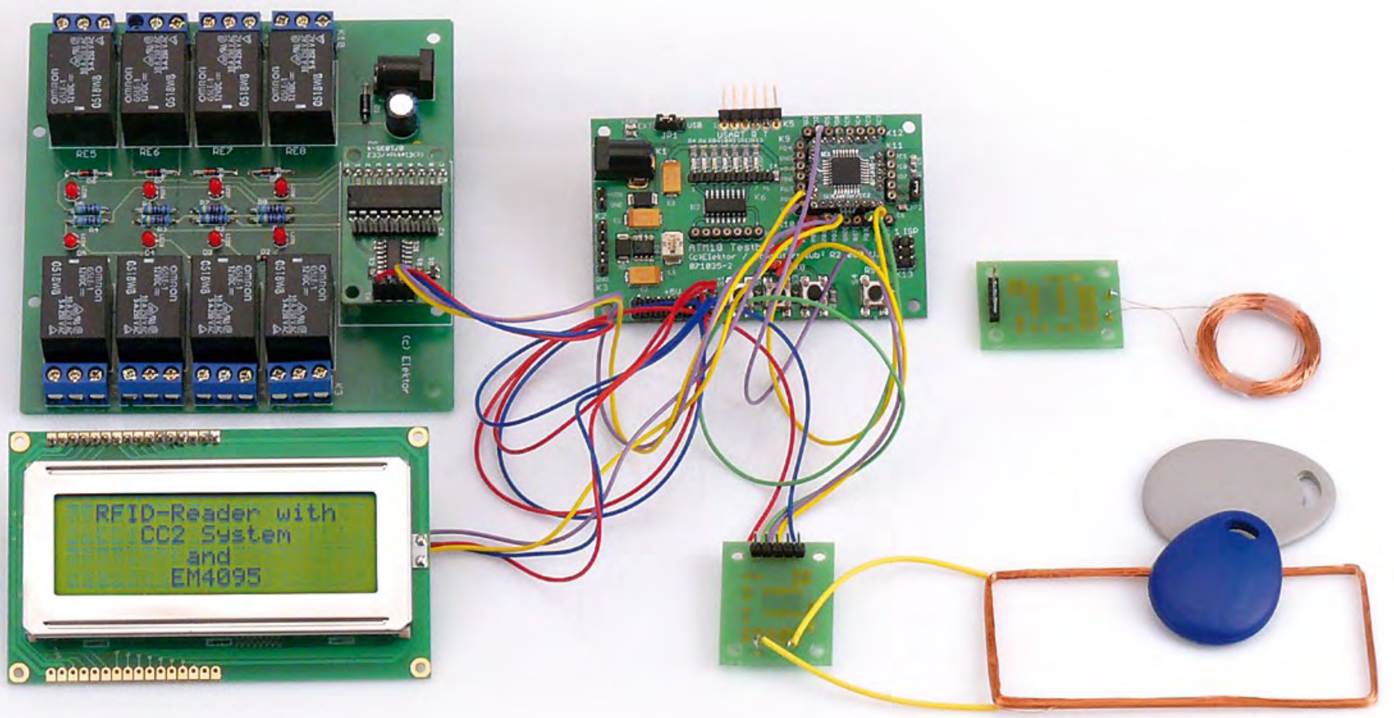
The driver stands on a rigid metal chassis which houses the rechargeable cells and compact control electronics in a protective metal casing. Safety has not been overlooked; in the event of a fall an emergency switch disconnects the motors from the batteries.

ATM18 = RFID Savvy

EM4095, ATmega and Bascom

Wolfgang Rudolph and Gerhard Günzel (Germany)

RFID appears to be well on its way to becoming a technology of the future. Many people mistrust this technology, while some see it as the answer to every problem. One thing is certain: these tiny devices will be everywhere around us in the future, whether or not we notice them. Our ATM18 board provides the ideal basis for experimenting with RFID devices and implementing your own ideas.



One of the potential applications of the Bascom program for this project is using RFID to control a door opener. Naturally, you can also use the relay card to connect the board to many other types of equipment and switch a specific function on or off, with the process being triggered by an RFID device. But first let's take a brief look at the theory.

RFID operating principle

Let's start by considering a power transformer. If you connect the primary to the AC line and the secondary to a load, a current flows in the primary winding as well as the secondary winding. After all, how else could a current flow in the secondary? If you now remove the iron core but leave the two windings as they were, they are still coupled by the magnetic field and the same effect still occurs – although the secondary cannot supply as much power with this arrangement. If you connect an ammeter in the primary circuit, you can clearly see that the primary current changes when the load on the secondary winding is connected or disconnected. Even if the two wind-

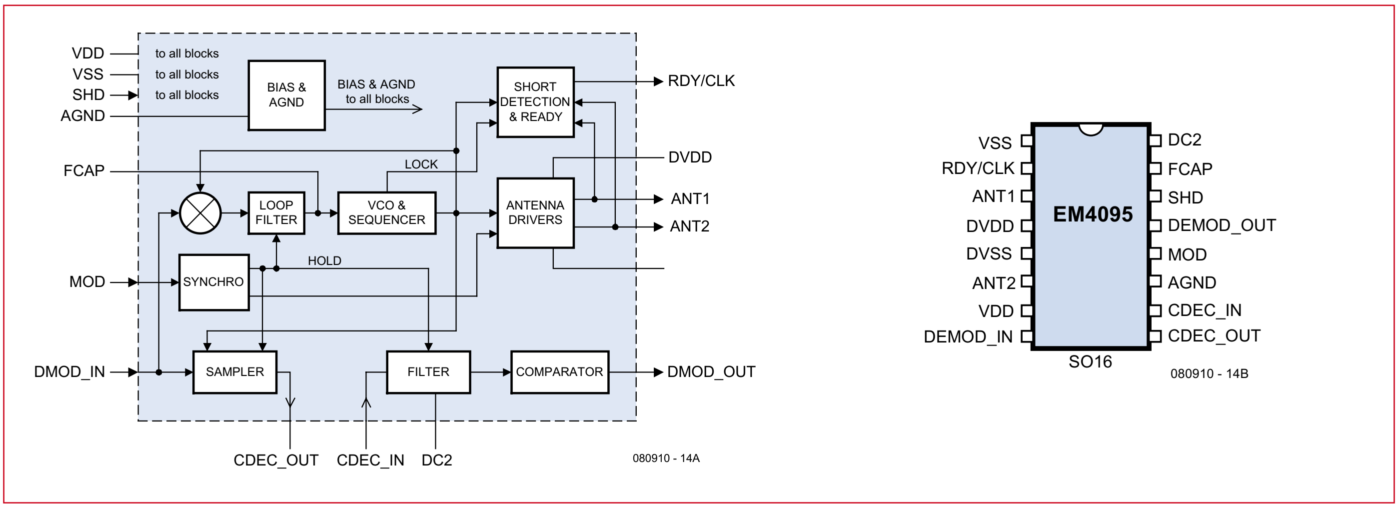


Figure 1. Block diagram and pin assignments of the EM4095 RFID reader IC.

ings are separated by a few centimeters, the effect of the load on the secondary winding is still measurable in the primary circuit.

This is the operating principle of a passive RFID transponder, in which an HF generator drives an antenna to generate an electromagnetic field. This field induces a voltage in the receiver circuit, and the energy transferred in this manner powers the receiver chip. The software in this chip controls a load in the receiver circuit. Just as with a power transformer, the different current levels in the receiver can be detected in the primary circuit. In this way, a RFID chip can send data to the transmitter without itself transmitting a signal.

Incidentally, utilization of this principle was explicitly prohibited in the early days of radio broadcasting. After the first German broadcasting station started operating on October 29, 1923, it didn't take long for a few hobby gardeners in the surrounding area to discover that with a suitable antenna, they could not only listen to the radio but also power their jury-rigged lighting system. This significantly reduced the effective range of "Radio Berlin Welle 400", and it was consequently prohibited.
Getting back to the present, there are now a variety of semiconductor devices that you can use to build a very simple RFID receiver. For our RFID reader we selected the EM4095, a transceiver IC made by the Swiss company EM Microelectronic-Marin SA, which can be used with various transponder chips made by the same company. The transponder, which is also called a tag, simply consists of a chip and a coil. The transponder chips that are compatible with the EM4095 include the EM4100, EM4102, EM4150, EM4170, and EM4069. We used a transponder with the EM4012 chip for our experiments. Although this chip is still available, according to the manufacturer it has been replaced by the EM4200, which can also replace the EM4005 and EM4105.
Unlike many other RFID devices, such as the Mifare cards already used in some Elektor projects, these EM chips are not ISO standardized, but they are nevertheless widely used and readily available.

Main specifications

RFID Reader:

- **Connects to Elektor ATM18 test board**
- **Compatible with RFID tags using EM4102 and EM4200**
- **5 V supply voltage**

Bascom RFID software for ATM18:

- **Reads RFID data**
- **Outputs RFID data via RS232**
- **Shows RFID data on LC display**
- **Relay control by RFID**

The EM4095

The block diagram and pin assignments of the EM4095 (**Figure 1**) show a handful of pins for the external circuitry. For our project, we use the application circuit shown in **Figure 2**. It has separate power rails for the antenna portion and the chip (DV_{DD} and V_{DD}). However, a single power supply is adequate for our simple application. The resonant circuit of the antenna coil has two tasks: it must generate the transmit signal for the transponder, and it must receive the amplitude-modulated signal from the transponder.

The resonant circuit consists of the antennal coil L_A and

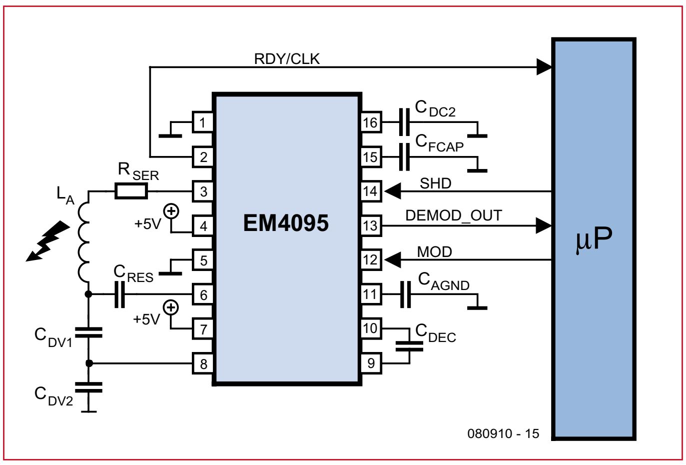


Figure 2. EM4095 application circuit diagram.

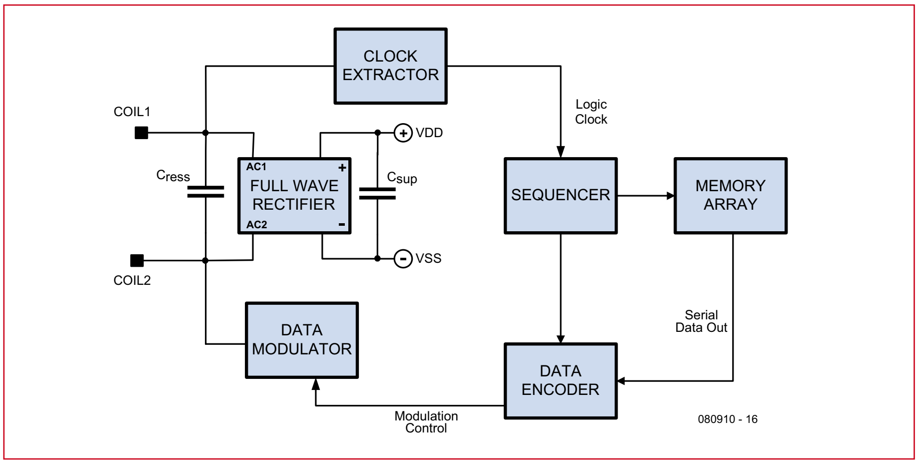


Figure 3. Block diagram of the EM4102 transponder chip.

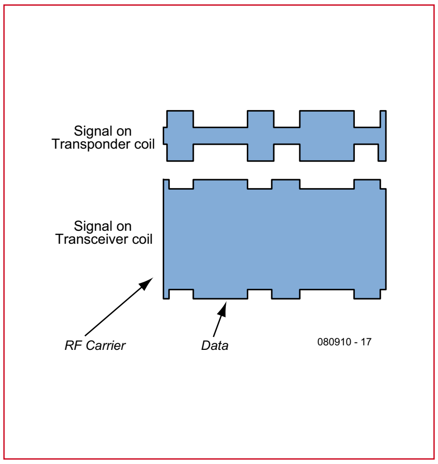


Figure 4. The 125-kHz signals on the reader and transponder .

the capacitor C_{RES}. These components determine the resonant frequency, which should be approximately 125 kHz. The EM4095 is designed for operation in the frequency range of 100 to 150 kHz and uses a phase-locked loop (PLL) to control the frequency. Naturally, the transponders also operate in this range. The series resistor R_{SER} keeps the current in the antenna driver below the maximum rated value. As backup protection, the EM4095 also has a short-circuit detection circuit that disables the output stage in case of an overload.

C_{DV1} and C_{DV2} form a capacitive voltage divider that feeds part of the antenna voltage back to the DMOD_IN input (pin 6). This input is used to feed in the amplitude-modulated signal generated by the transponder. The maximum rated voltage on this input is 4 V. Capacitor C_{DEC} decouples the DC supply voltage between the sampler output and the filter input. Capacitor C_{DC2} works with an internal filter circuit to form a bandpass filter.

Four lines are normally necessary for the connection to the microcontroller: SHD, MOD, DEMOD_OUT, and Ready/Clock.

The RDY/CLOCK line initially transmits the status signals, and later on, after the EM4095 has started operating, it transmits the clock signal to the microcontroller. The MOD signal is used to write data to the transponder. The microcontroller holds the MOD input Low during read operations. SHD is the enable input of the EM4095. The reader IC enters sleep mode when this input is set High, and in this mode its current consumption is only a few microamperes. When SHD is pulled Low, the EM4095 wakes up and executes a start-up process that takes 41 clock cycles. DEMOD_OUT feeds the demodulated Manchester-coded data stream to the microcontroller.

The manufacturer provides several formulas in the data sheet and Application Note 404 for calculating the values of the external components. If

RFID

Good things last long

Radio-frequency identification (RFID) technology is actually old hat. The first commercial predecessors of the current technology were launched in the 1960s. However, only now is the world ready for comprehensive data collection.

RFID is a refinement of a technology that originated during the Second World War. A system called Identification Friend or Foe (IFF) was developed at that time, with the objective of enabling the American armed forces to distinguish allied aircraft from enemy aircraft. The original equipment was a large as a suitcase and very expensive.

RFID technology was also used in electronic article surveillance systems as early as the 1960s. At that time, the memory capacity of an RFID tag was only 1 bit. The 1980s saw the introduction of RFID technology in the automobile industry. RFID chips were initially used in anti-start systems, fuelling cards, and remote vehicle entry systems.

As in all other fields of electronics, miniaturization proceed rapidly. This opened up more and more application areas, such as credit cards, access control systems, and personal identification systems.

In addition to security and logistics, animal identification is an important application area for RFID. In November 2002, the US Food and Drug Administration (FDA) approved a controversial use of RFID technology: chips embedded in people. The Verichip RFID chip produced by the US company Applied Digital Solutions is designed to be embedded subcutaneously (beneath the skin). In an emergency, doctors can immediately read out vital patient information, such as the person's blood type and any current allergies or illnesses. However, there are now access control systems for companies and even discos that are implemented using embedded RFID tags. Everyone should carefully consider whether he or she is willing to have this sort of system "installed" in their body.

Lending libraries, such as the new Vienna Main Library, use RFID tags for inventory control. Special types of RFID readers can read a group of RFID tags in a single operation. This technique is called "bulk reading". Another application for RFID technology, which is already extensively exploited, is electronic mass transit passes that can be read without physical contact and reloaded. They are used successfully in numerous Asian metropolises, such as Hong Kong and Singapore.

	1 1 1 1 1	1	1	1	1	9 header bits
8 version bits or customer ID	D00	D01	D02	D03	P0	
	D10	D11	D12	D13	P1	
32 data bits	D20	D21	D22	D23	P2	
	D30	D31	D32	D33	P3	
	D40	D41	D42	D43	P4	
	D50	D51	D52	D53	P5	
	D60	D61	D62	D63	P6	
	D70	D71	D72	D73	P7	
	D80	D81	D82	D83	P8	
	D90	D91	D92	D93	P9	10 line parity bits
	PC0	PC1	PC2	PC3	S0	
	4 column parity bits					080910 - 18

Figure 5. Configuration of the 64 bits stored in the EM4102.

you find this too complicated, you can use a spreadsheet available from the manufacturer's website or the project page on the Elektor website (www.elektor-usa.com/080910). This makes the calculations relatively easy and semi-automatic.

The transponder

RFID devices are actually modules that are available in a variety of forms, such as smart cards, small glass tubes, and key fobs.

Figure 3 shows block diagram of the EM4102 transponder chip and its individual functional blocks. The only external component is the coil connected to the Coil1 and Coil2 pins. The voltage induced in the coil is fed to a full-wave rectifier and used as the operating voltage. The clock frequency is generated in the Clock Extractor. The Sequencer uses this clock to shift data out of the memory into the data encoder. There the data is processed according to the protocol that is used and fed to the Modulator, which drives the antenna coil. The reader and transponder frequencies are synchronised. The modulator produces an amplitude-modulated HF signal in the transponder coil, with the data in the sidebands.

The signal envelope at the reader is exactly the opposite (see **Figure 4**). As previously mentioned, part of the modulated voltage is tapped off, and the reader can filter the transponder data out of its own 'attenuated' signal.

The read data can be coded in various manners. Protocols such as Manchester, bi-phase, PSK and FSK are widely used. In our EM4102, the data (which is hard-coded in the memory) is Manchester coded for output. Manchester coding is commonly used for serial data transmission on a data line. The payload data is XORed with a signal at twice the data clock rate, which eliminates the need for a separate clock line. The clock and payload data are first synchronized at the start of the coding process, and the clock and data are XORed on each edge of the clock signal. This produces the transmitted data stream, which is used to modulate the 125-kHz carrier signal.

In our case, the data stream consists of 64 bits. This is broken down as follows: header (9 bits), data (40 bits), row parity (10 bits), column parity (4 bits), and stop bit (1 bit). This is illustrated in graphic form in **Figure 5**. The data is read out row by row from the top left to the bottom right as 64-bit data string. The nine "1" bits are the header. Each of the next ten rows consists of four data bits and one parity bit. The last row consists of the four column-parity bits and the stop bit, which is always "0". The first eight bits of the data field are customer-specific. The purchaser can store a fixed company ID or internal company code here, assuming that a sufficiently large quantity of chips is ordered.

However, rapid technological progress in recent years has led to a confusing proliferation of incompatible systems, in part due to the failure to define uniform standards in a timely manner. The future widespread use of RFID technology will doubtless depend in part on the extent to which agreement on uniform standards can be achieved. To enable RFID technology to be used across company boundaries and national borders, interested parties in the industrial and mercantile sectors acting under the guidance of European Article Numbering (EAN) International and EPCglobal founded the Uniform Code Council (UCC). EPCglobal has developed the Electronic Product Code (EPC), which can be used to describe manufacturers and products uniquely. This code consists of 96 bits, divided into four groups: an 8-bit header, a 28-bit manufacturer code, a 24-bit object class code, and a 36-bit serial number. This is sufficient to identify 6.87×10^{10} items in each of 1.67×10^{10} object classes for each of 2.68×10^{8} manufacturers. This standard is currently supported by Wal-Mart, the Metro Group, Carrefour, and Tesco. With the combination of the product code and a database, it should be possible to fully describe every merchandise item in the world.

Several manufacturers, such as NXP, Infineon and Texas Instruments, produce various types of RFID tags for a wide range of applications. In the simplest and most economical versions (read-only tags), the transponders contain fixed, non-alterable ID codes These tags are very small and maintenance-free. Transponders are often attached to a plastic film along with their antennas. This form of transponder can be printed with visible information and handled similarly to paper. These "smart labels" are available in several versions. Depending on the type and the frequency band, they can be read out at distances ranging from a few centimeters to 100 meters.

RFID tags with writable memory offer higher performance and increased versatility. Depending on the type, the memory capacity ranges from a few bits to several hundred kilobytes. RFID tags with built-in encryption mechanisms are used in applications with high security requirements. RFID tags with a microprocessor and an internal operating system are also available now. These tags are usually produced in the form of smart cards (dual-interface cards).

RFID devices are basically classified as passive, active or semi-active, depending on how they are powered. In contrast to active RFID devices, passive RFID devices do not have an internal source of power. Semi-active devices switch automatically into sleep mode, and they can attain a very long battery life of up to six years. Active tags have the advantage that they can be used together with integrated sensors for temperature monitoring or precise localization (in combination with a GPS receiver).

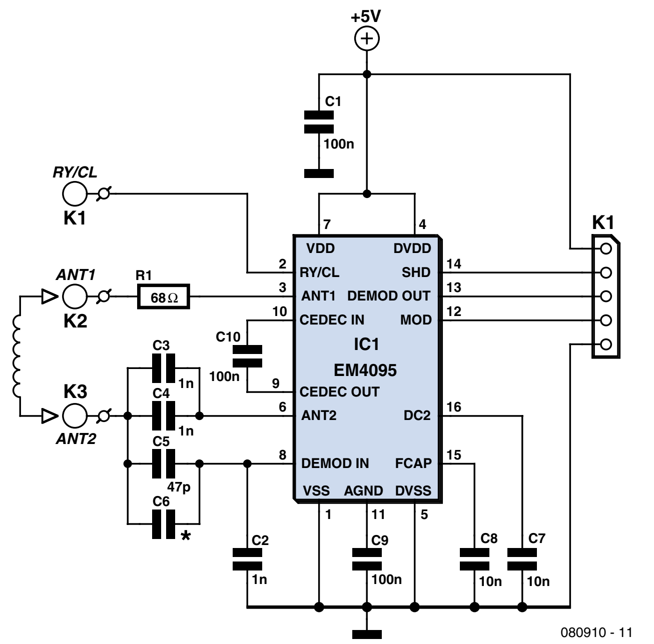


Figure 6. RFID reader circuit for connection to the CC2 AVR board.

The transponder sends this 64-bit sequence repeatedly as long as operating power is available, which means as long as it is within range of the reader. The coded signal starts and ends with the same phase state. As a result, the start sequence of nine "1" bits can be detected unambiguously when the received signal is processed.

Transponders using the EM4102 are among the simplest type of RFID devices. They emit only the data stored in the chip during manufacture, with no possibility of storing user-generated data in the RFID device. Their sole utility arises from the fact that each EM4102 contains a code that is issued only once, which means that each tag can be identified uniquely. This is fully sufficient for applications such as door openers, anti-start systems, or identifying cattle.

The RFID reader board

The ATM18 board needs an extension to enable it to recognise and read RFID devices. This extension is the RFID reader board. For this purpose, we use the previously described EM4095 in the circuit shown in **Figure 6**. The IC is wired the same as in the data-sheet application circuit diagram shown in Figure 2. The capacitor values are: C_{RES} = 2 nF (C3 + C4), C_{DV1} = 47 pF (C5), and C_{DV2} = 1 nF (C2). Series resistor R_{SER} has a value of 68 Ω (R1). The second capacitor position C6 in parallel with C5 allows the value of C_{DV1} to be adjusted if necessary.

A small PCB (**Figure 7**) has been designed for assembling this circuit. It connects to the ATM18 board. The extension board is available from the Elektor Shop with the SMD components pre-assembled, so you only have to solder the coil leads and the connecting links to the ATM18 board.

The antenna coil is a DIY construction. The circular coil, which can be seen in the photo, consists of 160 turns of 0.6-mm enamelled copper wire. The coil diameter is approximately 23 mm, which means that you need 12 meters of wire. If you can find a suitable form in your junk box and chuck it in a drill, winding the coil is very easy.

The inductance of the coil is approximately 780 μH. If you have an inductance meter or a multimeter with an inductance range, you can check the value of the finished coil. However, the exact value is not especially critical. In our tests with this antenna coil, the transponder with the EM4102 was recognized immediately every time. We obtained the same result with the rectangular coil shown in the photo at the head of this article. It comes from an EM4095 reference design kit that is available from MCS Electronics (which also produces Bascom). The circuit diagram is described at a site referenced by one of the links at the end of the article.

In practice, the EM4095 reader board works OK without any alignment or tuning, but for maximum sensitivity the oscillator frequency should be as close as possible to 125 kHz. To avoid accidentally shifting the oscillator frequency while measuring it, do not make the measurement directly on the coil, but instead use a small "sniffer" coil brought within range of the antenna coil. A circular or rectangular coil with a diameter or edge length of around 60 mm, made from insulated or enamelled wire with a diameter of 0.5 to 1 mm, is suitable for use as a sniffer coil.

If the frequency measured using the sniffer coil differs significantly from 125 kHz, you can correct the situation by changing the number of turns of the coil. Reducing the number of turns

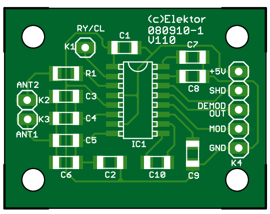


Figure 7. RFID reader PCB for assembling the reader circuit shown in Figure 6.

COMPONENT LIST

Resistor
(SMD 0805)
R1 = 68Ω

Capacitors
(SMD 0805)
C5 = 47pF
C2,C3,C4 = 1nF
C7,C8 = 10nF
C1,C9,C10 = 100nF
C6 = not fitted (see text)

Semiconductors
IC1 = EM4095 (SMD SO16)

Miscellaneous
K1 = solder pin
K2 = 2-way pin header, 0.1" lead pitch
K3 = 5-way pin header, 0.1" lead pitch
PCB with SMD parts prefitted, incl. pin headers, order # 080910-91

increases the frequency, and of course, increasing the number of turns reduces the frequency.

Testing and connection

For the first functional test of the EM4095 reader card, you need a 5-V power source and an RFID tag that can be detected by the EM4095. This can for example be a transponder with an EM4102 in the form of a key fob, as shown in the large photo.

Figure 8 shows an example of the acquisition of an RFID tag. The upper waveform in the oscillogram is the modulated 125-kHz signal, and the lower waveform is the data signal at the DEMOD_OUT output (pin 13 of the IC or pin 2 of connector K2 on the PCB). As you can see, the transponder sends its data as it is supposed to – this is what you should see when everything is in order.

In order to evaluate and display the data, the reader board must be connected to the CC2 system as shown in **Figure 9**. Here SHD is connected to PB3, MOD is connected to PB4, and DEMOD_OUT is connected to PD2, along with the connections for +5 V and ground. The connections between the CC2 board and the LC display module and the relay board are also shown in the wiring diagram. The only thing you still need at this point is the Bascom program, which is our next topic.

RFID and BASCOM

The program code is very simple because almost all of the tasks are handled by a library ("lib") function. The lib function formats the data read from the RFID tag into bytes and places the data on the stack. If you read this data as a normal array using the example Bascom code, the byte sequence is reversed. You should bear this in mind and take it into account in the further processing of the data. Familiar subroutines are used to display the data on the LCD module and to control the relays on the relay board. All of these routines have been used before in related articles in this series, where they are described in detail. The program outputs the data to the serial interface in addition to displaying it on the LCD module, so the data can be saved or further processed on a PC and displayed using a terminal emulator program.

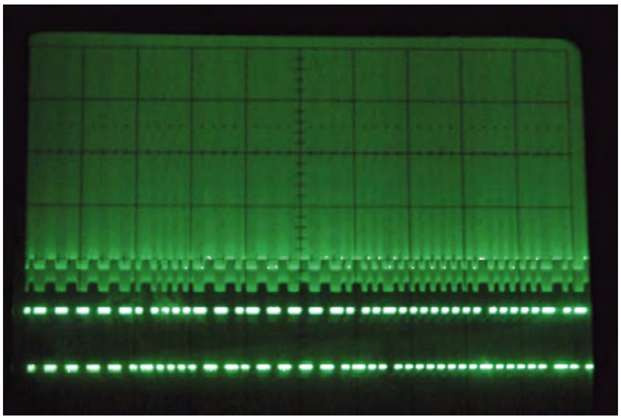


Figure 8. Oscillogram showing the modulated 125-kHz signal (top) and the data signal at the DEMOD_OUT output of the EM4095 (bottom).

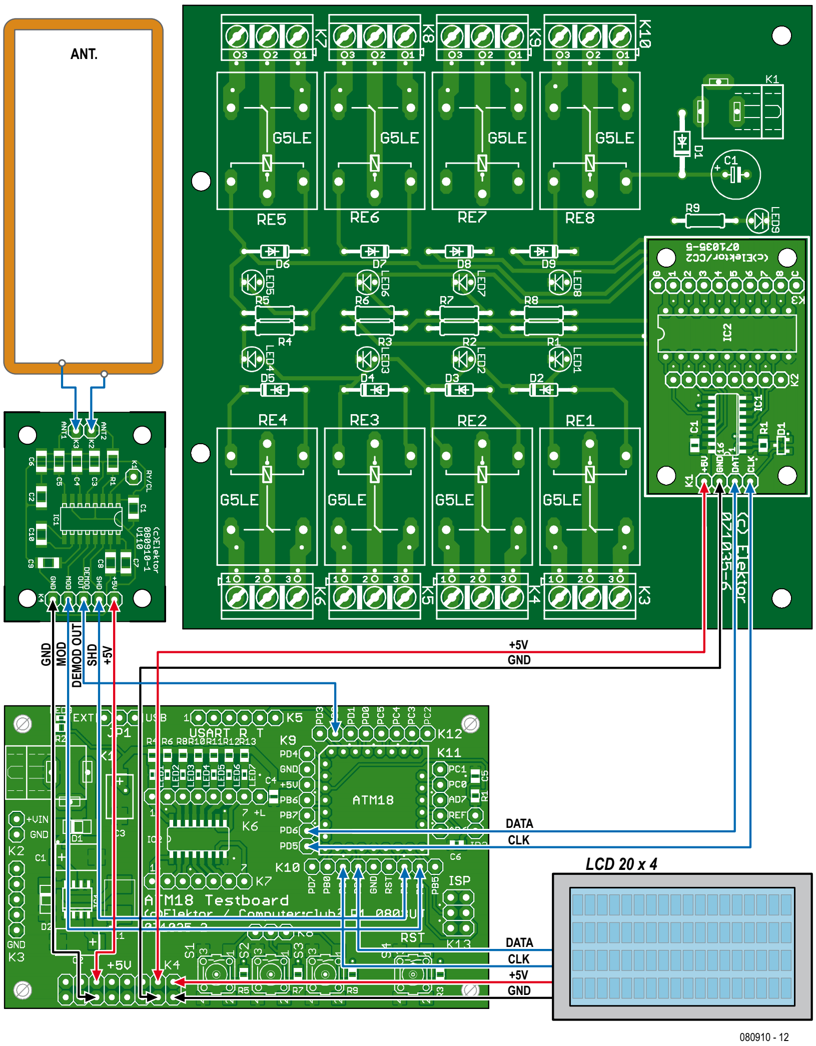


Figure 9. Wiring diagram of the RFID project with the RFID reader board, ATM18 board, LC display module, and relay board with port expander.

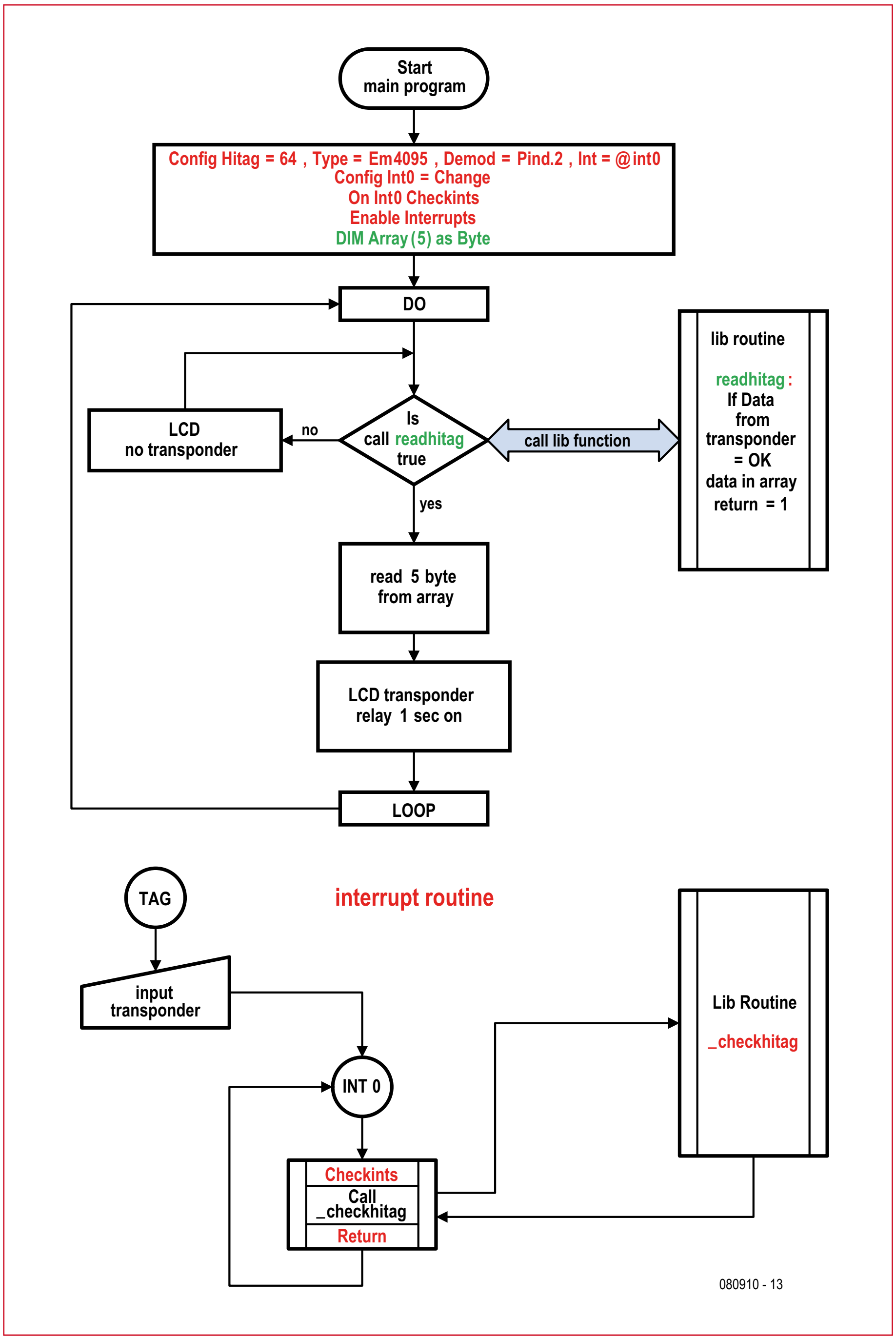


Figure 10. Flow chart of the Bascom software for the RFID project.

The flow chart in **Figure 10** depicts the logical structure of the RFID reader program. The actions shown in red and green are not handled by normal Basic commands, but instead call assembly-language routines in em4095lib. The RFID library for the EM4095 reader IC is integrated into Bascom version 1.11.9.0 and later.

When a transponder is recognized, the data is decoded using an interrupt routine. The data is saved in memory and can re read out as a byte array.

The details

A number of entries in the main routine are necessary in order to link in the library. The entries shown in red relate to interrupt handling, while the entries shown in green are for calls to the library function.

Config Hitag = 64 , Type = Em4095 , Demod = Pind.2 , Int = @int0

"Hitag" is the division factor for the clock frequency. "Typ" is the reader IC type. "Demod" is the number of the input pin for the Manchester-coded signal. "Int" is the expected interrupt. "Demod" and "Int" are physically linked together. As you can see from the data sheet, interrupt 0 is associated with PIND.2.

Config Int0 = Change

The Manchester-coded signal is applied to interrupt pin D.2. The interrupt routine is triggered by the rising and falling edges of the input signal.

On Int0 Checkints

"On Int0" declares the interrupt routine "Checkints".

Enable Interrupts

This sets the Interrupt bit in the status register.

```
Checkints:
  Call _checkhitag
Return
```

"Checkints" is the interrupt routine that was previously declared with 'On Int0'.

DIM Array(5) as Byte

"DIM Array(5)" reserves memory space for five bytes.

The main routine runs in a DO loop, and initially all it does is to indicate via the LC display that nothing is happening. The Checkints interrupt routine is only triggered when a transponder enters the range of the EM4095. The interrupt routine in turn calls the library function "_checkhitag". This assembly-language routine reads in and decodes the Manchester-coded bit string. It calculates and checks the parity and then stores the data bytes in an array. If a time-out or any other sort of error occurs, the function terminates without writing new data to the array. The main routine then continues from the point where it was interrupted.

The IF statement evaluates the return value of the "Readhitag(Array(1))" function. The "Readhitag" function, which is integrated in Bascom, also calls EM4095.lib. It passes the start address of the previously defined byte array (with "1" as the initial address) as a call parameter. The library routine stores the data at the address passed in the call and returns a "1" if the result is valid (data present in memory). The Interrupt bit in the status register is then cleared to prevent the data from being changed by

another interrupt. Now the data can be read from the array and displayed in a FOR…NEXT loop.
The example program also actuates a relay for one second at this point. After this, the Interrupt bit is set again in the status register and the entire process starts again from the beginning.

A wealth of possibilities

As usual, this project is intended to provide a sound basis for developing your own applications. The hardware and software described here are suitable for recognizing and reading RFID devices fitted with the very economical EM4095 chip (see **Figure 11**). A relay on the CC2 relay board closes and opens at one-second intervals as long as a RFID device is acquired by the reader. The relay contact can be used to control another device, such as a door opener.

However, the potential applications are practically unlimited. Some examples include a cat door controlled by a 'cat RFID' tag, a battery charger with RFID battery identification, childproofing a PC or television set, a DIY anti-start unit for a motor boat, and so on.
We're sure that you can come up with many other potential applications.

(080910-I)

Figure 11. When a RFID tag is recognized, the data read from the tag is shown on the LC display.

Internet Links

http://avrhelp.mcselec.com/index.html (EM4095 reader under: Bascom Hardware > Reference Designs)

www.elektor-usa.com/080910 (Elektor project page for this project, with download files for the software and PCB layout)

BeeProg+ in use at Elektor

The meaning of 'One for All'

Jan Buiting (Elektor UK/US Editorial)

Many readers are curious to know just what gear, software and tools are in daily use in the Elektor Labs. One really crucial piece of equipment is our BeeProg+ multi-device microcontroller programmer system.

The guys in the Elektor Labs are talkative like no other and good e-pranksters from time to time. On the cathode (down) side, they suffer from perennial writer's block and are too modest about their discoveries of real gems in the realm of electronics and embedded systems. In other words, they are sitting on heaps of useful information you have to pull out of them – from hidden FAT32 partitions or from under their desks. That happens to be my job.

A little history – from the lab

It must have been in 2005 when a Slovakian company called Elnec kindly supplied a sample of their SmartProg2 multi-device programmer so we could write a few words about it in Elektor (**Figure 1**). That was duly done, but the programmer was never returned – of course we told Elnec, but they didn't mind. In fact the SmartProg2 was so good that it was sort of confiscated for use in the Elektor Labs, more specifically in the ESS department (Elektor Software Service), where it went into permanent service. Since then, many hundreds of master devices for microcontrollers, (E)PROMs, EEPROMs and other programmable devices have been "burned" on the SmartProg2 for use in our prototype circuits (or for erasing or trashing if an error was found). The programmer was also cheerfully used by our lab workers Luc, Robert-Jan, Chris, Antoine, Paul and myself (for occasional programming of 24C16 EEPROMs). For a number of years we laughed at every new micro

Figure 1. Elnec's SmartProg2 was used for a number of years in the Elektor Labs for one-off microcontroller programming and small production batches.

thrown at us by Silicon Valley's joint forces. We pulled the latest device parameters from the Elnec website, plugged in the odd adapter board, and burned a guinea pig.

Here I have to mention that Elektor, unlike some of its competitors, is an independent publication not restricted to one specific kind of microcontroller for use in published projects. A solid principle for sure (very open-minded and all that), but one that calls for programming support of a galaxy of devices from an ever longer list of manufacturers great & small, famous & obscure. Equally long is the list of device packages like SOIC, PLCC, DIP, you name it. While you (or your boss) may be happy to stick to just one brand and have a matching programmer to burn your own micros, here at Elektor we have far wider requirements because we will strive to support whichever microcontroller our readers care (or dare?) to propose for their projects, once accepted for publication.

In Munich

The story continues in Munich, at the 2008 edition of the immense Elektronica show, with an unplanned visit to the booth of Elnec. Joined by Paula Brady, Elektor's advertisement executive, I talked to Elnec's Sales & Marketing Director Vladimir Doval and R&D Director Jan Puobis (see **Figure 2** for the backdrop). Vladimir explained that many of Elnec's programmers were marketed under different brand names in countries all over the world.

Figure 2. At Elektronica 2008 meeting up with Elnec representatives Jan and Vladimir.

In Continental Europe, for example, the programmer covered in this article is known as **BeeProg+** and sold by Elnec directly [1]. In the UK, the brand name is **Dataman-48Pro+** [2], and in the USA **BK Precision Model 866B** [3]. Together we recalled the story of the SmartProg2 supplied to Elektor and discussed the range of programmers currently manufactured by Elnec. It seemed to me that the BeeProg+ was the logical successor to the SmartProg2, and Vladimir did not hesitate to send me one by courier — it was on my desk within a week.

In the lab again

You can guess what happened. At Elektor House the BeeProg+ box was immediately opened by the lab guys to "inspect the build quality" as they said, but really to satisfy their instinctive urge to know what's inside (**Figure 3**). They were greeted by two (!) Spartan FPGAs, a PIC18F micro, a Cypress CY7 chip and lots of assorted logic, all on three high-density stacked boards. In what little time it took them to fit the cover again and me to tell that the BeeProg+ was a "Universal 48-pin-drive programmer with USB/LPT interface and ISP capability", the software was installed on the resident ESS PC and the unit powered up. The programmer was in full use within the hour and according to the main user, Jan Visser of our ESS, its distinct advantages are (quote):

1. Versatility to the highest level
2. Kissable software
3. Device updates whenever I need them
4. A socket converter to suit even the quirkiest of IC packages
5. ISP connectivity alongside the friendly 48-pin ZIF socket
6. Great for small product batches too

(end quote). As with the SmartProg2, I had to pull the BeeProg+ from my colleagues' hands to get the photos done for this article. It is truly a programmer's delight.

45k+devices supported

Recently the lab guys ran into "this horrible IC" they were struggling to get programmed, and in fact an entire project based upon it, the *LED Spinning Top with Special Effects* (December 2008) almost got delayed for publication. Almost. I decided to make a case of it and asked Vladimir at Elnec for a matching TQFP32 adapter (# 70-0135) to "do" this particular Atmel beast, the ATmega8-16AU. Within a week, shouts of hooray and a working prototype. Still later, a highly successful article.
The list of devices you can program on the unit is so long it would easily fill a complete edition of Elektor. If you are not convinced, or into really esoteric micros, give the Devices section on the Elnec website a try – you'll be amazed [4]. From a 2708 EPROM (8 kbits and 30 years old) right up to Actel IGLOOs, it's all there. The most recent device list we found (from mid-March 2009) has a length of **45,797 devices.** The BeeProg+ is also capable of testing logic ICs (54/74S/LS/ALS/H/HC/HCT series, 4000, 4500 series) and static RAMs (6116 through 624000), and it supports user-definable test pattern generation.

The socket converter list at [5] may well be the longest I have ever seen. From commonly encountered packages like DIL, TSSOP, SOIC and PLCC right up to esoteric stuff like QFP256 and FBGA484. The socket converters are very high quality builds without exception, but relatively expensive compared to the programmer proper.

Figure 3. A look inside the BeeProg+ – a very powerful microcontroller system on its own!

Technically speaking

The BeeProg+ has three internal DACs for the programming voltages VCCP (0–8 V, 1 A), VPP1 and VPP2 (both 0–26 V, 1 A) with support for controllable rise and fall time. It has a USB 2.0 High-Speed compatible port with a transfer rate of up to 480 Mbit/s, and an FPGA-based IEEE1284 (ECP/EPP) slave printer port with up to 1 MB/s transfer rate.
The pin drivers on the ZIF socket can "impersonate" either TTL (H, L, CLK, pull-up and pull-down) or analog (1.8–26 V) with protection against overcurrent, power failure and ESD (IEC 1000-4-2).
The ISP connector is a polarized 20-pin type with six TTL pin drivers, 1× VCCP (2–7 V, 100 mA); 1× VCCP (sink or source); 1× VPP (2–25 V 50 mA); 1× target system supply (2–6 V, 250 mA); ESD protection (IEC 1000-4-2); 2× status indicator; and a YES! equivalent input signal (max. 0.8 V active level).

Out of the box

The BeeProg+ comes with diagnostic pods (test adapters) for ISP and ZIF-48, an ISP flat cable, a dust cover for the ZIF socket, a USB cable, software on CD, and paperware (including a fine manual). Remarkably, the programmer also supports the vintage 25-pin parallel printer port. The power supply is internal and happily takes anything between 110 and 240 volts AC, 50 or 60 Hz.
A quad version of the BeeProg+ is also available under the name **BeeHive4+**, while a nest of eight BeeProg+ units is contained in the stand-alone BeeHive8S.

(090006-I)

Internet Links

[1] www.elnec.com

[2] www.dataman.com

[3] www.bkprecision.com

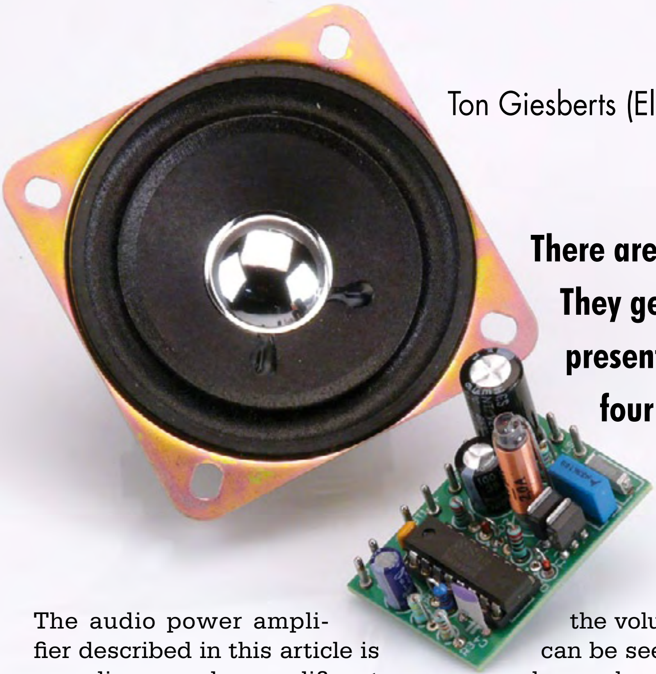
[4] www.elnec.com/search/device-list/?prog=22

[5] www.elnec.com/products/socket-converters/

Power in the Pocket (1)

A Simple PWM Amplifier

Ton Giesberts (Elektor Labs)



There are plenty of designs for simple audio power amplifiers. They generally have a class AB or class B topology. Here we present a very compact class D design that can be powered from four AA batteries and can elicit quite a few decibels from a loudspeaker thanks to its relatively high efficiency.

The audio power amplifier described in this article is no ordinary analog amplifier stage, but a "digital" version that uses pulse-width modulation (PWM). In fairness, we will be up front and state that this amplifier has quite a bit of distortion and is certainly not a hi-fi or high-end amplifier. The circuit is far too simple for that. On the other hand, the circuit does give a unique sound to the music. You may find that this digital amplifier has a "tube-like" sound.

PWM amplifier

In principle, a PWM amplifier has very high efficiency because the output is switched at a high frequency between the positive and negative power supply voltages (or ground) (see **Figure 1**). Since the output transistors are driven one at a time, either fully on or fully off, the voltage across the transistors is low when they are on, and the current through the transistors is low when they are off. This means that the losses and heat dissipation of the transistors remain small.
When a transistor is on, there is a pulse at the output. The width of this pulse is proportional to the amplitude of the original input signal. The width of this pulse is also a measure of the level of the output signal (and by extension the volume of the amplifier). This can be seen clearly in **Figure 1**: the places where the positive signal pulses are the widest correspond to the highest (sine wave) signal levels. This, of course, is also true for the negative pulses: the narrower the positive pulse (and therefore the wider the negative pulse), the smaller ("more negative") the output signal.
The level of the output signal is therefore determined by the ratio of the positive and negative pulses. The bigger the difference, the bigger the output signal. And the other way around: the output signal level decreases as the ratio of the positive and negative pulses approaches 50/50.
Only a low-pass filter is required to convert the PWM signal back into the (amplified) original signal. This filter removes the high switching frequency from the signal so that only a kind of "average" remains, which corresponds exactly to the original signal.

Technical specifications

- 1 W into 8 Ω, 1.7 W into 4 Ω
- Class-D
- Power supply 6 to 9 V (4x AA cell)
- Very compact
- Simple construction without SMDs

The circuit

The circuit (see **Figure 2**) is a self-oscillating pulse-width modulator. This is actually an amplifier stage with a bad case of oscillation. A low-frequency signal affects the oscillation, which results in pulse-width control.
Because the amplifier is powered from a single-ended power supply (6 to 9 V), decoupling capacitors are required at the input and output (C1 and C7). It is mainly the output capacitor that determines the lowest frequency that is passed. The selected value is always a compromise between physical size and bandwidth, just as with analog amplifiers.

For driving the output stage, a few buffers from the 4000 series of digital ICs are used. The main advantage of these devices is their large supply voltage range. Their limited speed is not really a concern here. In order to obtain sufficient gain, two gates are connected in series and the remainder are connected in parallel with the second buffer. This results in a better drive signal for the output stage (necessary

because of the high input capacitance of the output stage).
For the output stage, we chose MOSFETs in an I-PAK package (TO-251AA) made by IRF. These small transistors can handle more than 4 A (the N-channel version can cope with more than 7 A). The channel resistance of the N-channel MOSFET is about 0.25 Ω, and for the P-channel MOSFET it is about 0.5 Ω.

Due to these low channel resistance values, it is important that both transistors do not turn on at the same time (dead time is required). In series with the outputs from the gates are 220 Ω resistors, each in parallel with a Schottky diode. This ensures that the voltage on the gate of one MOSFET drops faster than it rises on the gate of the other one.

In our prototype we used a reasonably common noise suppression choke for the output inductor of the low-pass filter (L1). This choke is rated for loads up to 2 amperes. You can also use a smaller choke, such as axial versions for medium-current applications. Just make sure that the choke will fit on the PCB. We deliberately selected a choke that can handle more current than strictly necessary (at a load of 4 Ω the peak current is less than 1 A).
In order to keep the physical size of choke small, a core is used, but this causes nonlinearities that increase in magnitude when the core approaches saturation. We chose a slightly oversize inductance to enable the circuit to operate in a reasonably linear region. By using an axial version and mounting it upright, the space required is kept to a minimum. An air-core coil would be the best choice, of course, but this is not an option here due to its physical size.

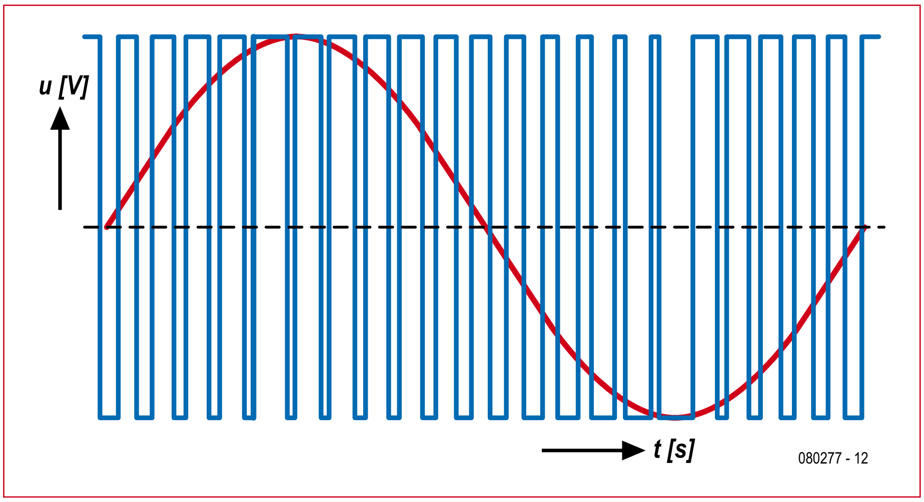


Figure 1. The PWM signal corresponding to a sine wave. After filtering of the PWM signal the original signal reappears.

As already mentioned, only a low-pass filter is required to turn the digital signal back into an analog signal. L1 and C5 form a second-order low-pass filter (Butterworth) which suppresses frequencies above 40 kHz. This is also necessary to ensure that the circuit does not cause interference to other devices (EMI). RC network R6/C6 ensures that the filter continues to work properly at higher frequencies.

R1 holds the input side of C1 at ground level so that no annoying sounds are generated when the signal source is connected with the circuit already turned on. We assumed that the loudspeaker is permanently connected, which is why there is no resistor in parallel with the output terminals.

Loudspeakers are complex loads and are mainly inductive at high frequencies. The "gain" of the circuit is determined by feedback network R2/R3. With the selected values, the gain is about 1, which given the power supply voltage and output range provides sufficient sensitivity. From practical tests

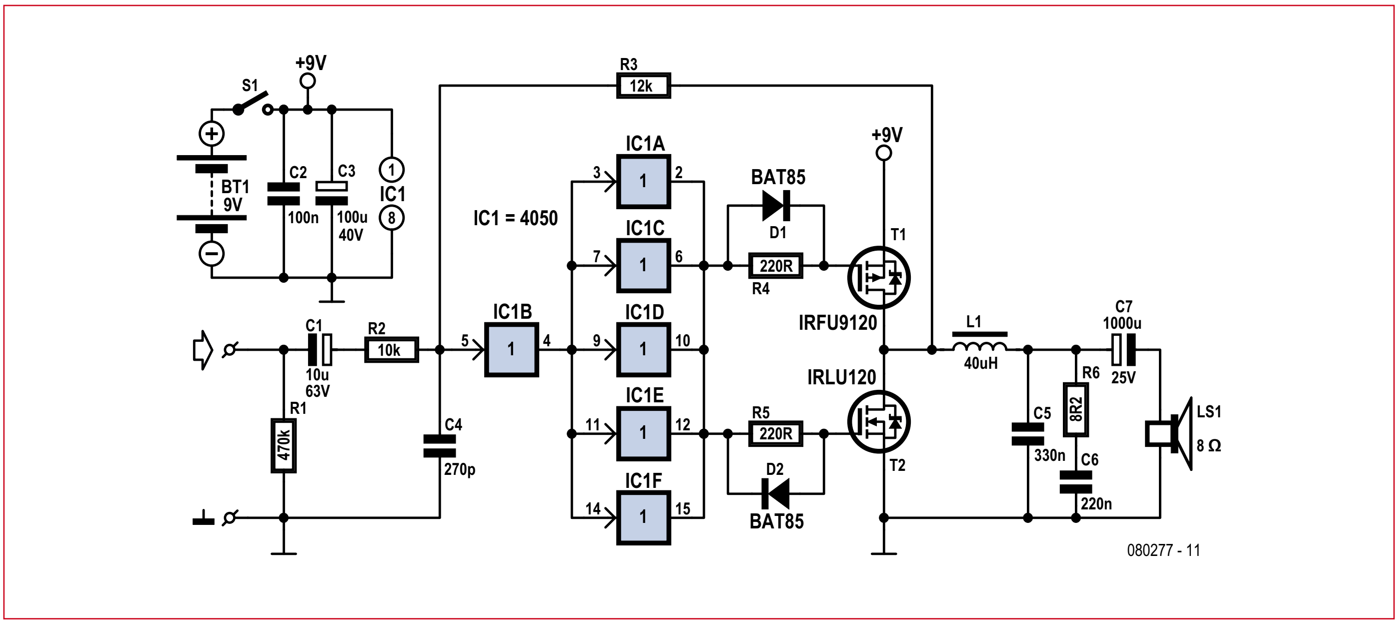


Figure 2. The circuit has very modest dimensions so it will all fit on a compact printed circuit board.

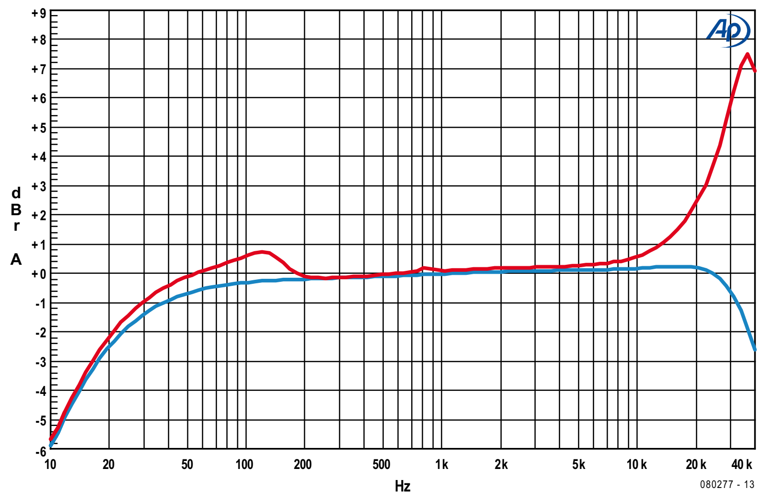


Figure 3. The frequency response depends in the load. Here are the curves for an 8-Ω resistor (blue) and a loudspeaker (red).

it appears that typical sound cards will probably not supply a sufficient signal to obtain full output power from the amplifier. But don't panic: in Part 2 we will describe a board of the same size, which contains a matching preamplifier and extensive tone control.

Results

The quiescent current consumption is 44 mA, which is clearly too high for battery operation, especially if more than one board is used. This is mainly due to the relatively high switching frequency of 660 kHz at a supply voltage of 9 V and the absence of proper dead-time control (the value of 220 Ω for R4 and R5 is a compromise).

Fortunately, the frequency drops at lower supply voltages because the buffers that are used here are slower at lower supply voltages, which benefits the current consumption. At 6 V (f_s = 510 kHz) the current consumption drops to 10 mA, and it is possible to use a set of four AA batteries. At 5 V (f_s = 450 kHz) the current consumption is only 6 mA. However, we recommend that you use the circuit with a supply voltage in the range of 6 to 9 V. The absolute maximum is 9.5 V, which is an overvoltage of a little more than 5%. At this voltage the current consumption rises to 60 mA. A supply voltage below 5 V gives an insufficient drive signal (not enough voltage for the gates).
At 9 V the maximum output power into 8 Ω (clipping level) is 1 watt. The maximum power into 4 Ω is about 1.7 watts (less than twice the value with 8 Ω). Voltage drops across the choke and output capacitor, for example, have a significant effect on the maximum available output level.

At 9 V this amplifier produces quite a bit of sound on the bench, even when a small loudspeaker is used. At 1 mW the distortion is less than 0.5%. The bandwidth with an 8 Ω load extends from 18 Hz to 40 kHz (blue curve in **Figure 3**). The lower corner frequency is determined by C7, and the upper corner frequency is determined by the low-pass filter (L1/C5). With small loudspeakers this is more than enough, because it more than what many small speaker boxes can reproduce.
As already mentioned, the blue test result (**Figure 3**) shows the amplitude characteristic into a pure 8 Ω load. When a loudspeaker is connected (red curve), a small rise (about 1 dB) in the output level can be seen around the resonance point. A peak of several dBs can occur at the corner frequency of the filter (around 40 kHz). This is because the Butterworth filter is not terminated properly under these conditions. In the figure it may appear that this peak is rather large, but if you look at the scale it is obviously not that bad. At 20 kHz the peak is only 2.5 dB. This does no harm in principle, and a lot of people actually like it.

The PCB is very compact. The accompanying preamplifier (planned for next month) has the same dimensions, so a complete and very compact mini-amplifier can be implemented. We have more to say on the availability of the PCB in the next installment (September 2009).

(080277-I)

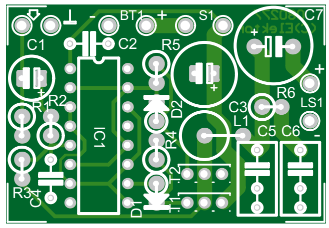


Figure 4. Although "standard" parts are used, the PCB is very small due to the high components density.

COMPONENT LIST

Resistors
R1 = 470kΩ
R2 = 10kΩ
R3 = 12kΩ
R4,R5 = 220Ω
R6 = 8Ω2

Capacitors
C1 = 10µF 63V, radial, 6mm diam.
C2 = 100nF ceramic, lead pitch 5mm
C3 = 100µF 40V, radial, 8mm diam., lead pitch 0.1" (2.5mm)
C4 = 270pF, ceramic, lead pitch 0.2" (5mm)
C5 = 330nF, MKT, lead pitch 0.3" (7.5mm)
C6 = 220nF, MKT lead pitch 0.3" (7.5mm)
C7 = 1000µF 25V, radial, 10mm diam., lead pitch 0.2"

Inductors
L1 = 40µH 2A axial (mount vertically) e.g. Epcos type B82111EC23; Farnell # 9753354

Semiconductors
D1,D2 = BAT85
T1 = IRFU9120NPBF (TO-251AA/I-PAK, International Rectifier) e.g. Farnell # 8659206
T2 = IRLU120NPBF (TO-251AA/I-PAK, International Rectifier) e.g. Farnell # 8651345
IC1 = 4050

Miscellaneous
S1 = 1 make contact, 1A min. (not on PCB)

FET Driver
for Microprocessors

Modern microprocessors can deliver respectable currents from their I/O pins. Usually they can source (i.e., deliver from the power supply) or sink (i.e. conduct to ground) up to 20 mA without any problems. This allows the direct drive of LEDs and even power FETs. It is sufficient to connect the gate to the output of the mP (see **Figure 1**).

Driving a FET from a weaker driver (such as the standard 4000 series) is not recommended. The FET would switch very slowly. That is because power FETs have several nF of input capacitance, and this input capacitance has to be charged or discharged by the mP (microprocessor) output. To get an idea of what we're talking about: the charge- or discharge time is roughly equal to *V* x *C* / *I* or

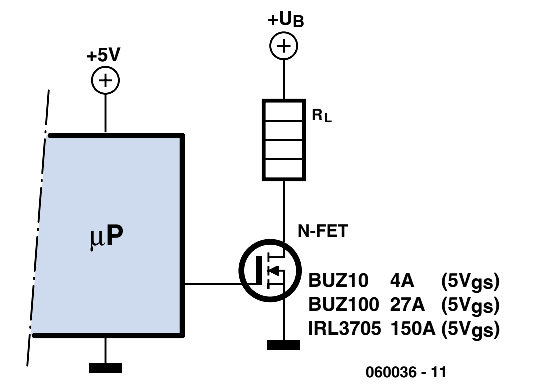
$5\ V \times 2 \times 10^{-9} / (20 \times 10^{-3}) = 0.5\ ms.$

Not all that fast, but still an acceptable switching time for a FET. However…

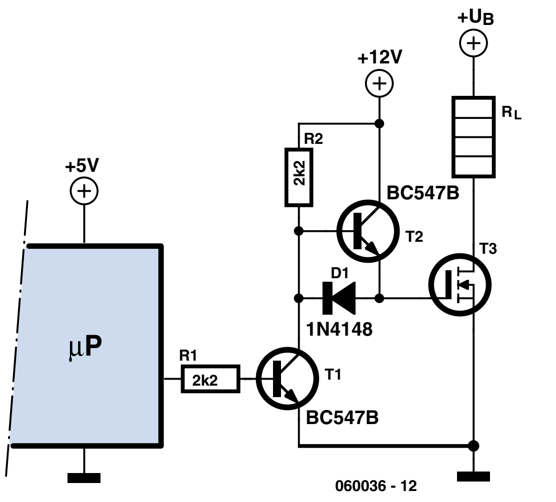
Not every FET is suitable for this. Most FETs can switch only a few amps with a voltage of only 5 V at their gate. The so-called logic FETs do better. They operate well at lower gate voltages. So take note of this when selecting a FET. To make matters worse, many modern mP systems run at 3.3 V and even a logic FET doesn't really work properly any more.

The solution is obviously to apply a higher gate voltage. This requires a little bit of external hardware, as is shown in **Figure 2**, for example. The mP drives T1 via a resistor, which limits the base current. T1 will conduct and forms via D1 a very low impedance path to ground that quickly discharges the gate.

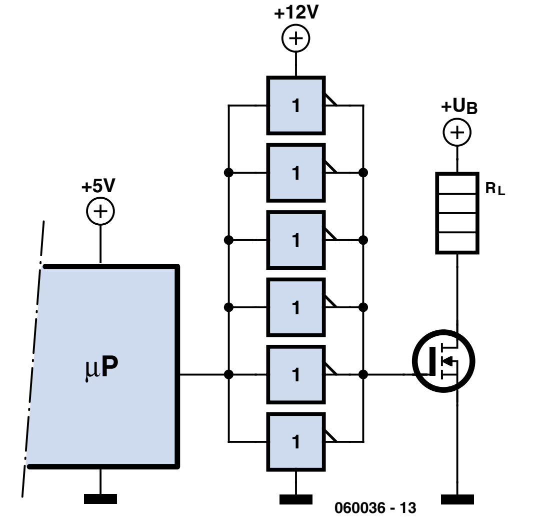
1



2



3



When T1 is off, the collector voltage will rise quickly to 12 V, because D1 is blocking and the capacitance of the gate does not affect this process. However, the gate is connected to this point via emitter follower T2. T2 ensures that the gate is connected quickly and through a low impedance to (nearly) 12 V.

In the example a voltage of 12 V is used, but this could easily be different. Note that if you're intending to use the circuit with 24 V, for example, that most FETs can tolerate only 15 or 20 V of gate voltage at most. It is therefore better not to use the driver with voltages above 15-V.

We briefly mentioned the 4000 series a little earlier on. There are two exceptions: the 4049 and 4050 from this series are so-called buffers, which are able to deliver a higher current (source about 4 mA and sink about 16 mA). In addition this series can operate from voltages up to 18 V. This is the reason that a few of these gates connected in parallel will also form an excellent FET-drive (see **Figure 3**). When you connect all 6 gates (from the same IC!) in parallel, you can easily obtain 20 mA of driving current.

This looks like an ideal solution, but unfortunately there is a catch. Ideally, these gates require a voltage of 2/3 of the power supply voltage at the input to recognize a logic one. In practice it is not quite that bad. A 5 V microprocessor system will certainly be able to drive a 4049 at 9 V. But at 12 V things become a bit marginal!

(060036-1)

Campsite AC Monitor

"I packed my bag and in it I put…"

Ton Giesberts (Elektor Labs)

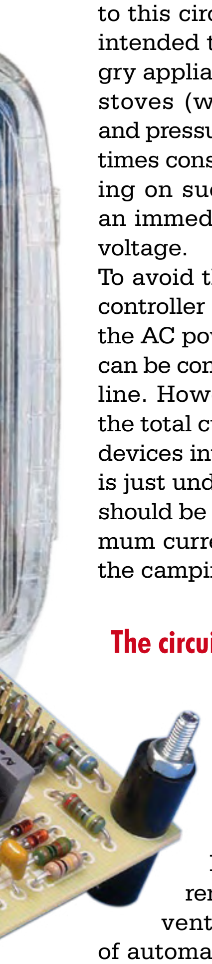
Those of you who go camping regularly will have experienced this before: you switch on a high-power stove burner just when the fridge is on and the campsite fuse blows. It's a pain because the campsite manager usually has to be called to replace or reset the fuse and the exercise can cost a lot of money. This campsite AC monitor makes these events a thing of the past.

Campsite power hookups usually have a limit on the amount of current that can be drawn. When a larger current is drawn it trips a circuit breaker, which usually has to be reset by the campsite manager and probably results in a fine (or "service charge") to be paid. To prevent such inconveniences we have designed this controller that can quickly limit the maximum current drawn.

Primary operation

This circuit prevents the current from increasing after a presettable value has been reached. One consequence of this is that electronic devices (such as TV sets, radios, and energy-saving light bulbs) must not be connected to this circuit. The circuit is primarily intended to be used with power-hungry appliances such as electric ovens, stoves (without electronic controls) and pressure cookers. These can sometimes consume as much as 3 kW. Turning on such an appliance can cause an immediate drop in the power line voltage.

To avoid this, it's best to connect the controller between these devices and the AC power line. Smaller appliances can be connected directly to the power line. However, you still have to take the total current consumption of these devices into account. For example, if it is just under 1 A the controller setting should be one amp less than the maximum current that can be drawn from the camping hookup.



The circuit

At the heart of the circuit is IC1, a U2008B made by Atmel (see **Figure 1**). This 8-pin phase controller requires only a few external components. The IC can sense the load current, which is ideal for the preventing an overload. Inclusion of automatic retriggering means that inductive loads won't be a problem. The IC also offers a soft-start function (connect a capacitor between pin 1 and ground) or detection of the load current via a shunt resistor in series with the triac (also between pin 1 and ground). We've chosen to use the soft-start function here.

The current through the load is measured using a shunt resistor in series with the triac. A separate detector circuit drives the control input (pin 3) of the IC.

The (negative) supply voltage of the circuit is internally regulated by the U2008B. In our prototype the voltage was found to be just below 16 V. The IC needs at least 3 mA, the rail-to-rail opamp (TS922IN) used here needs at most 3 mA (unloaded), the LED needs 4 mA (pulsed), and the reference needs 1 mA. This is the reason for increasing the current of the supply for the U2008B to 10 mA. For this we've used two 4.7-kΩ, 5-watt resistors and D1 in series with the AC line connection. The voltage across C4 is actually determined by the average current through R1 and R2. This current can be calculated using the following formula:

$$(U_{line} - U_{supply}) \times \sqrt{2} / [\pi (R1 + R2)]$$

We've ignored any voltage drop across D1. This formula is very similar to the one for the resistor found in the datasheet for the U2008B.

The effective value of a half-wave rectified voltage is $U_{peak}/2$. The average value, however, is U_{peak}/π. Because of the half-wave rectification, the heat generated in resistors R1 and R2 (U^2/R) is about 2.5 times as much as it would be for a DC current with a value equal to the average value of an AC current. From a safety aspect we decided to use two 5-watt resistors for R1 and

Technical specification

- For 230 VAC or 110 VAC campsite power hookups
- Limits at 3 A, 4 A, 5 A, 6 A, 7 A, 8 A, or 10 A
- Indicator LED
- Activation level configurable by jumper or rotary switch

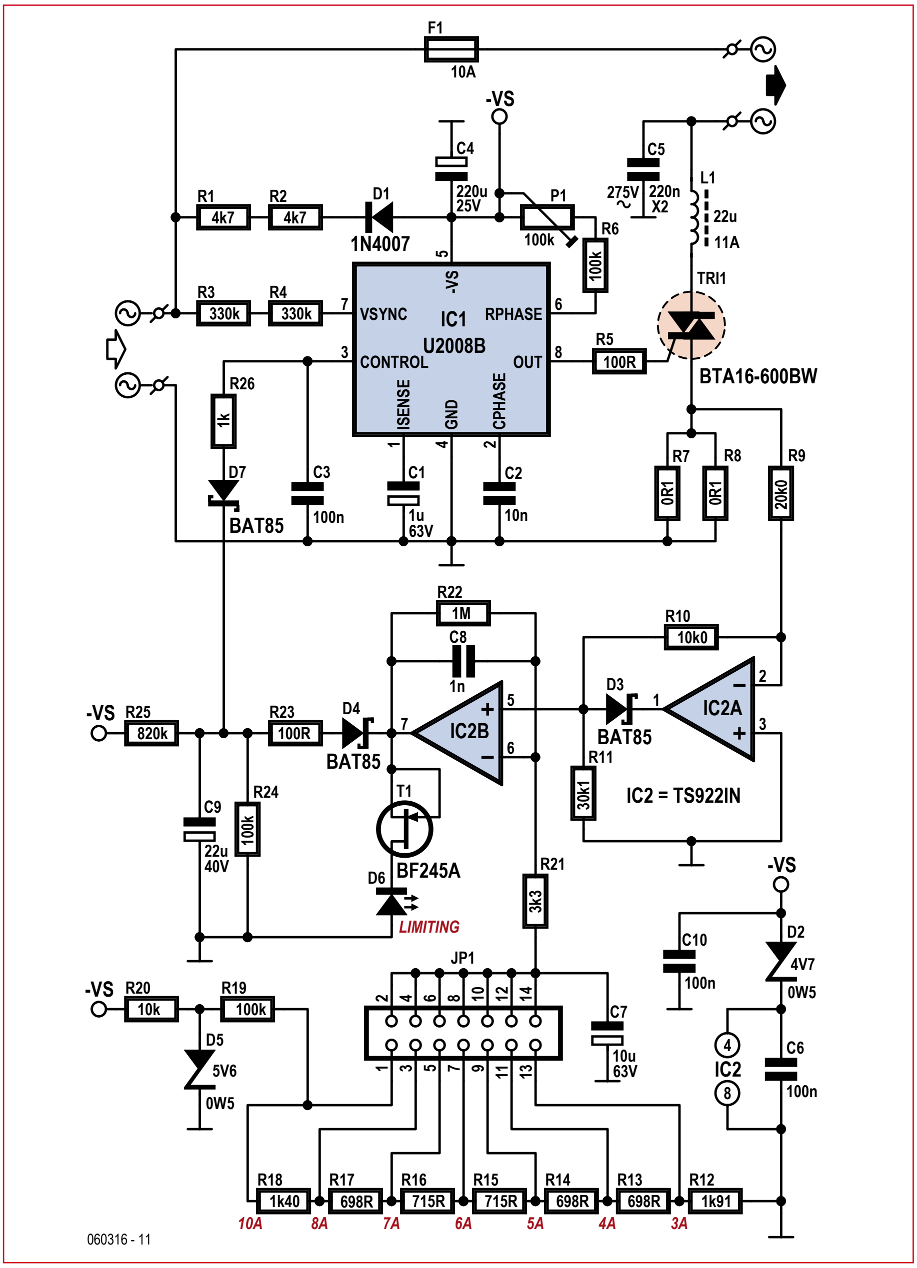


Figure 1. The circuit diagram of the campsite AC monitor shows that it isn't an easy to limit the AC line current.

R2, even though the total dissipation is only 2.5 W.
The supply voltage for the opamp should not be greater than 12 V. A Zener diode (D2) is connected in series with the supply to keep the voltage within safe limits.

Limiting

The circuit is designed for 230 VAC power lines. The above formula and the description of the circuit operation should allow adaptation to 110–117 VAC systems by changing relevant component values.
We decided not to make the threshold for the limiting adjustable, but instead is half of the input signal. The rectified signal is fed to comparator/amplifier IC2b, which compares the peak value of the current to the reference setting.

The reference can be chosen from seven values, which are configured for current limits of 3, 4, 5, 6, 7, 8, and 10 A. Jumper JP1 selects the desired limit. The speed at which IC2b switches is limited somewhat by C8, R22 and R21 in order to obtain a stable output. Any spikes, glitches, or other high-frequency interference is filtered out by these components. The pulse at the output of IC2b that is produced when the current reaches the limit is used to generate the control voltage for IC1. load resistance means that the current pulse becomes shorter and greater in amplitude. The control voltage across C9 then increases. The advantage of this is that the peak currents aren't as large.

Reference

The reference voltage is derived from a standard 5.6 V Zener diode (D5), which has a current flowing through it of about 1 mA, set by R20. The reference voltages for IC2b are relatively low and lie between 90 mV (3 A setting) and 340 mV (10 A setting). These voltages are generated by the voltage divider formed by R12–R19.

Meters don't lie, or do they?

The supply voltage for the U2008B is internally regulated. Our circuit hardly differs from the standard application. The only difference is that our circuit requires a higher current. We designed the supply for a current of about 10 mA, as mentioned in the article. However, during the test and measurement phase we learned a few things about RMS multimeters.

C4 is charged by a single-phase rectified current. Theoretically, the average value of a pure sine wave is 2Upeak/π, which also applies to a full-wave rectified sine wave. The effective value is also the same in both cases: Upeak/√2. This is where the well-known crest factor of 1.11 (π/2√2) comes from. Things are very different when we're dealing with a half-wave rectified sine wave. The average value is Upeak/π, but the effective value is a lot larger: Upeak/2. If we use a standard AC voltmeter to measure the voltage across R1 and R2 (and leave the blade terminal disconnected), we measure the average value. In our case, at our castle (Elektor House) with a somewhat low line voltage, it is only 220 VAC instead of 230 VAC. The peak voltage across R1 and R2 is then √2×220 – 16.6 V. The average value should be about 94 V, which is also what we measured. If we now use a true-RMS meter we expect to see the peak voltage divided by two, which is 147 V. The strange thing is that the true-RMS meter shows 115 V. Our first thought was: "Perhaps something is wrong with the meter; after all, it's getting old?", but another meter (from the same manufacturer, but newer) gave exactly the same result. A more advanced meter provided the solution. This was able to measure combined AC and DC, and it displayed the expected 147 V. It appears that many true-RMS meters can't cope with a DC component. This specifically indicated on most meters that can do so, and you should bear this in mind.

This also applies to digital (square-wave) signals and the like, not just half-wave rectified sinusoidal signals. This just goes to show that you have to know what you're measuring and select an appropriate meter accordingly, as the wrong choice can lead to an inaccurate result.

have a jumper on the board that selects one of seven limits via a 14-pin header. This also give you the option of using a (rotary) switch to make the setting. The shunt consists of two 0.1 Ω, 5 W resistors connected in parallel. At 10 A the power dissipation is only 5 W, and at the lower end of the scale the voltage can still be measured without any extra amplification.
The measured signal is first rectified. A simple full-wave rectifier is built around IC2a. When the signal is positive IC2a acts as an inverting amplifier and the voltage across R11 via D3 is determined by the ratio of R10 and R9, so the signal is attenuated by a factor of 2. The attenuation is necessary because of the simplicity of the full-wave rectifier; with this particular design only one diode is required.
When the signal is negative the output of IC2a stays at ground level and D3 is reverse-biased. R9–R11 now form a voltage divider. The voltage across R11 Junction FET (JFET) T1 is configured as a current source and drives an LED that lights when limiting is active. The current source is necessary because when a resistor is used a small pulse will hardly light up the LED (even when a low-current device is used). C9 is charged via D4 and R23. The voltage across C9 provides the control signal for IC1 via D7 and R26. C3 provides extra decoupling.
Due to the adjustment range of the control input and the amplification of the measured signal, the load current must increase a certain amount before the voltage can be reduced to its minimum value. This increase is about 1 A. Because of this, the reference voltage levels have been set to a slightly lower value than is indicated on the board. Limiting thus occurs a little bit before the current limit is reached.
As the overload increases, the limiter reduces the load current a bit further below the selected value. The lower For the calculations we assumed that about 50 μA flows through the resistor network. The voltage across Zener diode D5 will be less than 5.6 V. For this reason we chose a value of 100 kΩ for R19. The total resistance of R12–R18 can then be neglected and the current remains fairly constant. The resistor values are then easy to calculate.
C7 decouples the reference voltage selected via JP1. There is some non-linearity present in the feedback loop, because the initial increase of the phase angle has much less of an effect on the effective voltage than when the phase angle is changed at 90 degrees.
The controller also has a dead zone. Because the control input only becomes active when the voltage is less than minus 2 V, the load current has to increase by about 0.2 A relative to the selected current before limiting starts. This is another reason for making the thresholds a bit lower than indicated.

The resistor values for the divider were rounded to values in the E96 range, as otherwise the total error would be too high.
P1 is used to set the maximum phase angle. At the lowest setting it is still possible to limit the current to 3 A during a large overload; otherwise it stays a bit lower.

Heatsink

For the triac we selected a snubberless type made by STMicroelectronics, the BTA16-600BW. This triac is available in an insulated version (still with a metal tab) and can handle 16 A. The BW version needs a trigger current of at least 50 mA. The value of 100 Ω chosen for R5 provides a gate current slightly higher than this.
The disadvantage of the insulated version is a higher internal thermal resistance: 2.1 K/W instead of 1.2 K/W. On top of this, the maximum permitted junction temperature is only 125 °C. The voltage across the triac is partially dependent on the junction temperature. At 10 A the voltage at a junction temperature of 125 °C is about 0.25 V lower than at 25 °C.
For calculating the size of the heatsink we assumed that the ambient temperature could be 50 °C. This may seem high, but if the circuit is housed in a case and located in a trailer it could be even higher in the summer. The dissipation at 10 A is about 11 W. The maximum total thermal resistance must be:
(125 – 50 °C) / 11 W = 6.8 K/W.

This value is reduced by 2.1 K/W and 1 K/W for the triac and the insulation.

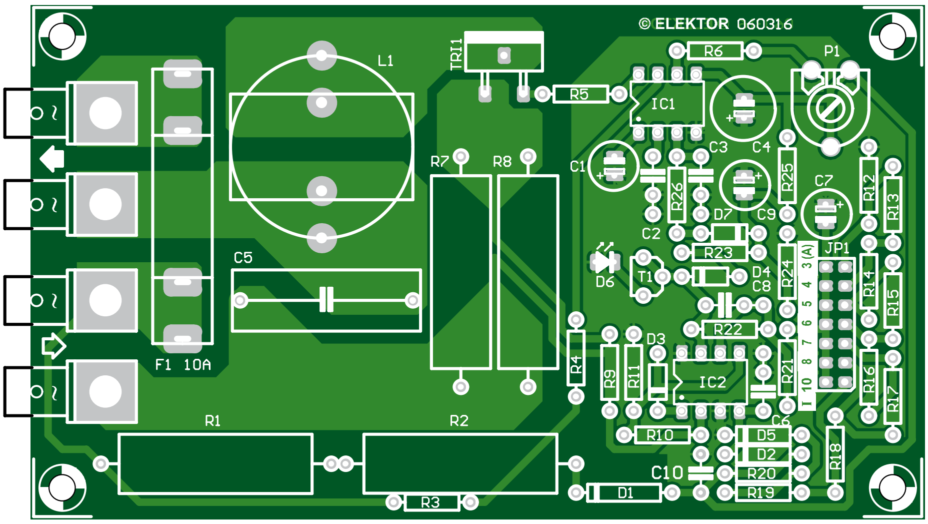


Figure 2. You can see from the component layout and the lighter track layout that the AC section is more spacious in order to comply with electrical safety regulations.

COMPONENT LIST

Caution:
Circuit designed for 230 VAC power. Refer to the circuit description for component changes to suit 110–117 VAC systems.

Resistors
R1,R2 = 4kΩ7 5W, lead pitch 30mm max.
R3,R4 = 330kΩ
R5,R23 = 100Ω
R6,R24 = 100kΩ
R7,R8 = 0Ω1 5W, lead pitch 30mm max.
R9 = 20kΩ0
R10 = 10kΩ0
R11 = 30kΩ1
R12 = 1kΩ91
R13,R14,R17 = 698Ω
R15,R16 = 715Ω
R18 = 1kΩ40
R19 = 100kΩ
R20 = 10kΩ
R21 = 3kΩ3
R22 = 1MΩ
R25 = 820kΩ
R26 = 1kΩ
P1 = 100kΩ preset

Capacitors
C1 = 1µF 63V, radial, lead pitch 2.5mm, diam. 6.3mm max.
C2 = 10nF, lead pitch 5mm or 7.5mm
C3,C6,C10 = 100nF, lead pitch 5mm or 7.5mm
C4 = 220µF 25V, radial, lead pitch 2.5mm, diameter 8.5mm max.
C5 = 220nF 275VAC X2, lead pitch 22.5mm
C7 = 10µF 63V, radial, lead pitch 2.5mm, diam. 6.3mm max.
C8 = 1nF, lead pitch 5mm or 7.5mm
C9 = 22µF 40V, radial, lead pitch 2.5mm, diam. 6.3mm max.

Inductors
L1 = 22µH 11A, e.g. Murata Power Solutions 1422311C (Farnell order code 1077056)
or
22µH 10.3A, e.g. 2205-V-RC (J.W.Miller Magnetics), Digi-Key # M8868-ND

Semiconductors
D1 = 1N4007
D2 = 4.7V 0.5W Zener diode
D3,D4,D7 = BAT85
D5 = 2.7V 0.5W Zener diode
D6 = red low-current LED
T1 = BF245A
TRI1 = BTA16-600BWRG (TO220AB insulated) (Farnell # 1175636)
IC1 = U2008B (Atmel), 8-pin DIP
IC2 = TS922IN (ST), 8-pin DIP

Miscellaneous
K1 = 14-pin (2x7) pin header + 1 jumper
F1 = 10A 1¼” x ¼” e.g. Farnell # 1175149 + 2 fuse clips 15A rated, Farnell # 1175125
4 AMP connectors , M4 screw mounting, + 4x 10 mm M4 bolt + nut + washer + locking ring
Ceramic insulator, 4.5mm, e.g. type AOS220SL (Fischer Elektronik)
Heatsink for 10A: R_{th} < 3.7 K/W (< 9.4 K/W for 6A max.)
PCB # 060316-1 from www.thepcbshop.com

The heatsink used should therefore have a thermal resistance of less than 3.7 K/W to provide sufficient cooling for the triac at the maximum current of 10 A.
If the maximum available current at your favorite campsite is only 6 A, you can use a smaller heatsink:

$$(125 - 50\ °C) / 6\ W - 2.1 - 1 = 9.4\ K/W$$

This calculation shows that a few amps difference results in a big change in the size of the heatsink.
We should make one thing clear though: these calculations are based on the maximum rated operating temperature of the triac. This isn't beneficial for the lifespan of the device. If you want the triac to live to a ripe old age, it's better to keep it nice and cool.

Printed circuit board

Since the circuit board is single-sided, the 10 A tracks require a certain minimum amount of copper, and the triac is at the edge of the board for ease of assembly, we decided to use a thick ceramic insulator (see the components list). This insulator wasn't chosen to comply with electrical safety regulations, as they are already covered by the internal insulation of the triac. It provides more space on the board for the A2 pad of the triac (with the non-insulated version this is also the tab). The pads for the gate and A1 are located a bit further away from the triac in order to make more room for the copper to the A1 pad.

Due to the large currents involved, we didn't scrimp on copper for the connections to the other components (F1, L1, R7, R8, and the AC line and load connectors). For the 10 A fuse, there are two separate fuse clips for a 32-mm fuse mounted on the board. These clips are rated at 15 A. The pads for L1, R7 and R8 are formed without the usual thermal reliefs. This does mean that you will need a higher- power soldering iron to solder these components than for the rest of the components.

For the load and AC line connectors we used automotive blade (AMP) connectors that are attached to the board with 4-mm screws. The distance between these connectors is slightly more than the minimum required 3 mm. When you screw the connectors in place you must make sure that they are mounted perfectly straight. On the prototype they were fitted on the component side, but depending on the way the board is housed, you may consider fitting them on the solder side. This has the advantage that losses caused by the resistance of the screw connection are avoided. You should still make sure that there is a minimum separation of 3 mm between the connectors (and PCB tracks) that carry AC line voltage.

The current limits are clearly marked on the board next to JP1. To reduce the stress on the solder joints, it's advisable to form a small S-shaped bend in the leads of the power resistors before soldering them onto the board (this also applies to the middle lead of triac A2).

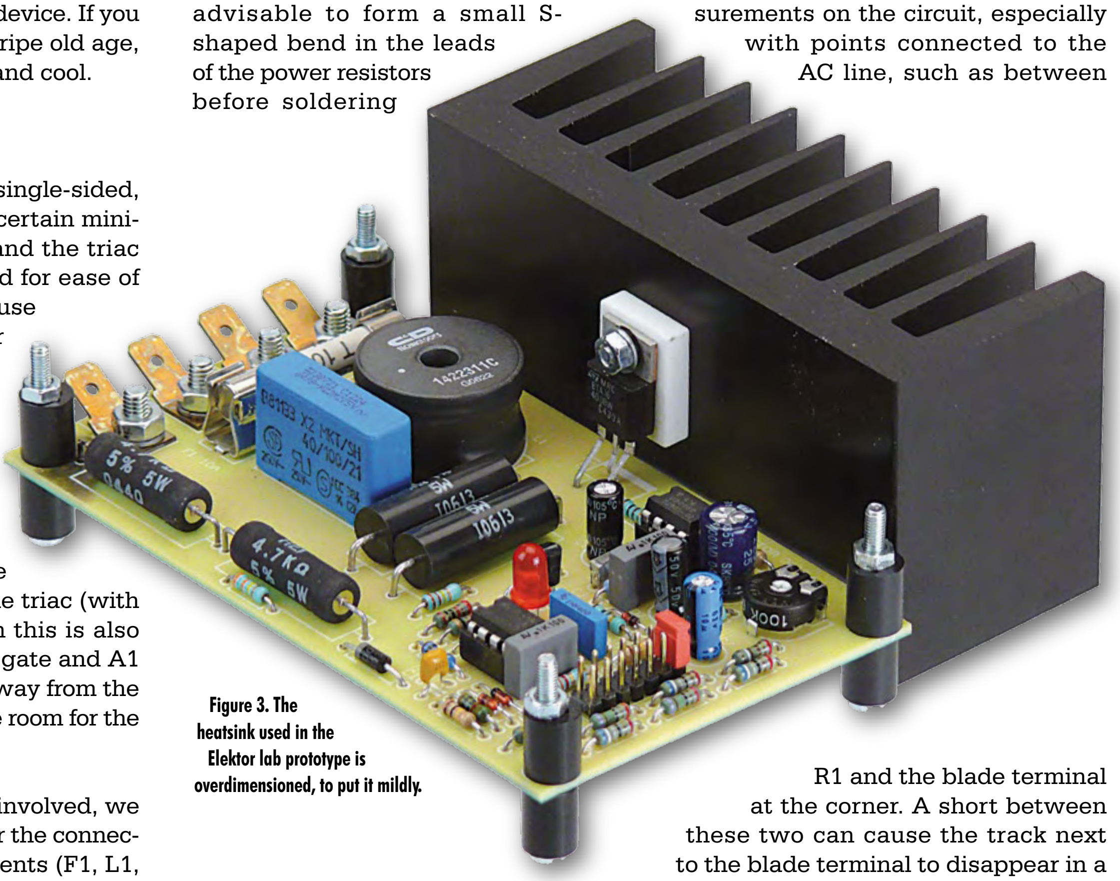


Figure 3. The heatsink used in the Elektor lab prototype is overdimensioned, to put it mildly.

Safety and grounding

Since the triac is positioned at the edge of the board, it's easiest to mount the heatsink at the edge of the board as well. To comply with insulation requirements, you should put some insulating tape between the heatsink and the board (because of the required 3 mm separation). For safety reasons the heatsink must be grounded.
The controller is intended for use as a Class-I electrical device. This means that if it's part of a distribution panel it should include a reliable safety ground lead. An LED is connected to the output of IC2b to indicate when the circuit is limiting the current. The entire circuit is connected directly to the AC line, including the LED. For this reason the LED may not be mounted such that it protrudes through the case and can be touched. It is thus best to fit the LED close to the board.

For your own safety you should disconnect the circuit from the AC line when changing the jumper setting (or use a well-insulated set of pliers). You must also be very careful when making measurements on the circuit, especially with points connected to the AC line, such as between R1 and the blade terminal at the corner. A short between these two can cause the track next to the blade terminal to disappear in a puff of smoke, as we learned the hard way during testing.

The way in which this circuit is housed depends whether you want to build it into an existing installation or you want to create a sort of enhanced distribution panel. You should also bear in mind the size and temperature of the heatsink and the amount of heat dissipated.

(060316-I)

A Three-Dollar Light Box

Recycling a backlit TFT or LCD monitor

Daniel Arnaud (France)

Recycling (including destructive recycling) is undoubtedly necessary so that future generations will suffer as little as possible from present-day excesses in consumption across the planet. But before destroying and recycling equipment that can no longer be used for its intended purpose, it's sometimes possible to find another use for it at minimal cost, thereby postponing its ultimate recycling.

It all started when I bought a faulty TFT monitor via the Web at a "pocket money" price, intending to use parts from it to repair another monitor I had with a PSU fault. Unfortunately, the PSU in the model I'd just bought turned out not to be compatible. Disappointed, I decided to recover whatever I could, and I started to dismantle the monitor, which was cracked and displayed only half of the screen image. In light of what I discovered while I was dismantling it, a little glimmer soon turned into a bright idea (pun intended): *why not re-use the backlight?*

A TFT monitor consists of a TFT (or LCD) panel which produces the image, and behind this panel another thicker one consisting of a sheet of Perspex® with backlighting around all four sides and a coating that diffuses a very neutral white light.

So the first operation consists of dismantling the monitor (which must, of course, at least be able to light up), leaving only the panel with its electronics hidden behind a sheet-metal screen (**Figure 1**). Then carefully dismantle the screen and the TFT or LCD panel, which is often held in place by a piece of black adhesive tape that must be removed so you can detach the screen and disconnect its connector. Be careful: it's made of quite thin glass and breaks easily (depending on local regulations, dispose of this in the general waste container, not in the glass recycling bin).

At this stage, if you plug the monitor back in you'll be surprised to find you have a superb white luminous panel. But the satisfaction is short-lived, since the screen switches off after about 30 seconds or so in the absence of a video signal. The solution is to find the control connection of the high-voltage generators for the backlight tubes and use a resistor with a value of a few kilo-ohms to pull this pin up or down to the appropriate logic level so it stays lit all the time (**Figure 2**).

All that then remains is to remove the control panel, which is not used in this application, optionally attach a sheet of transparent plastic to protect the diffusing surface, and mount the whole thing in a housing of your choice. Be careful with the lamp tube HV generators, whose voltage is in the range of 900 V.

Applications for this light box are left to your imagination: checking PCB negatives (**Figure 3**), for an advertising sign, customizable ambient lighting, or even a large-format photo frame for displaying enlarged transparencies.

(081168-I)

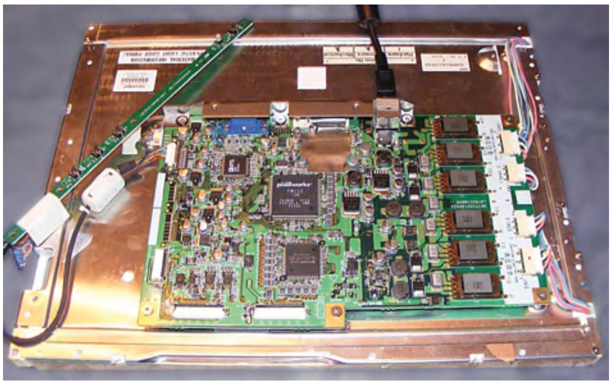


Figure 1.
The panel with its electronics hidden beneath a sheet-metal screen.

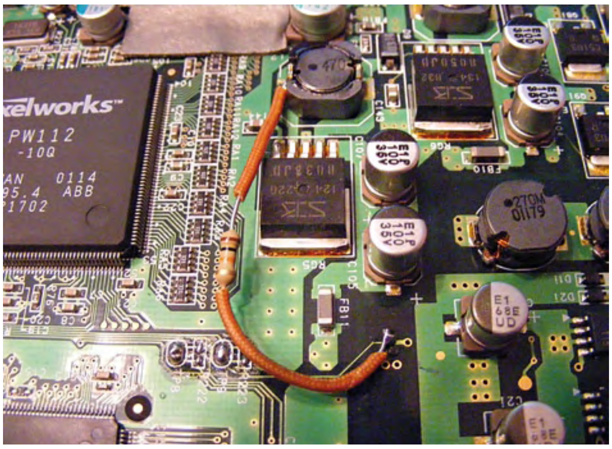


Figure 2.
Just one resistor makes it possible to keep the backlight lit all the time.

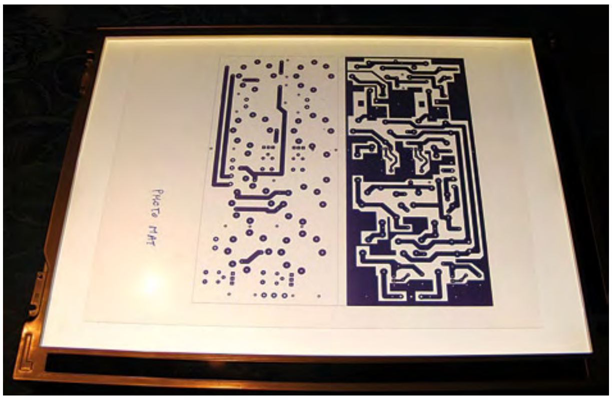


Figure 3.
An ideal unit for checking PCB negatives.

Getting Started wit

Part 2: C functions and a coffee

A.J. (Bert) Korthof (The Netherlands)

The first installment of this short course looked at the hardware and took the first steps in programming the MSP430 board using the IAR Embedded Workbench software. Now we continue with a description of a number of frequently used C functions. In addition we deal with reading pushbuttons, and we program a complete coffee machine. At the end it's time for a bit of fun, with a little game using the 7-segment display.

Every program includes the function main() and a number of other functions, each containing the appropriate functionality in a well-organized way. Note that functions have to be declared first, so that the compiler can take them into account when making the conversion to machine code.
In this course the following functions will be used (among others):

```
void delay(unsigned int);              // adjustable delay
void tick(void);  // small beep
void init_elektor_board(void);         // initialization of the MSP430
void set_7segment(int, int );          // display a number on the 7-segment display
```

An example of the structure of a C program is shown in **Figure 1**. The program begins with main() and runs through all the statements one after the other (sequentially). Sometimes certain sections of code are skipped. This is determined by a statement with an expression which can be either true (1) or false (0), for example with the **if-else** command:

```
if (expression)
{
      /* do something */
}
(when expression = false  skip "do something"!)
```

or by:

```
if (expression)         // if expression = true
{
    /* do something */
}
else             // if expression = false
{
    /* do something else */
}
```

Sections of code are often repeated in program loops. These loops can be made by using:
- for (expression; expression; expression) {statements}
- while (expression) {statements}
- do {statements} while (expression)

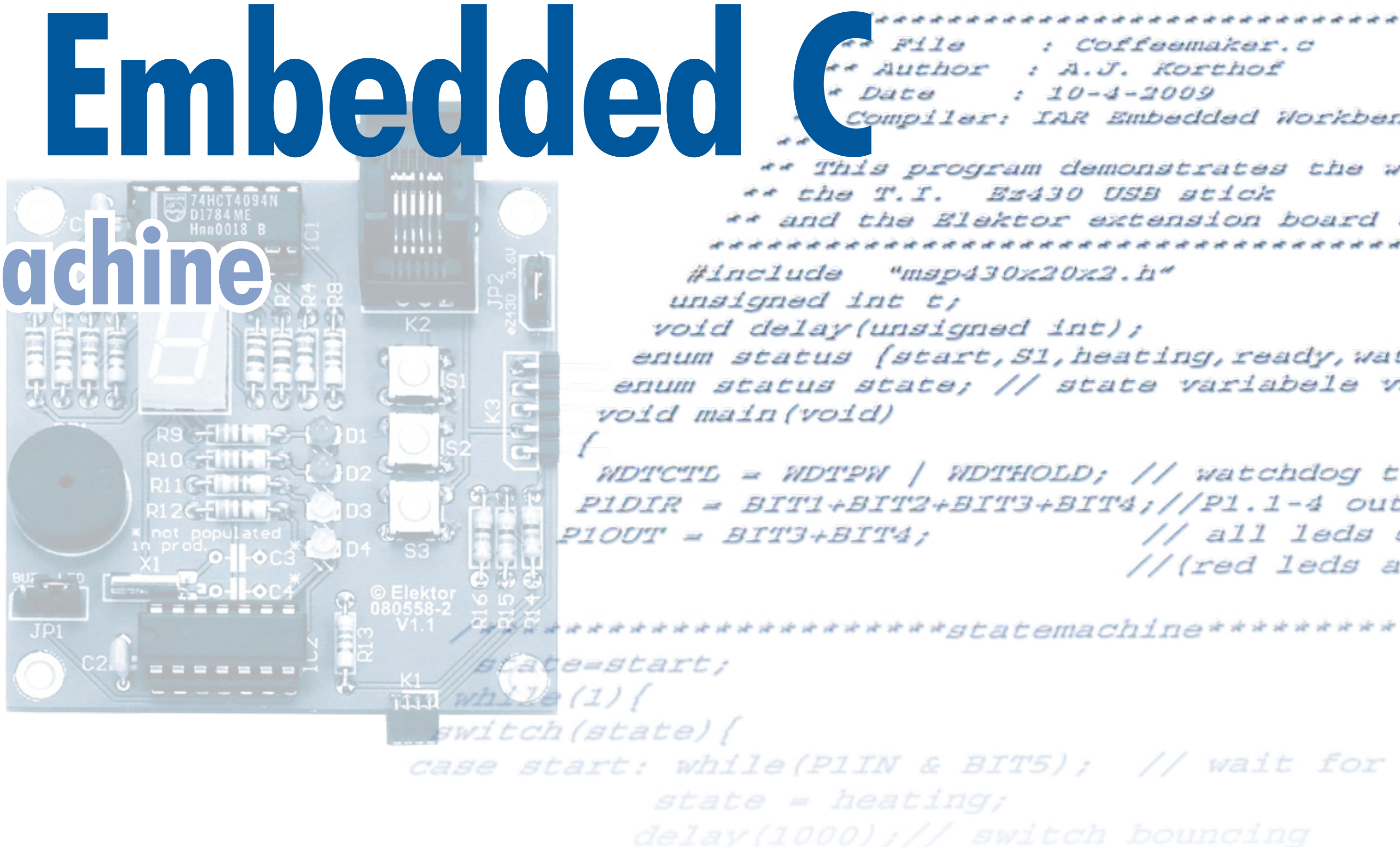
Some examples of expressions are:

- if (a >=b) means: if a is greater that or equal to b
- while (a == b) means: as long as a is equal to b
  (note: a = b means that a is assigned the value of b)

You can also perform standard mathematical operations in C. You have to take into account the size of the numbers when doing this. For this processor, **int a** is a variable a from –32768 to +32767 (16 bits); **unsigned int b** is a variable b from 0 to 65535. If you want to work with bigger numbers, you can use **long int** (32 bits) or even bigger yet with **float**. In the latter case, numbers are displayed in scientific notation (powers of 10, such as 1.234E10+8).
C is aware of the following mathematical operators:
add (+); subtract (–); multiply (*); divide (/); remainder after division (%).
Try it for yourself: take the file BlinkingLeds.c from Part 1 and change **unsigned int i;** into **unsigned int i,a,b,c,d;**.
Add the following code in main above the while(1) loop, for example:

```
a=10;
b=3;
c=a/b;
d=a%b;
```

h Embedded C machine



Enter the variables c and d in the Watch window (look under the View tab). By single-stepping through the program you will see that c gets set to the value 3 and d is assigned the value 1 (10/3 = 3 with remainder 1). Make sure that “Release JTAG on Go” is not ticked (under the Emulator tab).

Reading buttons

Next, let’s have look at how to write code in C for reading the state of the pushbuttons. On the MSP430 board the buttons S1, S2 and S3 are connected to port pins P1.5, P1.6 and P1.7 respectively. The buttons have pull-up resistors to the positive supply voltage. In this case the port pins have to be defined as inputs, which is the default setting for port P1. When you push the button, the input signal is pulled to GND, so it is a low level, and in the C language this means “0” or not true (false). You could execute the following instruction (S1 is declared as unsigned int S1).

```
S1 = P1IN & BIT5;
```

Only when the processor executes this instruction is the logical value of pin P1.5 determined by taking the AND function. The result can be either S1 = 0 x BIT5 = 0 or S1 = 1 x BIT5 = 1 x 00100000 = 32 (decimal). Due

```
#include  “msp430x20x2.h”
void delay(unsigned int);
void set_7segment(int, int );         // declare function and variables
unsigned int t;

void main(void)
{
                                      // main program for calling the functions
   delay(100);
   set_7segment(3,1)
   …
}

void delay(unsigned int k)
{                                     // definition of the function
   int i;
   …
}
void set_7segment(int nr, int dp)
{
   …
}
```

Figure 1. Example of the structure of a C program.

Figure 2.
Your aim is to simulate the three operating buttons of this popular coffee machine in a C program.

to the AND function with BIT5, only port pin P1.5 has an effect on the value of S1.

You can conveniently use the if statement to test whether the button is pressed:

```
if ((P1IN & BIT5)== 0)
{… execute these statements when button is pressed …}
else
{… execute these statements when button is not active …}
```

An expression is not true (false or "0") if the result equals 0; all values greater than 0 (such as 32) count as true (or "1"). Because the program has to react to the push of a button, you have to include the instruction above in a loop so that it is executed periodically. In Part 3 of this course you will see that you can an interrupt instead, which reacts immediately to the button push.

Here's a snippet of code from the file *LoopsJumps.c*, which can be downloaded from the Elektor website (file 090251-11):

```
if ((P1IN & BIT5)== 0)   // switch S1 active
{
    do
    {
        P1OUT |= BIT1;   // red led 1 on
        delay(3);
        P1OUT &= ~BIT1;  // red led 1 off
        delay(3);
    }
    while(P1IN & BIT6); // repeat until S2 active
```

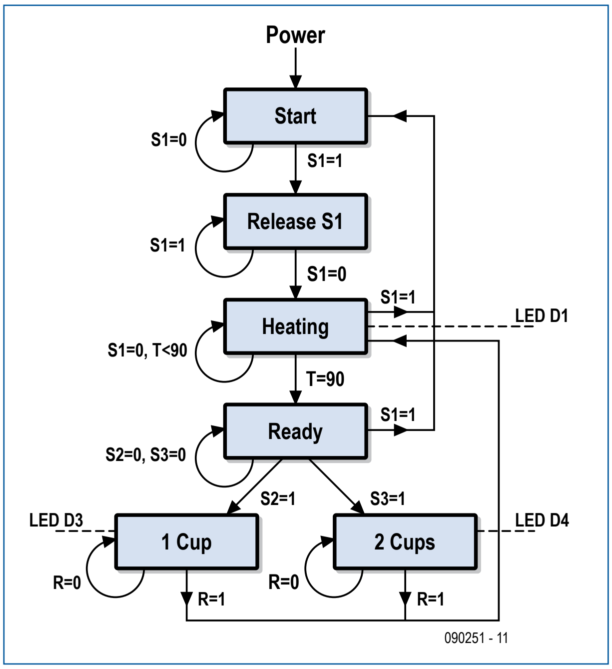


Figure 3.
The state diagram for the coffee machine.

When S1 is pushed, the if statement block will be executed. The red LED D1 will continue to flash while button 2 is held down. The program will then continue (not shown here), but it will always turn the red LED D1 off because the while() instruction comes last.

As "homework" for the course you can single-step through *LoopsJumps.c* and explore all the possible options (loops and jumps) in the code. You could also draw a state diagram from the code; see below for an explanation.

A coffee machine

A good example of embedded C programming is generating the software for a microcontroller in a coffee machine. You start this by drawing a state diagram (state machine). Begin by defining the necessary states such as Start, Heating, Ready, etc. The transitions from one state to another depend on the input signals, which come from the pushbuttons on the appliance (see photo **Figure 2**). The middle button functions as the On/Off button, and on our board it is represented by pushbutton S1. When the appliance is heating the water, an LED in this button flashes (represented on the board by red LED D1). When the water has reached the correct temperature (90 °C), the LED is turned on continuously. To the left and right of this button are the buttons that indicate the amount of water required: 1 cup (S2) or 2 cups (S3). The state diagram is shown in **Figure 3**. To allow the software to be tested for correct operation, we've added a green LED D3 (for 1 cup) and LED D4 (for 2 cups), which are turned on when the coffee is poured.

The advantage of working with a state machine is that a button can have different functions depending on the present state of the machine. Pushing S1 in the *Start* state means start heating, but in the *Heating* state it means the opposite, which causes heating to stop and triggers a return to the *Start* state. To check the completeness of the state machine, you can check whether for each state all the arrows point to another (or the same) state for every combination of inputs. For example, there are two inputs that have an effect in the *Heating* state and cause a change of state, and two combinations that result in staying in the *Heating* state (water is not yet 90 °C and S1 is not active). S1 active means "go back to the *Start* state", and when the water is at 90 °C it means "go to *Ready*".
This state diagram is implemented in C code in *Coffeemaker.c* (available in file 090251-11 on the Elektor website).
Tip: when you are writing your own application software, it's often tempting to quickly start writing code without first considering what the state machine should look like exactly. Although this may result in a program without syntax errors, there's a good chance that it doesn't do exactly what it is supposed to do.
We use the "switch" statement in the *Coffeemaker.c* program. This is often used when you have to make a decision based on a variable which was set from a menu with multiple options. This could also be done with a series

```
state=start;
while(1){
   switch(state){
   case start: while(P1IN & BIT5);             // wait for button S1
      state = heating;
      delay(1000);                             // bounce suppression
      break;
   case S1: P1OUT &= ~BIT1;                    // LED D1 off
      while(!(P1IN & BIT5));                   // wait for the release of S1
      delay(1000);
      while(P1IN & BIT5);                      // wait for button S1
      state = heating;
      t=20;                                    // initial value for water temperature
      break;
   case heating:  do
      {
```

Figure 4.
A code snippet from the Coffeemaker.c program.

of if-else constructions, but the latter method is much less convenient.
Example:

```
int n;
...
switch (n)
{
    case 1: state1; break;     // go to option 1
    case 2: state2; break;     // go to option 2
    case 3: ...
    default: error();          //  show  error
message
}   // end switch statement
```

Depending on the value of n (1, 2, 3, etc), execution jumps to the corresponding case statement. If the value of n does not have a defined case, execution jumps to the default statement. Instead of assigning the states a number (data type **int**), you can also assign an order to a series of names by using the data type **enum**, such as **enum** days {Sunday, Monday, ...} or **enum** status.
A portion of the code in the Coffeemaker.c file is shown in **Figure 4**.

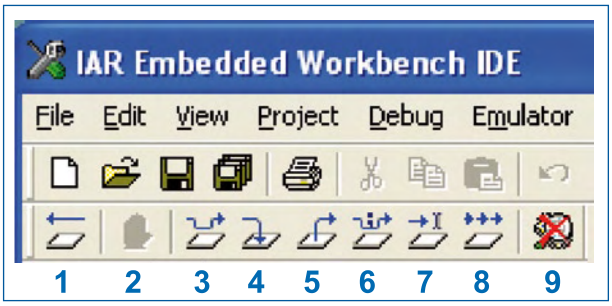


Figure 5. The debug options of IAR Embedded Workbench.

A comments is in order here regarding the practical aspects of reading the states of pushbutton switches in software. Because a pushbutton is a mechanical system, the make contact usually vibrates after the button is pushed. This is called contact bounce. In the software you take this into account by building in a delay of 50 to 100 ms before testing the switch state again.
You can now load and compile the file, download it to the board, and run through the code step by step using the arrows (check again that the option "Release JTAG on Go" is not ticked in the Emulator menu). The debug options (see **Figure 5**) are:

1. Reset the processor; the program starts at the first line of main().
2. Stop execution. You will see a green bar over the last instruction reached by the program. The little hand is red when the program is running.
3. Execute one statement and wait.
4. Step into a function, for example delay(). This can take many steps.
5. Step out of a function.
6. Execute the next statement.
7. Run to the cursor location.
8. Run to the end of the program, execute an infinite loop, or run to a breakpoint.
9. Exit debug mode. Always do this before you unplug the board from the USB interface.

For more information, look in the Help menu.

You can easily set a breakpoint in the program by placing the cursor in front of the line and double-clicking; a red dot will appear. By double-clicking again you can remove this breakpoint.
When you single-step through the program, you will not go any further than the loop:

```
case start: while(P1IN & BIT5);
```

If button S1 is not pressed, the while loop is always true and it will not exit from this loop. By simultaneously pressing S1 and clicking arrow 3 or 5, you proceed to the next statement.
On reaching the state *Heating*, you find:

```
case heating:  do
               {
                   P1OUT ^= BIT1;
                   delay(65000);
                   t=t+5;
                   if(!(P1IN & BIT5)) t=90;
               }
               while(t < 90);
```

You can run through this loop much faster by directly assigning a value to the variable t and storing it in the memory of the MSP430 via the JTAG connection. You do this by selecting Watch from the View menu. The Watch window allows you to see the values of variables and change these values (double-click the value).

By stepping through the code one line at a time, you get a good understanding of how the state machine works.
If you want to change the code, you first have to exit Debug mode via button 9. After modifying the code, you can compile it again and re-flash the processor.

When you want to test the program in run mode, you have to select "Release JTAG on Go" in the Emulator menu. After that you can test the proper operation of the coffee machine using the pushbuttons.

7-segment display

While debugging the code, you probably noticed strange characters on the 7-segment display from time to time. This is because some of the I/O pins of the processor have more than one function. You used P1.1 for LED D1 and P1.5 for pushbutton S1, but these pins are also connected to the shift register that drives the display. We're sure that you don't want to wait for Part 3 of this C course to learn how to drive the display. For this you can use the routines generated for the Elektor eVents Embedded C Programming Workshop. Link the following three files to your project: *elektor_080558.c*, *elektor_080558.h*, and *Game1Elektor.c* (also in software package 090251-11).

If all is well, the program should compile without errors and you can flash the code into the microcontroller. When you run this program (button 8 in **Figure 5**), you will see the numbers 0 through to 9 appear on the display in very quick succession. You can make this into a little game by thinking of a number and trying to push S3 at just the right time to make that number appear on the display. The program that does this is very short, partly because it uses the function *set_7segment(i,0)*:

```
while(1)
{
    for (i = 0; i < 10; i++)
    {
        set_7segment(i,0);
        for (j = 0; j < 30000; j++);   // delay
        while (!(P1IN & BIT7));        // endless
loop while S3 is active
    }                                  // for i
}                                      //
while(1)
```

The while() loop that tests the state of pushbutton S3 (active low) is very short: **while() { };** or even shorter: **while();**. The while loop is executed when the expression between the brackets is true, which is only when S3 is pressed. The program remains in this loop and does not reach the for(;;) loop. The number will remain on the display until you release the button.

(090251-I)

Bert Korthof is a lecturer in the department of Automotive Technology and Electrical Engineering at Rotterdam University.

Hexadoku

Puzzle with an electronics touch

Hexadoku now also reaches our North American and Canadian readers and two of them even won a prize. It's very rewarding to see our monthly e-puzzle getting active response from all over the globe. All correct solutions we receive enter a prize draw for an E-blocks Starter Kit Professional and three Elektor Shop vouchers.

The instructions for this puzzle are straightforward.

In the diagram composed of 16 × 16 boxes, enter numbers such that **all** hexadecimal numbers 0 through F (that's 0-9 and A-F) occur once only in each row, once in each column and in each of the 4x4 boxes (marked by the thicker black lines). A number of clues are given in the puzzle and these determine the start situation.
All correct entries received for each month's puzzle go into a draw for a main prize and three lesser prizes. All you need to do is send us the numbers in the grey boxes. The puzzle is also available as a **free download** from 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 **$425**

and three **Elektor SHOP Vouchers** worth $55.00 each.

We believe these prizes should encourage

all our readers to participate!

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

PARTICIPATE!

Please send your solution (the numbers in the grey boxes) by email to:
hexadoku@elektor.com
Subject: hexadoku 06-2009 (please copy exactly).
Include with your solution: **full name and street address.**
Alternatively, by fax or post to: **Elektor Hexadoku**
PO Box 876 - Peterborough NH 03458-0876 - USA
Fax (+44) 208 2614447
The closing date is **1 July 2009.**

PRIZE WINNERS

The solution of the April 2009 Hexadoku is: **A2543**.
The **E-blocks Starter Kit Professional** goes to:
Jan ten Dam (The Netherlands).
An Elektor SHOP voucher worth $55.00 goes to:
Benoit Body (France); Todd Adams (USA);
Lars Risting (Sweden).
Congratulations everybody!

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

(c) PZZL.com

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

Air Ionizer

Negative is not always unhealthy

Ton Giesberts (Elektor Labs, The Netherlands)

The amount of negative oxygen ions in the ambient air seems to affect the psychological and physical state of many people. The air in the mountains and near the sea contains relatively high numbers of negative ions compared to elsewhere, and this is one of the reasons that you feel better in this type of environment. You can improve the air quality at home too by using the ionizer described here.

There are two good reasons for ensuring that there are enough negative ions in the ambient air. Firstly, ions are able to attach themselves to aerosols and dust particles. These then become heavier than the surrounding air and settle. Ions can also become attached to bacteria and germs, and make them harmless by electrically charging them. In this way the air is purified by removing dust and harmful organisms.

In addition, scientific research has shown that negative oxygen ions are essential for our metabolism. Breathing ionized air improves the oxygen concentration in the blood, which results in better functioning organs and improved cell metabolism. These negative ions also seem to influence the production of serotonin in our body, a hormone that in the brain, among other things, influences people's mood and self confidence. A greater amount of negative ions therefore ensures that you will feel better. Since the balance between the amount of positive and negative ions in the air at work or at home is often upset, adding negative ions can positively influence both the air quality and the mood of the people in a room. This can be done quite simply with the ionizer described here.

High voltage

What do we need to increase the amount of negative ions in the air? Not much: you only need a voltage which is high enough to cause the air at the point of a metal pin to be ionized. The oxygen ions produced this way easily spread through the air.

To do this, we designed a small generator which uses a converter followed by a cascade stage consisting of diodes and capacitors to generate a high voltage of 3.5 kV. The circuit uses standard components and does not contain an awkward transformer or other parts that are difficult to obtain. The component values are not all that critical either. You can certainly use a number of parts that you are likely to find in your parts box.

The schematic in **Figure 1** shows the design. For the power supply we assume a DC voltage of about 15 V, obtained from an AC adapter. The oscillator that we use here is a classic astable multivibrator with two transistors (T1 and T2). The frequency is set by R1/R2 and C1/C2 to a little more than 1 kHz. The two opposite-phase signals drive a power transformer

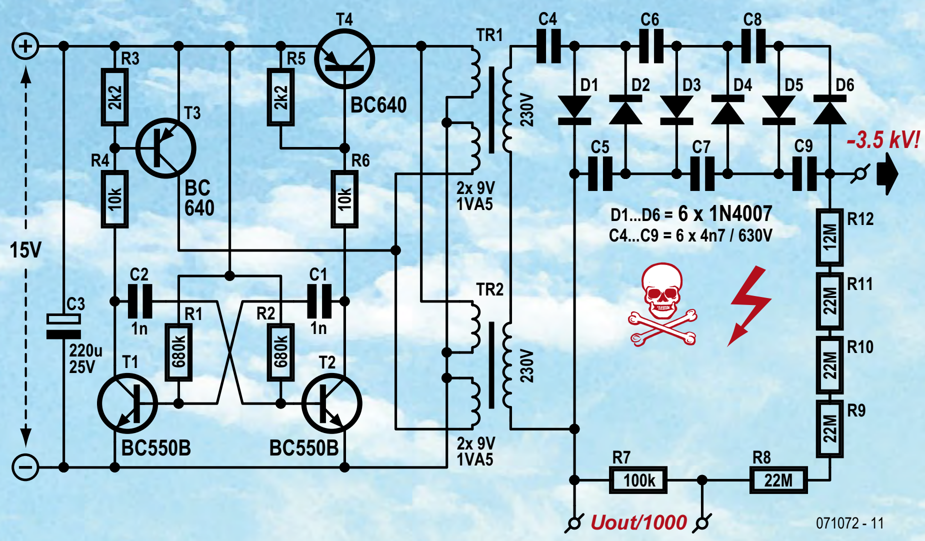
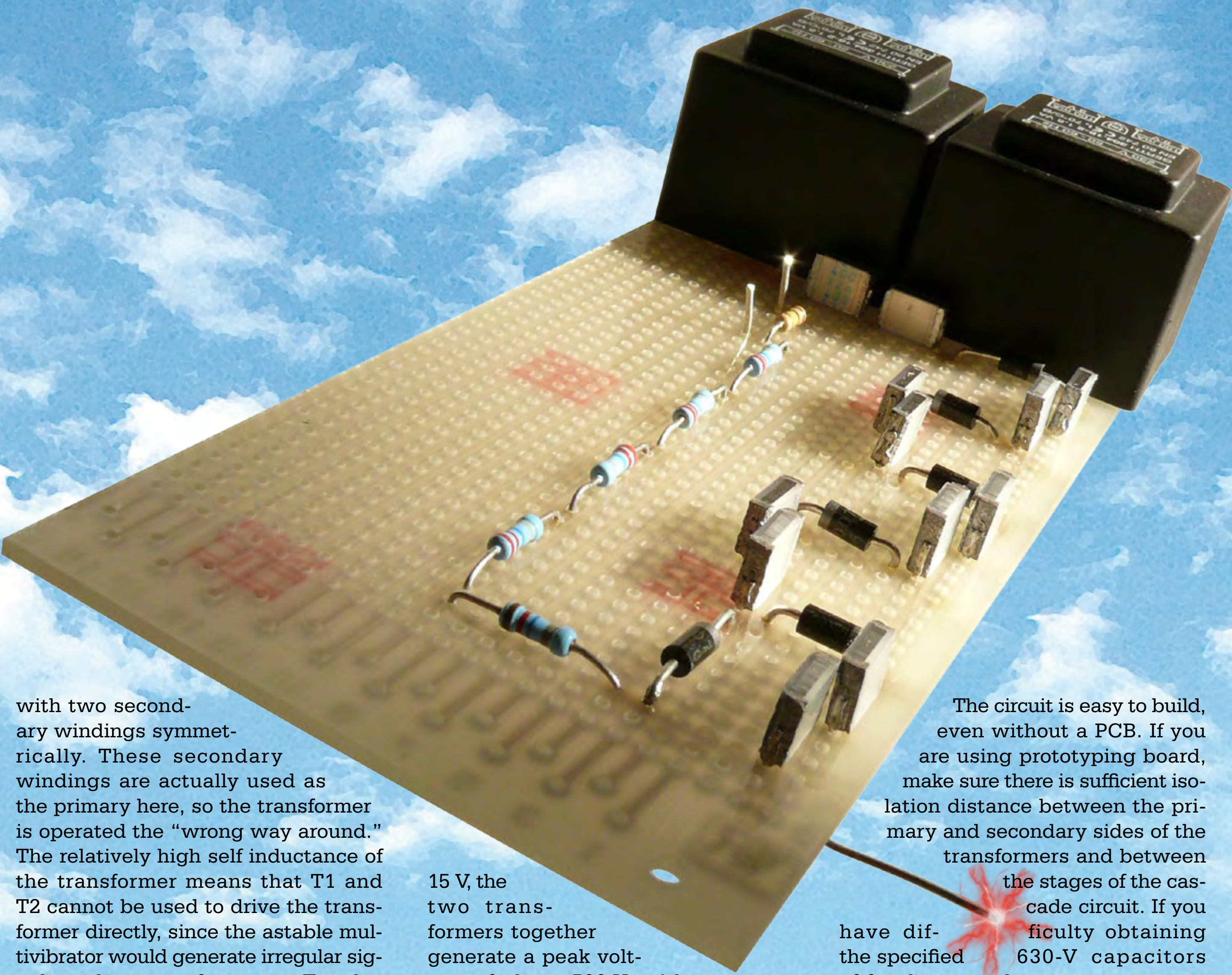


Figure 1. The ionizer circuit generates a high voltage of about 3.5 kV.



with two secondary windings symmetrically. These secondary windings are actually used as the primary here, so the transformer is operated the “wrong way around.” The relatively high self inductance of the transformer means that T1 and T2 cannot be used to drive the transformer directly, since the astable multivibrator would generate irregular signals at the wrong frequency. To solve this problem, two PNP transistors (T3/T4) are added. They can switch more current and handle a higher voltage, but are still housed in a TO-92 package (BC640, 80 V/1 A). R3 and R5 ensure that T3 and T4 do not turn on too early.

As you can see from the schematic, we actually use two small transformers here (small, short-circuit proof types, rated at 1.5 VA; you can use even smaller ones, for example 0.35 VA). The low-voltage windings (which are the primary side here) are connected in parallel, while the high-voltage windings are connected in series. In this way we immediately obtain twice the output voltage compared to using only a single transformer. The consequence of this is that the cascade network needs fewer diodes and capacitors (half as many in fact). The cascade, which consists of diodes D1 through D6 and capacitors C4 through C9, ensures that the peak output voltage is multiplied by six. With a supply voltage of 15 V, the two transformers together generate a peak voltage of about 500 V, with ringing up to nearly 600 V. After the cascade multiplier, the result is an output voltage of about 3.5 kV.

For measuring this voltage, a voltage divider is connected to the output. It consists of high-voltage resistors (type VR25 made by Vishay/BC Components, 1600 V_{DC}). This means that R8 through to R12 are not ordinary resistors. You can measure the output voltage divided by 1000 (or 1001 if you want to be exact) across R7. This voltage divider is not essential, but does enable you to check the actual output voltage. The input impedance of normal probe, even with an impedance 10 MΩ, would load the cascade way too much to allow the real output voltage to be measured accurately.

A needle with a sharp point is connected to the output. Here is where the ions are generated. It is also a good idea to connect a few high-voltage resistors between the output and the needle to limit the maximum current if the needle is touched.

The circuit is easy to build, even without a PCB. If you are using prototyping board, make sure there is sufficient isolation distance between the primary and secondary sides of the transformers and between the stages of the cascade circuit. If you have difficulty obtaining the specified 630-V capacitors of for the cascade, you can use two 12 nF/400 V MKT capacitors in series instead.

Never touch the high voltage side when it is energized. Also wait a while after turning off the generator to give the capacitors time to discharge.

Once the circuit is working well, it can be built into a suitable enclosure. Make a small hole in the case (5 mm diameter, for example) and fit the needle behind this hole in such a way that you cannot touch the point when the enclosure is picked up.

Place the enclosure somewhere in your office or living room (not too close to large metal surfaces), connect it to a suitable AC adapter, and let it do its job. After a while you will notice that the air seems to be cleaner and fresher, and you will also be in a better mood!

(071072-I)

Hewlett Packard Model 3300A function generator (1969)

Manoel Conde de Almeida (Brazil)

Agilent Technologies is renowned in the electronics R&D community for their high quality and high-tech products, and the company should be known even to those of you just starting out in the world of test and measurement. However, Agilent's current illustriousness is due to a large extent to an older company called Hewlett Packard.

More than ten years after the spin-off that gave birth to Agilent, it's not uncommon to see vintage Hewlett Packard T&M equipment operating faithfully and accurately in laboratories and electronics manufacturing departments, sometimes well hidden from the manager's view, showing no signs of fatigue and leaving no doubt that it was built to last. The function generator presented here was manufactured back in 1969 and is unquestionable living proof of this statement. Its frequency range is 0.01 Hz to 100 kHz for sine, square and triangle waves.

I acquired it in 1992 at an auction of used electronic equipment, for much less than its market value. The 3300A has been with me since then, playing an active role on my workbench whenever sinewave, triangle or square waves are required. It's amazing to see this old fellow, at its 40+ years of age, work almost like it was pulled from the original box.

Where does all that robustness and endurance come from? A closer look reveals the secret. The first thing you notice is the cabinet – entirely made from aluminum pieces cut, bent and stamped with high precision. Everything fits perfectly, revealing a design aimed to make the product easy to assemble, maintain and repair (even if that may never be called for). Markings and symbols are engraved on the front panel and look like they will be there, perfectly readable, for another 40 years. The black plastic knobs are shiny and show no cracks or any other sign of deterioration. The same can be said about the switches and potentiometers – no signs of mechanical or electrical degradation. The traces on the printed circuit boards are all gold plated and look shiny after all these years. Oxidation is an unknown phenomenon here. Wiring is kept to a minimum and components are all top quality, coming from remarkably few vendors, showing HP's tight criteria for component selection. The analysis of the electronic circuit (yes, a complete schematic set and theory of operation are part of the User Manual) reveals a design distinguished by simplicity of concept and improvements that guarantee stability, reliability and precision – rock-solid US engineering rarely found these days.

The heart of the circuit is a relaxation oscillator which, inherently, produces square and triangle waves. Sine waves are synthesized from the triangle waves by a non-linear network.

Born in an age when integrated circuits were neither popular nor accepted for use in high-end (almost mil-grade) test equipment, everything is implemented with discrete components.

In order to guarantee stability, key parts of the circuit are enclosed in what the manual calls "the oven", a sealed plastic enclosure with tightly controlled internal temperature.

Each functional block has easily accessible calibration points. Calibration procedures are clearly described in the User Manual.

The HP 3300A provides two signal outputs with independent

Hewlett & Packard's garage

Jan Buiting

While on a business trip in sun-drenched Silicon Valley, California, I set out to locate the place where two students, William R. Hewlett and David Packard, developed their very first test instrument, the Model 200 Audio Oscillator, around 1940. With the help of Elektor US Publisher Hugo Vanhaecke, one "Garmin" and one "Google", the place was easily found at Addison Avenue, Palo Alto. According to HP's official website the premises have been restored to a state "much as it would have been while Bill and Dave lived there". Regrettably the house and the garage are not accessible to the public.

At the Computer History Museum in nearby Mountain View I was able to see a real HP Model 200 generator on display. Although not a computer in any way, the Model 200 is as iconic for the birth of Silicon Valley as the HP Garage in Palo Alto. Entrance to the CHM is free, there is an incredible amount of historical computer stuff to marvel at, and the museum is run by knowledgeable and enthusiastic volunteers. A ***must visit*** place for all Elektor readers.

amplitude adjustment and waveform selection.

On the back panel the user can access an input for variable-voltage remote frequency control and a sync output that supplies pulses in phase with the rising edge of triangle and sine waves. Maintaining a long tradition of modularity and scalability, the HP 3300A has an expansion bay that allows you to connect special purpose plug-in modules like the HP 3302 (Advanced Trigger and PLL) shown in one of photos. Such modules are currently much sought after by collectors.

Finally, an "all US-style" (i.e. dry and authoritative) 52-page User Manual (including schematics, BOM and approved parts vendor list) tells all you need to know to install the 3300A, as well as understand the theory of operation of each functional block, not forgetting troubleshooting, calibrating and maintenance guidelines to keep the instrument at top performance.

You might say that this is all outdated technology superseded by microcontrollers and digital signal processing three or so decades ago. And that is not incorrect. But then, there's great pleasure in seeing this analog dinosaur still alive and – regardless of its age – setting an example and hopefully inspiring the younger generations when it comes to quality assurance and customer satisfaction.

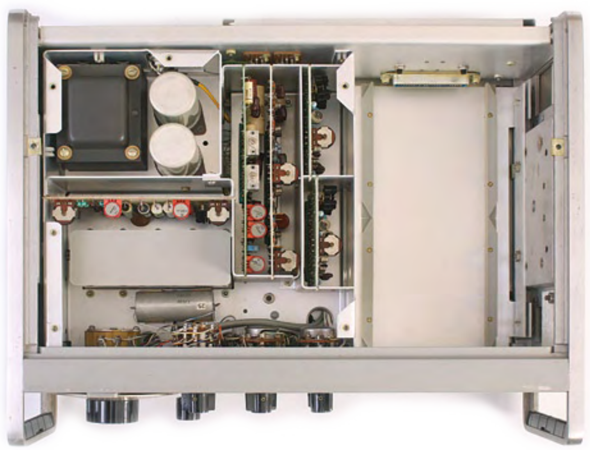
HP test equipment is widely available from tech surplus outlets, ebay and at hamfests. If you are appreciative of a big gun in electronics like HP, Glenn Robb's HP Archive [1] is the place to go to first.

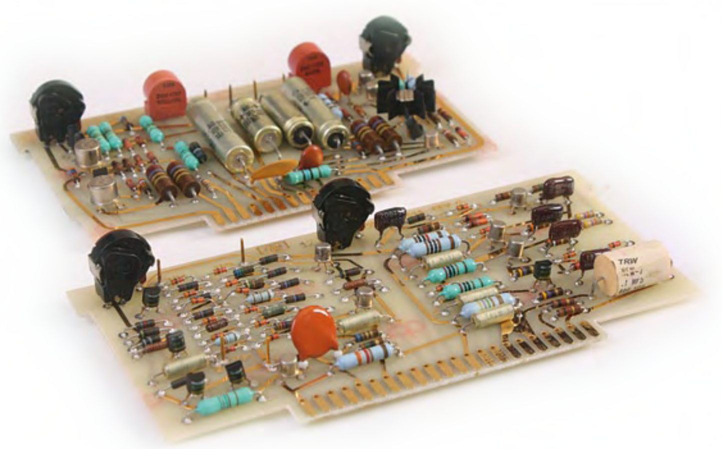
(090008-I)

Internet Link

[1] www.hparchive.com

Retronics is a monthly column covering vintage electronics including legendary Elektor designs. Contributions, suggestions and requests are welcomed; please send an e-mail to editor@elektor.com





ELEKTOR SHOWCASE

To book your showcase space contact Strategic Media Marketing Inc.

Tel. 1-978-281-7708 | **Fax 1-978-281-7706** | **Email ElektorUSA@smmarketing.us**

MICROENGINEERING LABS, INC.

www.melabs.com

PICBASIC PRO™ Compiler for PIC® MCUs

Development tools for PIC® microcontrollers, including Software, Device Programmers, Prototyping Boards, Experimenter Boards, Serial Displays, and Books.

MICROENGINEERING LABS, INC.

www.melabs.com

Serial Displays

Software and hardware products for embedded development, including BASIC Compilers for PIC® MCUs, Experimenter Boards, Device Programmers, Books, and other resources.

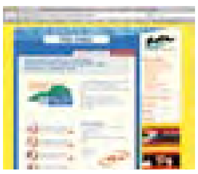
AVIT RESEARCH

www.avitresearch.co.uk

USB has never been so simple... with our USB to Microcontroller Interface cable. Appears just like a serial port to both PC and Microcontroller, for really easy USB connection to your projects, or replacement of existing RS232 interfaces.

See our webpage for more details.

BETA LAYOUT



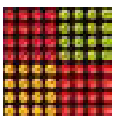
www.pcb-pool.com

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

ByVac

www.byvac.com

- USB to I2C
- Microcontrollers
- Forth
- Serial Devices



C S TECHNOLOGY LTD

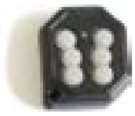
www.cstechnology.co.uk

Low cost PIC prototyping kits, PCB's and components, DTMF decoder kits, CTCSS, FFSK, GPS/GSM, radio equipment and manuals. PCB design and PIC program development.

DECIBIT CO.LTD.

www.decibit.com

- Development Kit 2.4 GHz
- Transceiver nRF24L01
- AVR MCU ATmega168



DESIGNER SYSTEMS

http://www.designersystems.co.uk

Professional product development services.

- Marine (Security, Tracking, Monitoring & control)
- Automotive (AV, Tracking, Gadget, Monitoring & control)
- Industrial (Safety systems, Monitoring over Ethernet)
- Telecoms (PSTN handsets, GSM/GPRS)
- AudioVisual ((HD)DVD accessories & controllers)

Tel: +44 (0)1872 223306

EASYDAQ

www.easydaq.biz

- USB powered, 4 relays + 4 DIO channels
- Will switch 240VAC @ 10 amps
- Screw terminal access
- LabVIEW, VB, VC
- Free shipping

Design & supply of USB, USB Wireless, Ethernet & Serial, DAQ, Relay & DIO card products. info@easydaq.biz

EASYSYNC

http://www.easysync.co.uk

EasySync Ltd sells a wide range of single and multi-port USB to RS232/RS422 and RS485 converters at competitive prices.

ELNEC

www.elnec.com

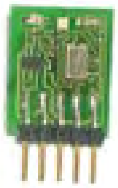
- device programmer manufacturer
- selling through contracted distributors all over the world
- universal and dedicated device programmers
- excellent support and after sale support
- free SW updates
- reliable HW
- once a months new SW release
- three years warranty for most programmers

FIRST TECHNOLOGY TRANSFER LTD.

http://www.ftt.co.uk

- Training and Consulting for IT, Embedded and Real Time Systems
- Assembler, C, C++ (all levels)
- 8, 16 and 32 bit microcontrollers
- Microchip, ARM, Renesas, TI, Freescale
- CMX, uCOSII, FreeRTOS, Linux operating systems
- Ethernet, CAN, USB, TCP/IP, Zigbee, Bluetooth programming

FLEXIPANEL LTD



www.flexipanel.com

TEAclippers - the smallest PIC programmers in the world:

- Per-copy firmware sales
- Firmware programming & archiving
- In-the-field firmware updates
- Protection from design theft by subcontractors

FUTURE TECHNOLOGY DEVICES

http://www.ftdichip.com

FTDI designs and sells USB-UART and USB-FIFO interface i.c.'s.

Complete with PC drivers, these devices simplify the task of designing or upgrading peripherals to USB

HEXWAX LTD

www.hexwax.com

World leaders in Driver-Free USB ICs:

- USB-UART/SPI/I2C bridges
- TEAleaf-USB authentication dongles
- expandIO-USB I/O USB expander
- USB-FileSys flash drive with SPI interface
- USB-DAQ data logging flash drive

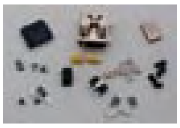
products and services directory

LONDON ELECTRONICS COLLEGE

http://www.lec.org.uk

Vocational training and education for national qualifications in Electronics Engineering and Information Technology (BTEC First National, Higher National NVQs, GCSEs and GCEs). Also Technical Management and Languages.

LCDMOD KIT

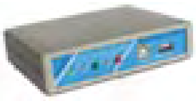


http://www.lcdmodkit.com

Worldwide On-line retailer

- Electronics components
- SMT chip components
- USB interface LCD
- Kits & Accessories
- PC modding parts
- LCD modules

MQP ELECTRONICS



www.mqp.com

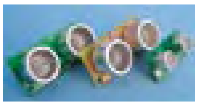
- Low cost USB Bus Analysers
- High, Full or Low speed captures
- Graphical analysis and filtering
- Automatic speed detection
- Bus powered from high speed PC
- Capture buttons and feature connector
- Optional analysis classes

ROBOT ELECTRONICS

http://www.robot-electronics.co.uk

Advanced Sensors and Electronics for Robotics

- Ultrasonic Range Finders
- Compass modules
- Infra-Red Thermal sensors
- Motor Controllers
- Vision Systems
- Wireless Telemetry Links
- Embedded Controllers

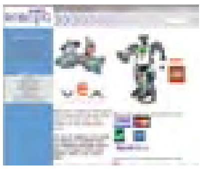


ROBOTIQ

http://www.robotiq.co.uk

Build your own Robot!
Fun for the whole family!

- MeccanoTM Compatible
- Computer Control
- Radio Control
- Tank Treads
- Hydraulics



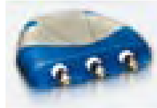
Internet Technical Bookshop,
1-3 Fairlands House, North Street, Carshalton,
Surrey SM5 2HW
email: sales@robotiq.co.uk Tel: 020 8669 0769

www.elektor-usa.com

USB INSTRUMENTS

http://www.usb-instruments.com

USB Instruments specialises in PC based instrumentation products and software such as Oscilloscopes, Data Loggers, Logic Analaysers which interface to your PC via USB.



VIRTINS TECHNOLOGY

www.virtins.com

PC and Pocket PC based virtual instrument such as sound card real time oscilloscope, spectrum analyzer, signal generator, multimeter, sound meter, distortion analyzer, LCR meter. Free to download and try.

CANDO – CAN BUS ANALYSER

http://www.cananalyser.co.uk

- USB to CAN bus interface
- USB powered
- FREE CAN bus analyser S/W
- Receive, transmit & log. CAN messages
- ISO11898 & CAN 2.0a/2.0b compliant
- Rugged IP67 version available

netronics

SHOWCASE YOUR COMPANY HERE

Elektor Electronics has a feature to help customers promote their business, Showcase - a permanent feature of the magazine where you will be able to showcase your products and services.

- For just $385.00 + VAT ($35.00 per issue for eleven issues) Elektor will publish your company name, website address and a 30-word description
- For $550.00 + VAT for the year ($50.00 per issue for eleven issues) we will publish the above plus run a 3cm deep full colour image - e.g. a product shot, a screen shot from your site, a company logo - your choice

Places are limited and spaces will go on a strictly first come, first served basis. So-please fax back your order today!

I wish to promote my company, please book my space:
• Text insertion only for $385.00 + VAT • Text and photo for $550.00 + VAT

NAME: .... ORGANISATION: ....

JOB TITLE: ....

ADDRESS: ....

....

.... TEL: ....

PLEASE COMPLETE COUPON BELOW AND FAX BACK TO 1-978-281-7706

COMPANY NAME ....

WEB ADDRESS ....

30-WORD DESCRIPTION ....

....

....

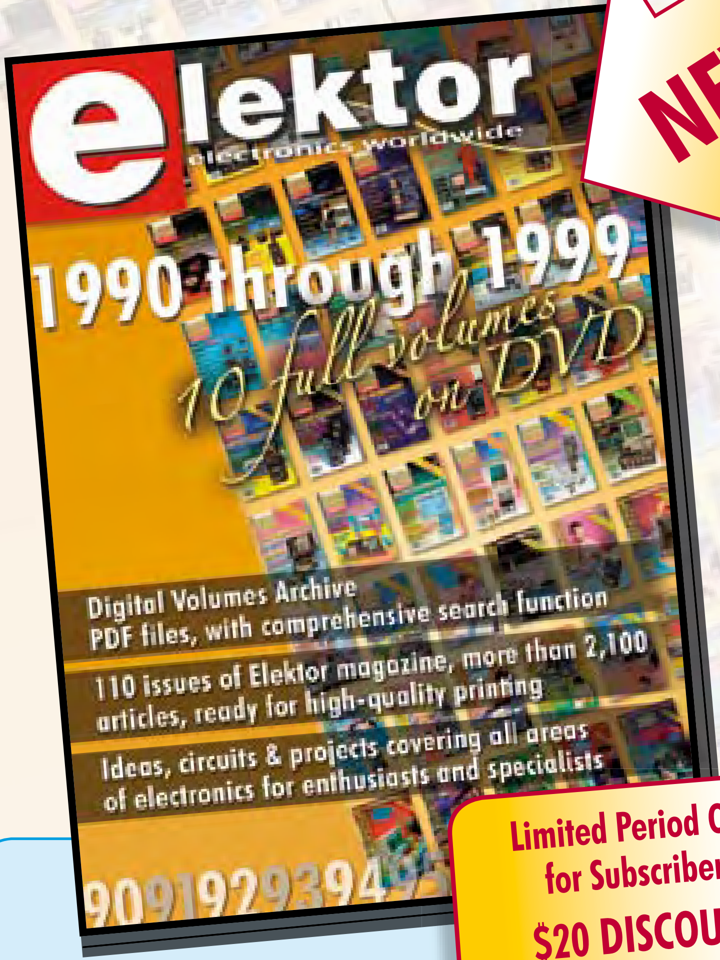
....

....

Going Strong

A world of electronics from a single shop!

NEW!



Limited Period Offer for Subscribers!
$20 DISCOUNT
www.elektor-usa.com/90s

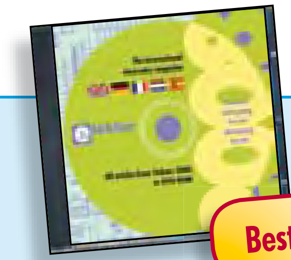
CD/DVD-ROMs

110 issues, more than 2,100 articles

Elektor 1990 through 1999

This DVD-ROM contains the full range of 1990-1999 volumes (all 110 issues) of Elektor Electronics magazine (PDF). The more than 2,100 separate articles have been classified chronologically by their dates of publication (month/year), but are also listed alphabetically by topic. A comprehensive index enables you to search the entire DVD. The DVD also contains (free of charge) the entire 'The Elektor Datasheet Collection 1…5' CD-ROM series, with the original full datasheets of semiconductors, memory ICs, microcontrollers, and much more.

ISBN 978-0-905705-76-7 • $99.00



Bestseller!

All articles published in 2008

DVD Elektor 2008

This DVD-ROM contains all editorial articles published in Volume 2008 of the English, Spanish, Dutch, French and German editions of Elektor magazine. Using Adobe Reader, articles are presented in the same layout as originally found in the magazine. The DVD is packed with features including a powerful search engine and the possibility to edit PCB layouts with a graphics program, or printing hard copy at printer resolution. Thanks to the use of an Internet browser program, the requirements for the PC are minimal.

ISBN 978-90-5381-235-8 • $35.00

New!

Incl. searchable i-TRIXX archive

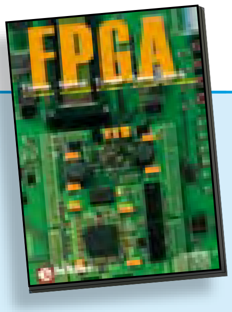
DVD i-TRIXX

Freeware Collection 2009

This DVD contains 100 nifty freeware applications, tools and utilities for the Windows PC. And as a free extra, it contains the full and searchable (!) i-TRIXX archive, with all the editions up until week 8 of 2009 from i-TRIXX, the e-magazine published by Elektor. Do you feel the need for a decent and reliable antivirus program? A bandwidth monitor which keeps track of your current up and download rate and displays it in a graph? An application for recording, editing and converting video to any conceivable format? Anonymous surfing from any internet access point from a USB stick? Easy backups, restores and updates for all your drivers? Checking, optimizing and cleaning up your computer? Keeping track of your privacy? You can expect that and much more in the i-TRIXX Freeware Collection 2009.

ISBN 978-90-5381-244-0 • $39.50

Prices and item descriptions subject to change. E. & O.E



Modern technology for everyone

FPGA Course

FPGAs have established a firm position in the modern electronics designer's toolkit. Until recently, these 'super components' were practically reserved for specialists in high-tech companies. The nine lessons on this courseware CD-ROM are a step by step guide to the world of Field Programmable Gate Array technology. Subjects covered include not just digital logic and bus systems but also building an FPGA webserver, a 4-channel multimeter and a USB controller. The CD also contains PCB layout files in pdf format, a Quartus manual, project software and various supplementary instructions.

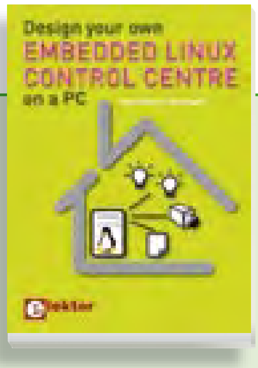
ISBN 978-90-5381-225-9 • $29.00

Software Tools & Hardware Tips

Ethernet Toolbox

This CD-ROM contains all essential information regarding Ethernet interfaces! Ethernet Toolbox includes a collection of datasheets for dedicated Ethernet interface ICs from many different manufacturers. It provides a wealth of information about connectors and components for the physical layer (PHY) and specific software tools for use with the Ethernet (Software). To help you learn about the Ethernet interfaces, we have compiled a collection of all articles on this topic that have appeared in Elektor and complemented them with additional documentation and links to introductory articles on Ethernet interfaces. The documents are PDF files.

ISBN 978-90-5381-214-3 • $39.00



A DIY system made from recycled components

Design your own Embedded Linux control centre on a PC

This book covers a do-it-your-self system made from recycled components. The main system described in this book reuses an old PC, a wireless mains outlet with three switches and one controller, and a USB webcam. All this is linked together by Linux. This book will serve up the basics of setting up a Linux environment – including a software development environment – so it can be used as a control centre. The book will also guide you through the necessary setup and configuration of a webserver, which will be the interface to your very own home control centre. All software needed will be available for downloading from the Elektor website.

234 pages • ISBN 978-0-905705-72-9 • $42.00

More information on the Elektor Website:

www.elektor-usa.com

Elektor US
PO Box 876
Peterborough NH 03458-0876
USA

Toll-free: 888-924-9465
Phone: 603-924-9464
Fax: 603-924-9467
E-mail: custservus@elektor.com

elektor SHOP

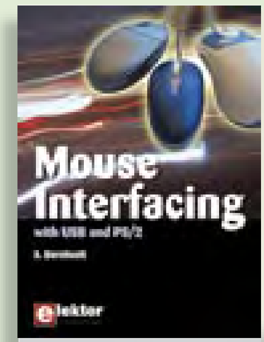
Bestseller!

Learn by doing

C Programming for Embedded Microcontrollers

If you would like to learn the C Programming language to program microcontrollers, then this book is for you. No programming experience is necessary! You'll start learning to program from the very first chapter with simple programs and slowly build from there. Initially, you program on the PC only, so no need for dedicated hardware. This book uses only free or open source software and sample programs and exercises can be downloaded from the Internet.

324 pages • ISBN 978-0-905705-80-4 • $52.00



Connect your mouse into new embedded applications

Mouse Interfacing

This book describes in-depth how to connect the mouse into new embedded applications. It details the two main interface methods, PS/2 and USB, and offers applications guidance with hardware and software examples plus tips on interfacing the mouse to typical microcontrollers. A wide range of topics is explored, including USB descriptors, a four-channel, millivolt-precision voltage reference all with fully documented source-code. A wealth of clear illustrations enhance this highly readable text.

256 pages • ISBN 978-0-905705-74-3 • $42.00

Books

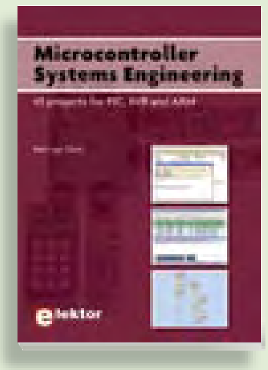
Books

Bring your microcontroller to life

Artificial Intelligence

This book contains 23 special and exciting artificial intelligence machine-learning projects, for microcontroller and PC. Learn how to set up a neural network in a microcontroller, and how to make the network self-learning. Or discover how you can breed robots, and how changing a fitness function results in a totally different behavior. Several artificial intelligence techniques are discussed: expert system, neural network, subsumption, emerging behavior, genetic algorithm, cellular automata. roulette brains etc.

256 pages • ISBN 978-0-905705-77-4 • $46.00

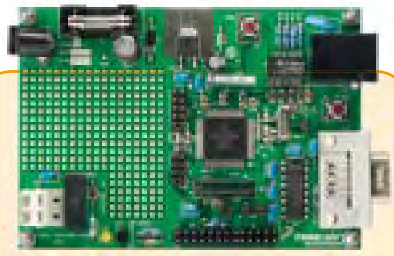


45 projects for PIC, AVR and ARM

Microcontroller Systems Engineering

This book covers 45 exciting and fun Flowcode projects for PIC, AVR and ARM microcontrollers. Each project has a clear description of both hardware and software with pictures and diagrams, which explain not just how things are done but also why. As you go along the projects increase in difficulty and the new concepts are explained. You can use it as a projects book, and build the projects for your own use. Or you can use it as a study guide.

329 pages • ISBN 978-0-905705-75-0 • $52.00



DigiButler

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

Kit of parts including SMD-stuffed PCB, programmed microcontroller, all leaded parts and CD-ROM containing both Elektor articles, TBLCF documentation, datasheets, application notes and source code files.

Art. # 071102-71 • $52.50

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

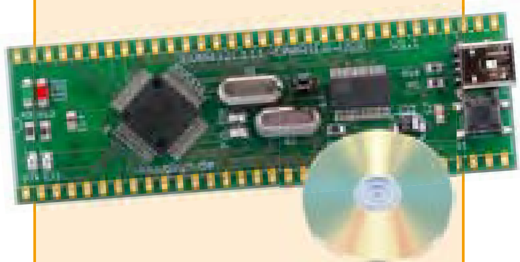
Art. # 080671-91 • $79.00

Software Defined Radio

SD radio receivers use a bare minimum of hardware, relying instead on their software capabilities. The Elektor SDR project (by Burkhard Kainka) demonstrates what's achievable, in this case a multi-purpose receiver covering all bands from 150 kHz to 30 MHz. It's been optimised for receiving DRM and AM broadcasts but is also suitable for listening in to the world of amateur transmissions. The designer's aim for this project was to create a receiver displaying high linearity and phase accuracy. Development was focussed on the characteristics that were most important for a top-notch DRM receiver and the end result is a receiver with remarkable interference rejection characteristics!

Ready-populated and tested board

Art. # 070039-91 • $145.00



The 32-bit Machine

(April 2009)

With this attractively priced starter kit you get everything you need for your first hands-on experiments with the new R32C/111 32-bit microcontroller. The power supply is drawn from your computer via the USB connection, which simplifies things rather nicely. The starter kit consists of an R32C carrier board (a microcontroller module equipped with the R32C/111 chip) and a software CD-ROM containing the necessary development tools.

R32C/111 Starterkit (32-bit-Controller-board & CD-ROM)

Art. # 080928-91 • $42.50

Kits & Modules

Prices and item descriptions subject to change. E. & O.E

Product Shortlist

June 2009 (No. 6)		$
Campsite AC Monitor		
060316-1	Printed circuit board	30.00
ATM18 = RFID Savvy		
080910-91	PCB, partly populated PCB populated with all SMDs	26.00
Battery Monitor		
080824-1	Printed circuit board	18.75
080824-41	Programmed controller LPC2103	24.00
030451-72	LC display	15.00

May 2009 (No. 5)

Experimenting with the MSP430		
080558-91	PCB, populated and tested	55.00
080558-92	TI eZ430-F2013 Evaluation Kit	35.00
RGB LED Driver		
080178-41	Programmed controller	13.75

April 2008 (No. 4)

The 32-bit Machine		
080928-91	R32C/111 Starterkit (32-bit-Controllerboard & CD-ROM)	42.50
Automotive CAN Controller		
080671-91	Kit of parts, incl. PCB with SMDs prefitted	79.00
Automatic Running-in Bench		
080253-71	Kit of parts incl. PCB-1 with SMDs prefitted	270.00
090146-91	ARMee plug-in board mk. II	74.00

March 2009 (No. 3)

M16C TinyBrick		
080719-91	Kit of parts: TinyBrick-PCB with SMD parts and microntroller premounted; plus all other parts	87.50

February 2009 (No. 2)

Model Coach Lighting Decoder		
080689-1	PCB, long (l = 230 mm)	10.95
080689-2	PCB, medium (l = 190mm)	10.95
080689-3	PCB, short (l = 110mm)	8.95
080689-41	PIC12F683, programmed	9.50
Transistor Curve Tracer		
080068-1	Main PCB	42.00
080068-91	PCB, populated and tested	82.50

January 2009 (No. 1)

Radio for Microcontrollers		
071125-71	868 MHz module	11.50
ATM18 on the Air		
071125-71	868 MHz module	11.50
Meeting Cost Timer		
080396-41	ATmega168, programmed	12.50
Capacitive Sensing and the Water Cooler		
080875-91	Touch Sensing Buttons Evaluation kit	39.95
080875-92	Touch Sensing Slider Evaluation kit	39.95
Three-Dimensional Light Source		
080355-1	Printed circuit board	39.90
Moving up to 32 Bit		
080632-91	ECRM40 module	46.50

December 2008

PLDM		
071129-1	Printed circuit board	11.00
Hi-fi Wireless Headset		
080647-1	Printed circuit board: Transmitter	14.90
080647-2	Printed circuit board: Receiver	14.90
LED Top with Special Effects		
080678-71	Kit of parts incl. SMD-stuffed PCB and programmed controller	59.00

Bestsellers

Books	1	C Programming for Embedded Microcontrollers	ISBN 978-0-905705-80-4	$52.00
	2	Artificial Intelligence	ISBN 978-0-905705-77-4	$46.00
	3	Microcontroller Systems Engineering	ISBN 978-0-905705-75-0	$52.00
	4	PIC Microcontrollers	ISBN 978-0-905705-70-5	$52.00
	5	Embedded Linux Control Centre	ISBN 978-0-905705-72-9	$42.00
CD/DVD-ROMs	1	DVD Elektor 2008	ISBN 978-90-5381-235-8	$35.00
	2	FPGA Course	ISBN 978-90-5381-225-9	$29.00
	3	ECD 5	ISBN 978-90-5381-159-7	$38.00
	4	DVD i-TRIXX Freeware Collection 2009	ISBN 978-90-5381-244-0	$39.50
	5	Ethernet Toolbox	ISBN 978-90-5381-214-3	$39.00
Kits & Modules	1	Software Defined Radio	Art. # 070039-91	$145.00
	2	DigiButler	Art. # 071102-71	$52.50
	3	Automotive CAN controller	Art. # 080671-91	$79.00
	4	The 32-bit Machine	Art. # 080928-91	$42.50
	5	Stand Alone OBD2 Analyser	Art. # 070038-93	$119.95

Order quickly and securely through www.elektor-usa.com/shop or use the Order Form near the end of the magazine!

elektor SHOP

Elektor US
PO Box 876
Peterborough NH 03458-0876
USA
Toll-free: 888-924-9465
Phone: 603-924-9464
Fax: 603-924-9467
E-mail: custservus@elektor.com

Summer Circuits 2009

Elektor's July & August double issue packed with 100+ tips, small circuits and design ideas

You really can't afford to miss our annual top-selling Summer Circuits issue with its collection of more than 100 articles. Elektor editors and tens of free-lance contributors again come up with more than 100 exciting, stimulating and innovative articles covering the whole gamut of electronics, including new ICs, small circuits, software and design tips.
Be sure to get your copy of the 2009 Summer Circuits edition as demand is bound to be high.

A selection from the contents

Automatic Bicycle Lights
Crystal Tester
Curtain Governor
Electricity Monitor
FM Audio Transmitter
Improved Hybrid Headphones Amp
Inclinometer
Lithium Battery Charger
Lithium-Polymer Monitor
Low-drop Voltage Regulator
Milliohm Meter
Mobile 3-watt LED Lighting
Port Extension for Microcontrollers
Servo Scales
Stress Meter

Extra in this year's Summer Circuits edition: ElektorWheelie

The first article on the construction of a two-wheel self-balancing electrical vehicle. The essential ingredients: two hefty motors, two batteries, two sensors and control electronics built around two small but powerful AVR microcontrollers.

Article titles and magazine contents subject to change, please check 'Magazine' on www.elektor-usa.com for updates and announcements.
The June 2009 edition of Elektor is published on **Monday, May 18, 2009**. Elektor is available on subscription or from selected Borders and Barnes & Noble bookshops.

w.elektor-usa.com www.elektor-usa.com www.elektor-usa.com www.elektor-usa.co

Elektor on the web

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

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

Also on the Elektor website:

- Electronics news and Elektor announcements
- Readers Forum
- PCB, software and e-magazine downloads
- Surveys and polls
- FAQ, Author Guidelines and Contact

Order Form 06-2009

Description		Price each	Qty.	Total	Order Code
DVD Elektor 1990 through 1999	NEW	$99.00			
DVD i-TRIXX Freeware Collection 2009	NEW	$39.50			
DVD Elektor 2008	NEW	$35.00			
C Programming for Embedded Microcontrollers	NEW	$52.00			
Artificial Intelligence	NEW	$46.00			
DVD Elektor 2008		$35.00			
Mouse Interfacing with USB and PS/2		$42.00			
Microcontroller Systems Engineering		$52.00			
		Sub-total			
		Shipping & Handling (Airmail from Europe) $		20.00	
		Total paid			

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

Name/Company

Street & No.

City/State/Zip Country

Tel E-mail

EL06 Date – – Signature

METHOD OF PAYMENT

Remit in US $ drawn on a US bank. Please see next page for ordering information.

- ☐ Check or Money Order
- ☐ Mastercard
- ☐ VISA
- ☐ Discover
- ☐ American Express

Expiry date: ____________________

Verification code: ____________________

Send order form to:

Elektor US
PO Box 876
Peterborough NH 03458-0876
USA

Toll-free: 888-924-9465
Phone: 603-924-9464
Fax: 603-924-9467
E-mail: custservus@elektor.com
www.elektor-usa.com

elektor electronics worldwide

Subscription Order Form 06-2009

Yes, I want to subscribe to Elektor US for 1 year*

I would like:

- ☐ **Standard Subscription for $39.95 (11 issues)**
- ☐ **Plus Subscription for $54.95 (11 issues plus the Elektor Volume 2009 DVD-ROM) As a special limited period offer I also receive the Volume 2008 on DVD-ROM. Free of charge!**

* *Offer available in US & Canada only. Canada please add $11.00 per year for postage.*

Name/Company

Street & No.

City/State/Zip Country

Tel E-mail

EL06 Date – – Signature

METHOD OF PAYMENT

Remit in US $ drawn on a US bank. Please see next page for ordering information.

- ☐ Check or Money Order
- ☐ Mastercard
- ☐ VISA
- ☐ Discover
- ☐ American Express

Expiry date: ____________________

Verification code: ____________________

Send order form to:

Elektor US
PO Box 876
Peterborough NH 03458-0876
USA

Toll-free: 888-924-9465
Phone: 603-924-9464
Fax: 603-924-9467
E-mail: custservus@elektor.com
www.elektor-usa.com

ORDERING INFORMATION

To order contact customer service:

Toll-free: 1-888-924-9465
On-line at www.elektor-usa.com
Fax: 603-924-9467
Mail: Elektor US
PO Box 876
Peterborough NH 03458-0876 USA
E-mail: custservus@elektor.com

Customer service hours: 8:00 AM–4:30 PM Monday–Thursday. Voice mail available at other times.
When leaving a message please be sure to leave a daytime telephone number where we can return your call.

PLEASE NOTE: While we strive to provide the best possible information in this issue, pricing and availability are subject to change without notice. To find out about current pricing and stock, please call or email customer service.

COMPONENTS

Components for projects appearing in Elektor are usually available from certain advertisers in the magazine. If difficulties in obtaining components are suspected, a source will normally be identified in the article. Please note, however, that the source(s) given is (are) not exclusive.

PAYMENT

Orders must be prepaid. We accept checks or money orders (in US $ drawn on a US bank only), VISA, Mastercard, Discover, and American Express credit cards. We do not accept C.O.D. orders.
We also accept wire transfers. Add $20 to cover fees charged for these transfers.

TERMS OF BUSINESS

Shipping Note: All orders will be shipped from Europe. Please allow 3–4 weeks for delivery. Shipping and handling via airmail: US $20.00 per order. **Returns** Damaged or miss-shipped goods may be returned for replacement or refund. All returns must have an RA #. Call or email customer service to receive an RA# before returning the merchandise and be sure to put the RA# on the outside of the package. Please save shipping materials for possible carrier inspection. Requests for RA# must be received 30 days from invoice. **Patents** Patent protection may exist with respect to circuits, devices, components, and items described in our books and magazines. Elektor accepts no responsibility or liability for failing to identify such patent or other protection. **Copyright** All drawing, photographs, articles, printed circuit boards, programmed integrated circuits, diskettes, and software carriers published in our books and magazines (other than in third-party advertisements) are copyrighted and may not be reproduced (or stored in any sort of retrieval system) without written permission from Elektor. Notwithstanding, printed circuit boards may be produced for private and personal use without prior permission. **Limitation of liability** Elektor shall not be liable in contract, tort, or otherwise, for any loss or damage suffered by the purchaser whatsoever or howsoever arising out of, or in connection with, the supply of goods or services by Elektor other than to supply goods as described or, at the option of Elektor, to refund the purchaser any money paid with respect to the goods.

SUBSCRIPTIONS (US & CANADA ONLY)

Subscription rates (1 Yr.)

Standard Subscription: $39.95
Plus Subscription: $54.95

Canada add $11 per year for postage

All subscriptions begin with the current issue. Expect 3–4 weeks for receipt of the first issue. Subscriptions, renewals, and change of address should be sent to:

Elektor US
PO Box 876
Peterborough NH 03458-0876 USA

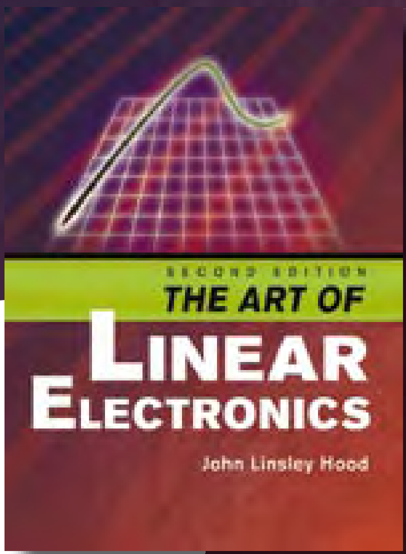
E-mail: custservus@elektor.com

Order subscriptions on-line at www.elektor-usa.com

Subscriptions may be paid for by check or money order (in US $ drawn on a US bank only). We accept Mastercard, VISA, Discover and American Express credit cards.

For gift subscriptions, please include gift recipient's name and address as well as your own, with remittance. A gift card will be sent on request.

Subscriptions may be cancelled at any time for a refund of all unmailed issues.



Index of Advertisers

Advertising space for the issue of 17 August 2009
may be reserved not later than 21 July 2009
with Strategic Media Marketing, Inc. - 2 Main Street -
Gloucester, MA 01930 - USA – Telephone 1.978.281.7708 -
Fax 1.978.281.7706 - e-mail: ElektorUSA@smmarketing.us to whom all
correspondence, copy instructions and artwork should be addressed.