

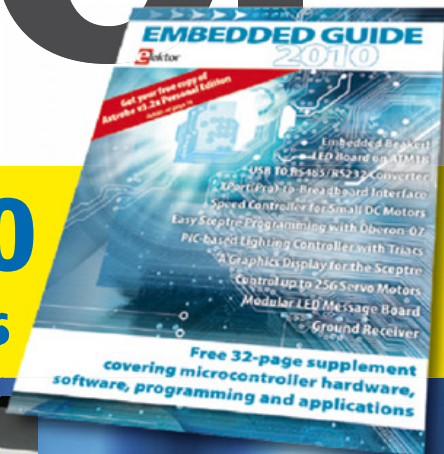
**32-page FREE SUPPLEMENT**

**+ Elektor DSP Radio Scanner**

# Elektor

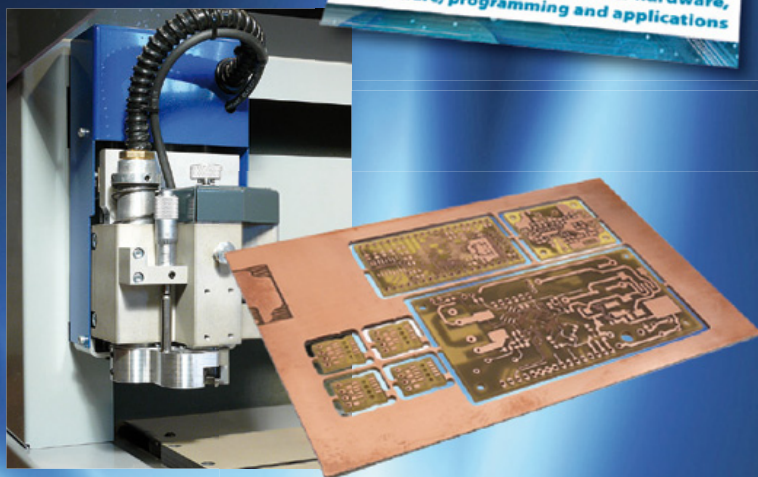
## EMBEDDED GUIDE 2010

32 pages of microcontroller projects



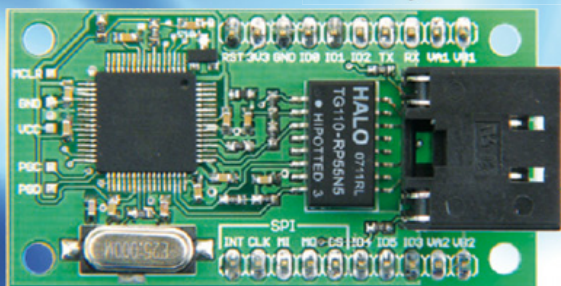
## Elektor PCB Prototyper

A professional PCB router with optional extensions



## NetWorker

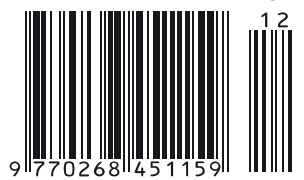
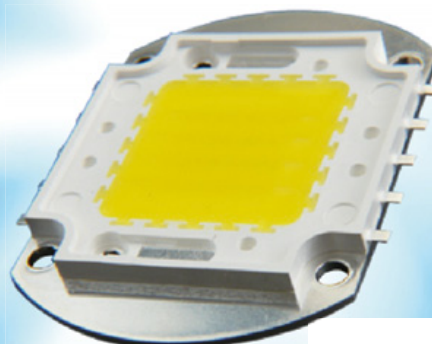
An advanced webserver with a micro



**+ 50-watt Power LED**

**+ Heating System Monitor**

**+ Stroboscopic PC Fan**





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## Sound & Light — Sound vs. Light

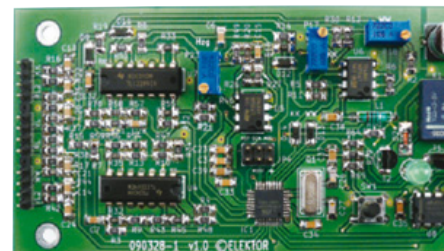
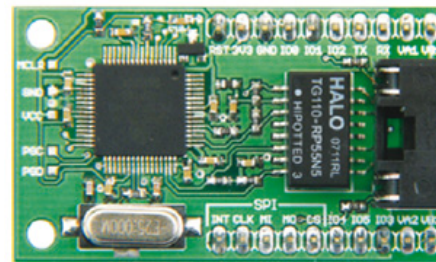
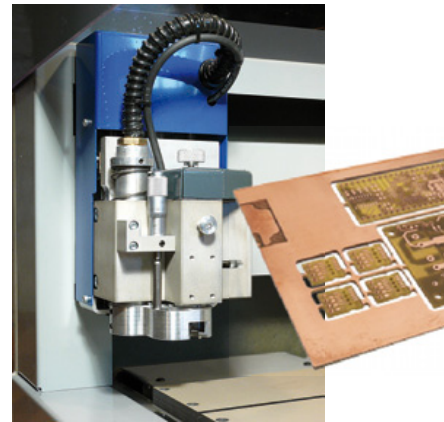
My generation and I reckon the majority of Elektor readers grew up with DIY electronics very closely associated with sound and sound reproduction, preferably at a high volume and no fuss but fuzz! If in the mid 1970s you showed off a homebrew 5 watts stereo amplifier, a Kraftwerk LP and homebrew loudspeakers with a terrible mismatch, you were considered a star and got invited to parties and gigs— just for the equipment of course. Looking at levels of interest in electronics as a pastime, home built radio can be identified as the catalyst for the post war generation, gradually changing to audio for those born in the late 1950s and 1960s (with radio still a strong contender I hasten to add). Today there's tonnes more radio and audio around than anyone could have foreseen 50 odd years ago. However, today's young people seem to take the technical aspects of audio, or even its basics and evolution, very much for granted, happily playing crunched MP3 files, damaging their ears and not bothering in the least about amplifiers "and stuff" that can be built or fixed at home because that's "all gone now ain't it?" Today, if there's anything to kindle the interest in electronics of, say, a 14 year old, it's the humble optoelectronic device called LED. Fortunately, nothing's changed. Just like I wired a germanium transistor the wrong way around and blew up a week's pocket money in a second, LEDs get connected to hefty battery packs and even AC powerlines with no current limiter resistor(s) to speak of because "them colour bands, ohms and watts are difficult and stuff." High power LEDs are all the craze on scooters, bikes and helmets; LED chains with dubious control circuits adorn PCs and student digs. Notice a few geeks in the corner who can spell 'cathode' and 'anode' correctly without assistance from Wikipedia — they are the truly enlightened ones. To help them build confidence in career development, as well as spread the word (or light?) that electronics is fun, there's a few articles in this edition to suit. Can you find them? No LED flashlight required.

Jan Buiting, Editor

# elektor

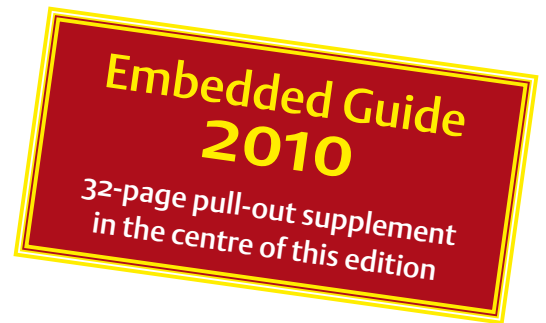
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Season's Wishes  
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Thank you for your continued support!

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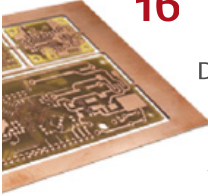


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Do you want to rout PCBs with isolation tracks only 100 µm wide and 0.2-mm holes? The Elektor PCB Prototyper is a compact, professional PCB router with a modular architecture in terms of software and hardware. What's more, this powerful machine is easily extended to create a multipurpose automated work centre for your lab or workshop.

## 26 NetWorker




This versatile webserver, which consists of a small printed circuit board, a free software library and a ready-to-use microcontroller-based web server, allows beginners to add Internet connectivity to their projects. More experienced users will benefit from features such as SPI communications, power over Ethernet (PoE) and more.

## 40 Heating System Monitor



This clever design measures the actual heat output and doesn't require any modifications to your central heating system. It also has a built-in control function for the circulation pump, which helps you reduce your environmental impact and keep your bank balance healthy.

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### 40 Heating System Monitor

This system employs the simple method of measuring supply and return heat pipe temperatures, all geared towards reducing the fuel bill.

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



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

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The Elektor Personal Organizer 2011 makes planning your appointments a real pleasure, and you always have ready access to have handy information that everyone who works with electronics needs to know.



**elektor**

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- 60 pages of technical information on electronics
- Seven sections, separated by tab sheets
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- Handy monthly planner
- Lined pages for your notes
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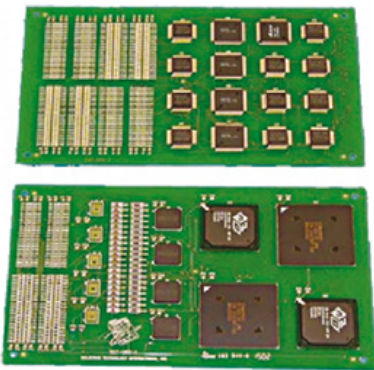
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Printed in the Netherlands

## Fine-pitch SMT kit with lead-free option

STI Electronics, Inc., a full service organization providing training, electronic and industrial distribution, consulting, laboratory analysis, prototyping, and small- to medium-volume PCB assembly, announces that its Fine-Pitch SMT Kit is now available in both lead-free and tin-lead versions. The lead-free component option is available with the ENIG board finish.



Today's SMT and lead-free processes present new challenges for employee skills and machine process capability. This kit allows users to develop critical skills and processes before they impact production. It is often used to determine overall production or machine process capability to meet the challenges of today's fine-pitch component technologies.

The Fine-Pitch SMT Kit offers guaranteed performance at a greatly reduced cost over operational assemblies. Select the kit with three popular component combinations, or create a customized component list and contact STI Electronics.

[www.stielectronicinc.com](http://www.stielectronicinc.com)  
(100708-IV)

## Class D amplifier brings affordable fidelity to consumer audio

Silicon Laboratories Inc. recently introduced the industry's first 5 watt stereo Class D amplifier that effectively mitigates electromagnetic interference (EMI), bringing affordable fidelity to consumer audio electronics. The first member of Silicon Labs' Class D amplifier family, the new Si270x amplifier is ideal for use in a wide range of

price- and noise-sensitive consumer audio products including smart phone docking stations, tabletop radios, TV sound bars and monitors, boom boxes and battery-powered radios.

For years, consumer audio engineers have wanted to replace power-hungry analog Class A/B amplifiers with power-efficient digital Class D technology. Until now, two issues have impeded the adoption of Class D amplifiers: the high EMI emissions inherent to traditional Class D solutions, which interfere with AM/FM radio and smart phone operation, and the high cost of adding expensive filtering and shielding for EMI regulatory compliance. While other Class D suppliers have attempted some level of EMI protection, Silicon Labs' Si270x changes the shape of the audio amplifier market with power-efficient Class D technology that substantially suppresses EMI emissions for operation with radios using inexpensive filters.

The Si270x amplifier uses multi-layer EMI mitigation technology to suppress traditional Class D interference at its source, ena-



bling easier EMI compliance, AM/FM radio co-existence and smart phone compatibility in consumer audio products. Compared to existing Class D solutions, the Si270x amplifier reduces radiated interference by 10x in the EMI compliance band, by 100x in the FM radio band and by 1000x across the AM band.

Smart Phone-Friendly Digital Architecture Traditional Class D amplifiers emit large amounts of EMI radiation in the 900 MHz transmission and reception band, which undermines the over-the-air (OTA) transmission and reception quality of smart phones and docking stations. In addition, analog architectures employed by most docking platforms are highly susceptible to time division multiple access (TDMA) transmission noise pickup. The Si270x amplifier's smart phone-friendly all-digital architecture is inherently immune to radiated noise pickup, and Silicon Labs' EMI mitiga-

tion technology enhances OTA performance and compliance.

The Si270x Class D amplifier can enable a 2.5x increase in play time over Class A/B-based systems while using only half the number of batteries (four instead of a typical eight). For example, a consumer audio system based on the Si270x amplifier can provide up to 8.4 hours of play time using four AA alkaline batteries.

The Si270x Class D amplifier is designed to be combined seamlessly with Silicon Labs' popular Si473x AM/FM radio tuner products to enable complete consumer audio platform solutions. The latest Si473x devices offer a stereo analog input and internal analog-to-digital converters (ADCs) multiplexed with the radio tuner front-end to support auxiliary analog system inputs without the need for additional external ADCs. The complementary Si270x and Si473x combination provides a cost-effective platform solution for a wide range of consumer audio products such as tabletop radios, docking stations, boom boxes and mini-stereo systems.

Samples and pre-production quantities of the Si270x Class D audio amplifiers are available today in a 24-pin QFN package. Pricing in 10,000-unit quantities for the Si270x amplifiers begins at \$1.17 (USD). To help accelerate application development, Silicon Labs offers audio engineers a full-featured Si270x-A-EVB evaluation board priced at \$325 (USD).

[www.silabs.com/pr/ClassD](http://www.silabs.com/pr/ClassD)  
(100708-V)

## Popular JJB now available in high temperature package

The popular JJB series antenna is now available in a high-temperature, reflow compatible housing: the JJB-HT. Designed for both hand and automated assembly, the anten-



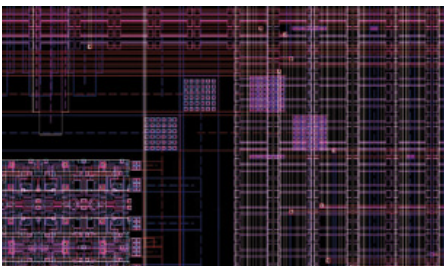


nas are RoHS compliant and can withstand reflow processing temperatures of up to 260°C. These compact monopole antennas are an ideal solution for OEM applications requiring a low-cost internal or external antenna solution. JJB-HT series antennas are supplied in tape and reel packaging. Each antenna costs less than \$1.28 in production quantities. Custom colours and logo options are available for volume OEMs.

www.antennafactor.com  
(100725-1)

## Semiconductor replication service

Rochester Electronics is proving that the combination of semiconductor re-creation and continuing manufacturing is a cost-effective and time-saving alternative to system re-design when critical semiconductors are no longer available from the original manufacturer. As the world's largest authorized manufacturer of discontinued semiconductors, Rochester Electronics has established a process that provides customers with a replica device that matches the original semiconductor's physical features, layer-by-layer and pin-for-pin, and is guaranteed to perform exactly as the original. Even when the IP is no longer available from the original manufacturer, Rochester's experienced design engineers can decon-



struct and electrically analyze a device, re-design it, and re-engineer it onto a matched mature foundry process. Rochester can then test all circuit parameters with a collection of custom developed tools to analyze device characterization.

Rochester's unique Semiconductor Replication Process™ (SRP™) guarantees that replicated devices perform as effectively as the original semiconductor devices. Rochester has successfully completed 83 semiconductor replication projects in the last 18 months and is currently engaged in more than 30 additional re-creation projects.

## New TI Stellaris EVALBOT evaluation platform

Delivering a fun platform for learning and evaluating real-time software and Stellaris® microcontrollers (MCUs), Texas Instruments announced the availability of its new Robotic Evaluation Board (EVALBOT) for use with Micrium's μC/OS-III. The evaluation kit is a mini robot that allows developers to experience the Stellaris



ARM® Cortex™-M3-based LM3S9B92 MCU in real-world applications that leverage the processor's integrated 10/100 Ethernet MAC/PHY, USB On-The-Go, CAN, and motion control capabilities. Based on a complete analog and embedded processing signal chain from TI, the kit includes all of the hardware and software required for quick assembly so that developers can begin evaluation in 10 minutes or less. The EVALBOT is available with a Stellaris-specific version of μC/OS-III: *The Real-Time Kernel* by Jean J. Labrosse, which reveals how a real-time kernel works using Micrium's μC/OS-III and the Stellaris EVALBOT as references. For more information, go to the first link below or for a video overview, go to the second link.

Stellaris EVALBOT and book bundle features and benefits (EKB-UCOS3-BNDL)

- 80 MHz Stellaris LM3S9B92 MCU with 256K flash, 96K SRAM, StellarisWare® software in ROM, as well as integrated Ethernet, USB On-the-Go (OTG)/Host/Device and CAN
- Two DC gear-motors that provide drive and steering, opto-sensors that detect wheel rotation with 45° resolution, and sensors for 'bump' detection
- TI motor drivers, voltage regulators, audio codec, interface and logic devices for easy evaluation of the complete signal chain
- Bright 96 x 6 blue OLED display and on-board speaker
- Integrated In-Circuit Debug Interface (ICDI) requires only a single (included) USB cable for software debugging, flash programming and serial port connectivity
- Two 20-pin headers enable future wireless communications using standardized TI low-power embedded radio modules
- Stellaris-specific version of μC/OS-III: *The Real-Time Kernel* includes example display, audio and motor control projects for EVALBOT, putting concepts into practice to expedite a user's proficiency

The Stellaris Robotic Evaluation Board plus Micrium's μC/OS-III book package is priced at US\$199 and can be purchased at [www.ti.com/evalbot-pr-es](http://www.ti.com/evalbot-pr-es). The Stellaris Robotic Evaluation Board is priced at \$149 US and can be purchased separately from the book at [www.ti.com/evalbot-bot-pr-es](http://www.ti.com/evalbot-bot-pr-es).

[www.ti.com/evalbot-pr-tf](http://www.ti.com/evalbot-pr-tf) [www.ti.com/evalbot-pr-v](http://www.ti.com/evalbot-pr-v) (100725-11)

Rochester recently did a successful re-creation for a company that had previously contracted with two other companies for emulations that turned out to be unsuccessful because they were based on the company's original intellectual property. Rochester's SRP went beyond the IP, evaluated the actual device, and produced an exact replica that worked exactly as the original on

the first production run, thus avoiding any additional foundry costs.

Rochester has agreements with most of the major semiconductor manufacturers and is proud to serve the industry as a reliable, long-term source for authorized, traceable, and quality end-of-life semiconductors.

www.rocelec.com  
(100725-11)

## Compact high efficiency fully featured AC-DC supplies

XP Power's HCP series of single output compact bulk power AC-DC power supplies is aimed at process control, factory automation and manufacturing equipment applications. These highly efficient units, typically up to 91%, comprise four output power models, a 650 W and 1 kW, which

are both less than 1U high, and a 1.5 kW and 3 kW. A single wire current share capability allows the configuration of multiple units to achieve a higher power output or to provide redundancy. All the popular nominal output voltages from +12 to +48 VDC are available across the range. To accommodate an even wider range of output voltage requirements, an output voltage trim capability allows adjustment of 30 - 105% of nominal output voltage. A similar function provides adjustment of current output between 40



## High-performance, cost-efficient RF ICs for car access systems



Atmel® Corporation recently introduced the next generation of smart RF devices for the automotive and consumer markets, enabling RF systems with high performance and application simplification. Committed to the automotive market, the Atmel ATA5830 and ATA5780 are the next generation of monolithic RF trans-

ceiver and RF receiver devices with worldwide leading RF performance like sensitivity and power consumption. The multiband devices are designed for the ISM frequency bands in the ranges of 310 to 318 MHz, 418 to 477 MHz and 836 to 928 MHz, and are the ideal solutions for today's demanding automotive remote keyless entry (RKE), remote start, passive entry go (PEG), and tire pressure monitoring (TPMS) systems.

The monolithic devices combine a highly advanced RF receiver or transceiver block with a proven Atmel AVR® microcontroller core. This enables the devices to poll multiple application channels to support, for example, the RKE/PEG, Remote Start and TPMS system with a single IC instead of having multiple ICs, which results in a very cost efficient solution.

The ATA5830 and ATA5780 are pin-compatible devices to ensure maximum reuse of development effort for 1-way and 2-way systems. Based on this pin-compatibility feature, the printed circuit board design can be the same for both the unidirectional and bidirectional car access system, which is a unique selling point in regards to variants, stock of replacement parts and cost savings.

These products are ideal for all car access applications due to their excellent RF performance, high flexibility and modular concept. These benefits, combined with a very high integration level, result in the requirement for less than half of the external components of previous products on the market.

The highly sensitive devices (typical -109 dBm, 10 kbps Manchester data rate, FSK modulation with ±10 kHz frequency deviation, IF bandwidth 165 kHz) provide a high image rejection and excellent blocking performance (typical 64dBc at 1MHz, IF bandwidth of 165 kHz) for the customer application. The transceiver's maximum power-down current of 600 nA ensures that customers enjoy maximum battery life and battery size is kept to a minimum.

[http://www.atmel.com/dyn/products/product\\_card.asp?part\\_id=5004](http://www.atmel.com/dyn/products/product_card.asp?part_id=5004)  
[http://www.atmel.com/dyn/products/product\\_card.asp?part\\_id=5005](http://www.atmel.com/dyn/products/product_card.asp?part_id=5005)  
 (100725-1V)

- 105% of maximum current. Both controls can be made by using either an external voltage input or by a variable resistor. A +5 VDC 0.5 A standby supply can be used to drive logic or control circuits without the need to design-in an additional voltage source or step down converters.

These fan cooled units are ideal for customers looking for a compact high efficiency power supply that has programmable features and monitoring signals. By varying the cooling fan speed depending on the output load fan noise is kept to a minimum. Monitor and control signals include DC OK, remote sense and remote on/off. A multi-function LED indicator gives a visual indication of the power supply's operational condition.

The HCP series are available from stock and come with a 3 year warranty.

[www.xppower.com](http://www.xppower.com)  
 (100725-V)

## Pico Technology Test & Measurement catalogue

The Pico Technology Test & Measurement Catalogue has been completely redesigned. It now contains more technical data on established and new products.

The PicoScope section now also contains the new PicoScope 2200 Ultra-Compact scopes and the PicoScope 3425 Differential scope. A PicoScope 2200 scope is also available in a new Education Kit designed for use in the classroom. The PicoScope 4000 Precision scopes, both with and without an arbitrary waveform generator, are now listed, as are the PicoScope 6000 High-Performance scopes with 350 MHz bandwidth and 5 GS/s real-time sampling rate. You will

also find the PicoScope 9000 12 GHz Sampling scopes, which use sequential sampling to analyse repetitive signals with a time resolution of only 200 femtoseconds.

The Accessories section introduces a range of new scope probes, including differential high-voltage types for measuring several kilovolts, and both active and passive types for bandwidths up to 1.5 GHz. In the PicoLog section you will find the new PicoLog 1000 Series 12-channel and 16-channel voltage data loggers, and the latest PT-104 4-channel platinum resistance data logger with USB and Ethernet ports.



All Pico Technology products are backed up by a free parts-and-labour warranty of up to 5 years depending on the product type, free technical support from our specialists, and an international network of distributors.

The Pico Technology 2010 Test & Measurement Catalogue is available to download now, free of charge, from the Pico Technology website at [www.picotech.com](http://www.picotech.com). You can also request a printed copy by filling in the online form.

[www.picotech.com](http://www.picotech.com)  
(100725-VI)

## T/R switches integrate clamping diodes to protect ultrasound imaging systems

Maxim's new transmit/receive switches integrate clamping diodes to cut solution size by more than 50% while protecting high-performance ultrasound imaging systems.

The new MAX4936/MAX4937 fully integrated octal high-voltage transmit/receive (T/R) switches integrate clamping diodes to isolate the low-voltage receive path from the high-voltage transmit path, thus protecting the receiver input from volt-

## Lost solar energy reclaimed by intelligent hotspot prevention

STMicroelectronics reports an innovation for solar panels aimed at allowing more of the energy from each cell to reach the power grid. The innovation replaces the simple bypass diode with an intelligent device that enhances efficiency and offers the same package outline. The new device can deliver a fast Return-



On-Investment, in terms of releasing additional energy for solar panel applications. ST's new SPV1001 contains a low-loss power switch and a precision controller. Directly replacing bypass diodes, which are used to prevent hotspot effects, the SPV1001 protects the energy normally lost in each diode. Compared to the use of diodes, the integrated power switch provides negligible leakage current when the photovoltaic (PV) panel is producing energy. ST's BCD6 chip fabrication process provides the key to this advance by integrating highly efficient power components with logic control circuitry. In addition to package options enabling one-for-one replacement of bypass diodes in the solar panel's junction box, the SPV1001 is available in an MLPD package that can be laminated directly into the panel, due to the device's ultra-low-profile and minimal power losses. This will simplify electronic design and assembly while also boosting system reliability.

Major features of the SPV1001:

- BCD6 and EHD5 power MOSFET processes
- Low conduction losses when operating in bypass mode
- Low leakage current minimizes losses in bypass stand-by mode
- Lower operating temperature optimizes junction box design
- High robustness to surge and lightning currents
- Integration of power and control functions
- TO-220 or D2PAK packages, pin- and outline-compatible with existing bypass diodes
- Optional ultra-low-profile Power MLPD package for in-panel assembly

The SPV1001 is in production now in the industry-standard TO-220 and ultra low-profile MLPD packages.

[www.st.com](http://www.st.com) (100725-X)

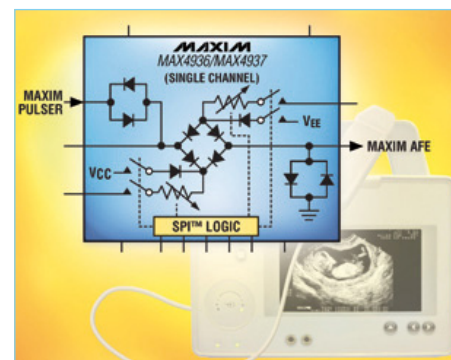
age spikes due to leakage currents flowing through the T/R switches. Maxim's integrated solution uses > 50% less board space than discrete circuits while providing high bandwidth, low jitter, and low signal distortion. The MAX4936/MAX4937 are ideal for use in ultrasound imaging and industrial flaw-detection probes, in which board space is at a premium.

The MAX4936/MAX4937 feature eight individually programmable switches controlled through an SPI(TM) interface with a 12-bit shift register and transparent latch. These features simplify device operation when updating the states of the T/R switch; they ensure that all switches are off at power-on; and they reduce noise due to clock feedthrough.

The MAX4936/MAX4937 T/R are based on the conventional diode topology, but include adjustable current biasing through

the serial interface. The devices are specified over the 0 degrees Celsius to +70 degrees Celsius commercial temperature range, and are packaged in a small, 5mm x 11mm, 56-pin TQFN. Prices start at \$12.00 (1000-up, FOB USA).

<http://www.maxim-ic.com/MAX4936>  
(100725-VII)



## RS Essentials

RS Components (RS) introduces its own range of products, 'RS Essentials', designed to deliver major cost reductions without ever compromising on quality. RS has always provided the widest range of products, competitive pricing and industry-leading service. Now it has put all this into its own wide range of products across key technologies. 'RS Essentials' offers more choice with cost savings when compared to the leading brands.

Over the years, RS has learned a lot from its customers and has built up a vast knowledge-base of what they need to operate efficiently and what they expect from the products they buy. It is this knowledge, together with keeping pace with technological developments, which has enabled RS to create its huge own-brand range – 'RS Essentials' – combining best value with best quality.



The 'RS Essentials' range now comprises over 30,000 products in such diverse areas as electronics and maintenance; covering capacitors and diodes, through to LED replacement lamps and bearings, to screen cleaners and hand tools.

'RS Essentials' products provide real value for money. Prices are regularly checked so that they stay ahead, and in these difficult times when margins are squeezed, choosing 'RS Essentials' will save customers money. On average, 'RS Essentials' are 20% cheaper than manufacturer prices, although this varies across the range, with some items offering even greater savings. RS sources its 'RS Essentials' products both locally and globally. Once a potential supplier has been found, RS has an in-house team of specialist engineers who thoroughly test the products for their quality, their ability to meet specifications and their compliance with regulations and guidelines. Alan Lund, Group Product Compliance Manager at RS, commented, "As a company, we're focused on always offering the highest quality products and there is a constant

stream that needs to be checked for compliance, often down to component level. Our lab even carries out a range of specialist procedures to check for BSI/RoHS compliance where appropriate. We also have advanced expertise across the full range of electrical testing procedures."

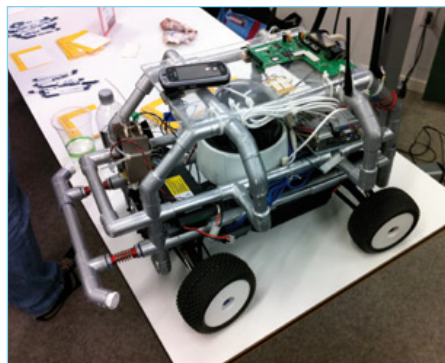
"Many vendors simply import and sell without product checks but this cannot be in the ultimate interests of anyone, particularly the customers'. When buying from the 'RS Essentials' range, customers can therefore be confident that they are getting outstanding quality and value."

RS has introduced flags to highlight the 'RS Essentials' products, both online and within the catalogue, making it easier for customers to identify the range and choice available.

<http://rswww.com>  
(100725-IX)

## SMU Skunkworks — cell phone controlled vehicle

Alibre, Inc. Developers affordable, professional 3D design solutions, announced that it co-sponsored and participated in the non-profit TEDxSMU and TEDxKIDS 2010 events, bringing the best ideas of today's minds together for two days of technological inspiration for the next generation of scientists, engineers, artists, doctors, marketers, DIYers, inventors and entrepreneurs. Held in October in Dallas, Texas, TEDxSMU & TEDxKIDS merged interesting people from around the world in the areas of technology, entertainment and design, supporting world-changing ideas with multiple initiatives. Short, exciting presentations by astounding thinkers on a broad array of topics, ranging from the science of yo-yos to space exploration, inspired both kids and adults alike.



"We are honoured to be involved with TEDx and TEDxKIDS — prestigious events that take students out of their everyday classroom environments and bring them into a setting where their teachers are the people actually thinking and executing big ground-breaking ideas," said J. Paul Grayson, CEO of Alibre Inc.

Alibre Inc. helped bring the TEDxSMU event to Dallas through its key sponsorship, and provided two presenters with Alibre's award winning design software, Alibre Design. One of the key TEDxSMU presenters, Nathan Huntoon, Director of the Innovation Gymnasium, Southern Methodist University (SMU), showed a GPS controlled unmanned vehicle activated via a cell phone interface, which was created in the SMU SkunkWorks Lab by Huntoon's students, including co-presenter Austin Hodges. The SkunkWorks Team used Alibre to design and place all the parts of their vehicle, before they ever built it.

"What is amazing, is the students designed the vehicle in 3D first and when it came time to fit all the parts together, every piece fell in place perfectly," said Huntoon. The unique vehicle can be seen live at TEDxSMU at: [www.youtube.com/watch?v=PvVoCnNgesA](http://www.youtube.com/watch?v=PvVoCnNgesA).

[www.alibre.com](http://www.alibre.com)    [www.tedxsmu.org](http://www.tedxsmu.org)  
(100725-XII)

## New GammaSafe™ portable memory line

The new GammaSafe™ memory token from Datakey Electronics is a non-volatile, reprogrammable, portable memory device that survives gamma sterilization with no loss of data. The GammaSafe data-carrier/receptacle system allows medical device manufacturers to easily add anti-counterfeit and limit-use capabilities to disposable attachments that are sterilized using gamma radiation.

The SGT4Kb GammaSafe memory token contains four kilobits of non-volatile, re-writable memory. The memory is accessed using an SPI bus and is functionally similar to an SPI EEPROM. But unlike actual EEPROM devices, which experience data loss and even device failure when exposed to significant doses of gamma radiation, GammaSafe memory tokens have been proven to withstand up to 45 kGy (4.5 Mrad) of gamma radiation with no data loss. Medical device manufacturers who pro-

## Triple-mode graphene transistors show potential

Rice University research that capitalizes on the wide-ranging capabilities of graphene could lead to circuit applications that are far more compact and versatile than what is now feasible with silicon-based technologies.

Triple-mode, single-transistor amplifiers based on graphene — the one-atom-thick form of carbon that recently won its discoverers a Nobel Prize — could become key components in future electronic circuits.

Graphene is very strong, nearly transparent and conducts electricity very well. But another key property is ambipolarity, graphene's ability to switch between using positive and negative carriers on the fly depending on the input signal. Traditional silicon transistors usually use one or the other type of carrier, which is determined during fabrication.

A three-terminal single-transistor amplifier made of graphene can be changed during operation to any of three modes at any time using carriers that are positive, negative or

both, providing opportunities that are not possible with traditional single-transistor architectures, said Kartik Mohanram, an assistant professor of electrical and computer engineering at Rice. He collaborated on the research with Alexander Balandin, a professor of electrical engineering at the University of California, Riverside, and their students Xuebei Yang (at Rice) and Guanxiong Liu (at Riverside). Mohanram likened the new transistor's abilities to that of a water tap. "Turn it on and the water flows," he said. "Turn it off and the water stops. That's what a traditional transistor does. It's a unipolar device — it only opens and closes in one direction."

"But if you close a tap too much, it opens again and water flows. That's what ambipolarity is — current can flow when you open the transistor in either direction about a point of minimum conduction."

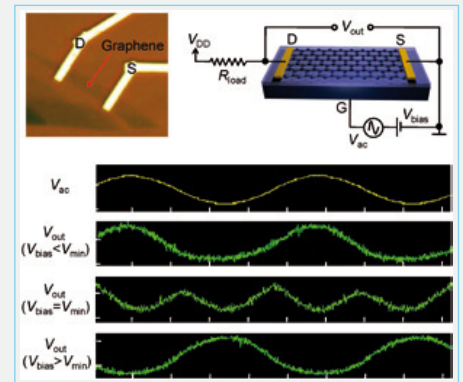
That alone means a graphene transistor can be n-type (negative) or p-type (positive), depending on whether the carrier originates from the source or drain terminals (which are effectively interchangeable). A third function appears when the input from each carrier is equal: The transistor becomes a frequency multiplier. By combining the three modes, the Rice-Riverside team demonstrated such common signalling schemes as phase and frequency shift keying for wireless and audio applications.

"Our work, and that of others, that focuses on the applications of ambipolarity complements efforts to make a better transistor with graphene," Mohanram said. "It promises more functionality." The research demonstrated that a single graphene transistor could potentially replace many in a typical integrated circuit, he said. Graphene's superior material properties and relative compatibility with silicon-based manufacturing should allow for integration of such circuits in the future, he added.

Technological roadblocks need to be overcome, Mohanram said. Such fabrication steps as dielectric deposition and making contacts "wind up disturbing the lattice, scratching it and introducing defects. That immediately degrades its performance (limiting signal gain), so we have to exercise a lot of care in fabrication.

"But the technology will mature, since so many research groups are working hard to address these challenges," he said.

The National Science Foundation and the DARPA-Semiconductor Research Corporation's Focus Center Research Program supported the work.



<http://pubs.acs.org/doi/abs/10.1021/nm1021583> (100725-VIII)

duce single-use or limited-use disposable attachments (e.g. catheters, filters, tubing, medical lasers, etc.) that plug in to a base controller can now add a non-volatile memory device to the attachment, even if their attachments contain no active electronics. Adding a GammaSafe memory token to an attachment enables several applications. For example, the GammaSafe memory token can store an encrypted product authentication code to protect against counterfeit disposables. The re-writable memory can also be used to limit the usage of the attachment, ensuring that it is not used more than the prescribed number of times. The disposable's model number and associated parameters, along with calibration information can be written to the GammaSafe token during production; then, in the field, this data can be automatically transferred to the base controller unit, eliminating the chance for human error from incorrect data entry. In addition to the memory token, the Gam-

maSafe product line includes a line of mating receptacles. The GammaSafe receptacles are based on Datakey Electronics' proven SlimLine receptacle design and are available in through-hole (GR4220PCB),



surface-mount (GR4220SMT), and panel mount (GR4310 and GR4410) models. The panel-mount receptacles are available in splash-proof (IP65-rated), immersion (IP67-rated), and EMI-reduction versions—supporting a variety of medical device appli-

cations, especially those with wash-down requirements.

The GammaSafe memory token is offered with an optional integrated tether. The optional tether consists of a 5-inch (12.7 cm) cable-tie that has been "pre-looped" and integrated into the head of the memory token. This allows OEMs an easy way to attach the GammaSafe token to their disposable devices.

The GammaSafe memory token also features an optional sterilization indicator, which is housed within a recessed window on the front side of the token. Before sterilization, the indicator is yellow/orange in colour. After gamma sterilization (10 kGy dosage or greater), the indicator changes to a vivid red colour. This optional feature enables medical personnel to confirm at-a-glance that the sealed medical device they are about to open has indeed undergone gamma sterilization.

[www.datakey.com](http://www.datakey.com)  
(100725-XI)

# The mbed Challenge Is On!

The mbed team is setting out to make rapid prototyping with microcontrollers a reality. Now it is your chance to get involved, develop something remarkable, and help move the industry forward. Are you up to the challenge?



By Simon Ford (UK)

We're calling on all of you to join the mbed challenge and create a project that helps move the industry forward on two fronts — insight and reuse. Why? Because insight drives invention and reuse drives innovation. And you might win a prize!

Insight is the thing that provides the inspiration for what is possible. It can be something as simple as when we explain the interface pinout for mbed. "Here you can see the digital I/Os, ADCs, PWM, Ethernet, ..." is often interrupted with "What? It's got Ethernet built in? So I could ..." PING! Right there, the insight that a cheap microcontroller could connect to a network has flicked on a switch and inspired something new. Part of our goal is met simply by using mbed to educate and give insight into what makes up a modern microcontroller.

But more often, it comes from seeing something is possible, such as a write-up where someone has used USB to log data to a thumb drive or the CAN interface to hook up a car's ECU. It could be some whacky project that in itself seems like technology for technology's sake, but demonstrates a concept that can be reapplied in a totally different domain with a slightly different twist to provide a really important technical step forward. This is why we have challenged you to help show what's possible!

This also brings us to the second goal — reuse. Good projects are naturally reference designs for similar projects. They have solved many problems that need not be solved again, and can act as starting points for you to gain confidence and understanding. However, really great projects are elegantly constructed of libraries and building blocks that have been created to abstract implementation details at different levels, allowing for simple understanding, easy development, testing, reworking, and repurposing. Whilst the approach makes development of the project much easier, it also provides components that can be reused in future projects. This is why we have challenged you to publish what you end up with!

Microcontrollers are solutions looking for problems, and many of these solutions will have to come from people in other problem domains. Early on, when trying to explain mbed, we used to throw around a hypothetical example to try and get this across: "Who is best placed to spot the opportunity for an automated pig feeder? The guy who knows everything about microcontrollers, or the guy who has to get up every Sunday morning to feed the pigs?"

It made the point, but in some ways our example suffers from exactly the problem we're highlighting. Whilst we think automating the pig feeder must be a killer app in pig farming, it is quite likely to be something totally different that we'd never have the insight to identify! That is why we think giving insight into the world of microcontrollers is essential to help exploit their potential, just as insight into computers was needed to help bring them out of the scientific labs and apply them to all sorts of non-scientific applications.

This is where your inventions and creations will bring new insights and show what is possible. They also will inspire people to learn how to do it for themselves to create new and wonderful things. By publishing projects that show off interesting ideas, technologies, and techniques, you'll be enabling insight in to what is possible and providing components that can be reused to help build future prototypes faster than ever.

The interest and support for this challenge has been outstanding, and we're already seeing the start of some great ideas. But we want more people, more ideas, more invention, more innovation! If you haven't registered to enter yet, why not?! We've even put up prizes to give you some additional motivation. If you have entered, time to get stuck in, burn the midnight oil, and create something awesome. Make your entry count! Good luck!

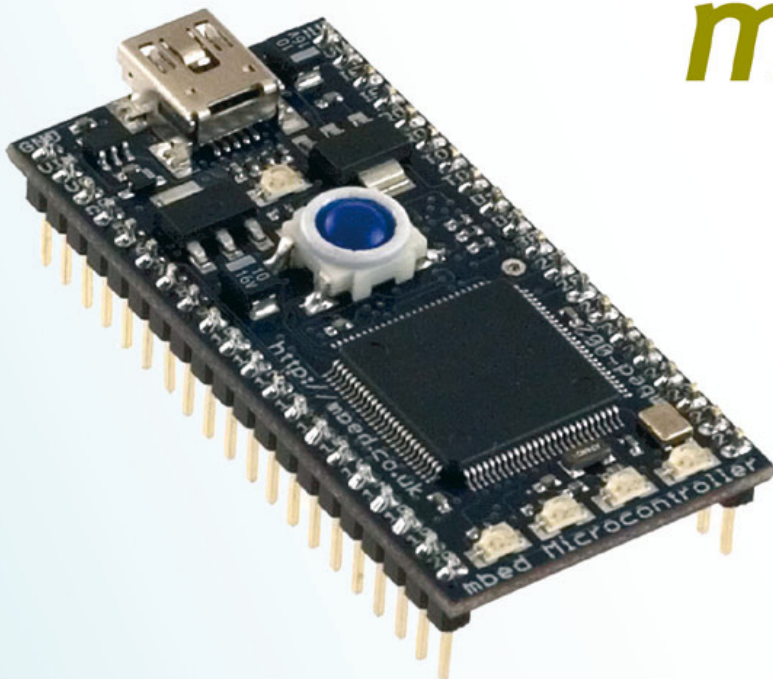
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**Simon Ford**, co-creator of mbed, is a lifelong electronics and computer engineer. He works at ARM, and before starting mbed was technical lead for the ARMv7/NEON architecture now found in most new smartphones.

To enter the NXP mbed Design Challenge 2010, go to: [www.circuitcellar.com/nxpmbeddesignchallenge/](http://www.circuitcellar.com/nxpmbeddesignchallenge/)



# Start prototyping the *mbed way!*



Redefine the way people build prototypes! NXP and ARM/mbed are challenging you to use the mbed NXP LPC1768 prototyping board and mbed online "Cloud" compiler to develop an innovative hardware- or software-based application. Succeed, and you could walk away with part of a prize pool worth \$10,000!

**Deadline for entries is  
February 28, 2011**

Register for the challenge at  
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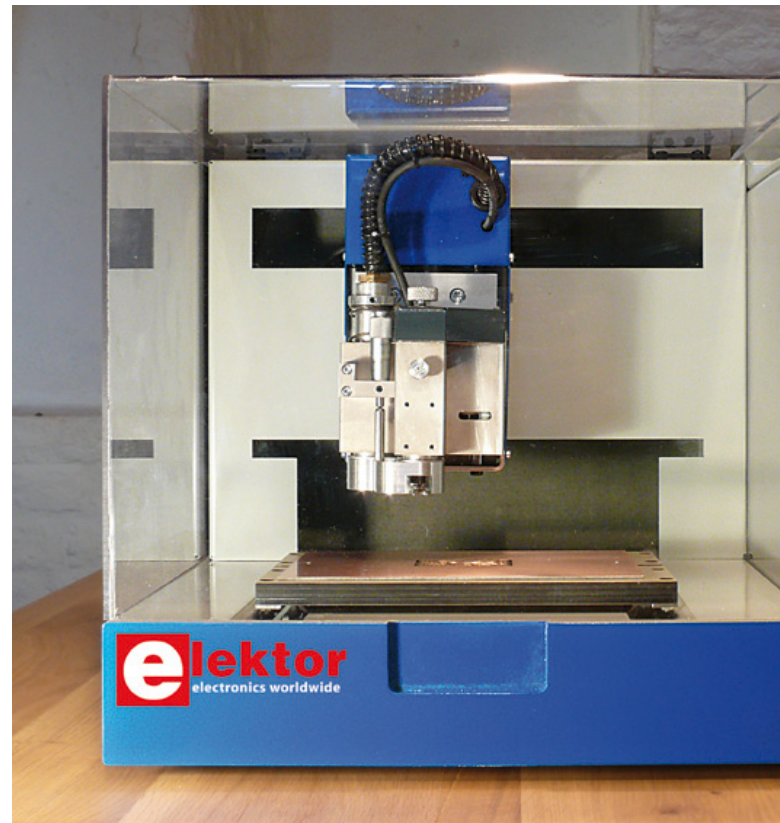
# Elektor PCB Prototyper

By Harry Baggen (Elektor Editorial Netherlands)

Do you want to rout PCBs with isolation tracks only 100 µm wide and 0.2-mm holes? The Elektor PCB Prototyper takes it all in stride. This compact, professional PCB router also has a lot more to offer. Thanks to the modular architecture of both the software and the hardware, you can easily extend it to create a multipurpose automated work centre for your lab or workshop. Colinbus has developed an entirely new drive system, along with an engraving module that makes it possible to offer a machine with this level of precision and versatility at a very attractive price – much lower than comparable products.

When we presented the Elektor Profiler in our magazine in January 2007, we didn't expect to receive so many enquiries about using the machine for routing PCBs. The Profiler is designed for general milling work, but not specifically for routing PCBs. Although it can be used for this purpose with suitable effort and skill on the part of the user, the results are nowhere near what can be achieved with a true PCB router. Users who only want to make run-of-the-mill PCBs for conventional (through-hole) components have been reasonably satisfied with the results from the Profiler, but many other users long for higher precision and more convenience. However, a true PCB router is expensive, and with good reason. The mechanical components must be very precise, and furthermore, it takes a lot of specialised expertise and technology to make such machines – and there are only a few manufacturers in the world who have these capabilities in house.

The Colinbus design staff faced two challenges in designing a new PCB router. The first challenge was to reduce the price of the entire machine to a level that would make it attractive for small companies, schools, universities, and hobbyists willing to invest a bit of money in their hobby – considering that you have to make a lot of circuit boards to recover your investment in a machine of this sort. The second challenge was to make the machine more versatile, so it could be used for many different jobs – not just



routing PCBs. It took a few years, but now we are able to present the PCB Prototyper: an extremely compact machine that fulfils both of the above requirements.

## Design

The PCB Prototyper is a compact, nearly cubicle machine that takes up only a small amount of space on your workbench. All moving parts are screened by a Plexiglas cover, which results in a quiet and dust-free working environment. The cover is also fitted with a safety switch that stops the machine when the cover is opened.

The PCB Prototyper design is based on professional PCB routers, which means that all guides and drives are extremely precise and that the embedded software includes special routines that facilitate PCB routing at a professional level.

The PCB Prototyper is the first PCB router with a modular design. The work table can be replaced by all sorts of other tables, the multifunctional head housing the high-speed spindle motor can be removed or modified, and there are provisions for fitting a camera, dispenser or other accessories. The multifunctional head clips in place, so it can easily be adapted to the job on hand, and the air feed and suction lines are integrated into the machine and can easily be connected or disconnected. The hinged rear panel can be opened to increase the working area of the machine or allow tubes or cables



# A professional PCB router with many extension options

## Technical specifications

Workspace:	220 × 150 × 40 mm (X × Y × Z)
Resolution:	1.8 μm
X/Y/Z drives:	Hybrid motors
Max. spindle motor speed:	40,000 rpm (adjustable under software control)
Machine table:	Precision table with single T slot
Tool changing:	Manual (automatic tool changer available as an optional accessory)
Tool collet:	1/8" standard (other sizes available as optional accessories)
Engraving module:	Adjustable, with integrated micrometer
Dust extraction:	Integrated in engraving module
Dimensions:	440 × 350 × 350 mm (W × D × H)
Supply voltage:	110–240 V <sub>AC</sub> , 50/60 Hz
Weight:	approx. 35 kg (78 lbs)
Software:	Accompanying CAM and control software (runs under Windows XP, Windows Vista or Windows 7)
Communication with PC:	USB port

to be fed in conveniently. These are only a few of the features of the PCB Prototyper, which is truly a multipurpose machine that can perform dozens of tasks in your shop or lab.

The PCB Prototyper comes with the Colibri control software, a shell program that holds all of the software modules used to operate the machine. The main software module included with the machine as standard is the PCB module. This CAM package, which is specifically designed for routing PCBs, is unquestionably one of the most powerful and user-friendly packages on the market.

### Mechanics

It is generally known that routing PCBs on normal milling machines yields poor results, which is largely related to the mechanical design of the machines. This doesn't mean that some machines are worse than others, but rather that they are simply designed to meet different requirements. The small details are what make the difference.

In the first place, a PCB router must be stable, and this is achieved by making its structure massive. For this reason, the PCB Prototyper features all-steel construction. The steel structure also ensures that the sturdy precision-ground guide rods for the sliding bushes don't move. Even the slightest deflection or motion of the guide

rods causes major errors in the finished product. A deflection of only 0.01 mm causes a routing error that is larger than the width of an isolation track, which makes it unacceptable in a PCB router. The PCB Prototyper is also equipped with anti-backlash ball nuts on the drive screws. These special nuts prevent mechanical play when the drives change direction, which is particularly important for routing small pads and narrow tracks.

### Electronics and embedded software

The biggest difference between a conventional milling machine and a PCB router is not in the mechanical components, but instead in the software that calculates the motions and controls the motors. It's obvious that making hundreds of small circles and tracks requires entirely different routines than milling objects such as front panels. It is therefore perfectly possible that a conventional milling machine with a top speed of 500 mm/s will take much longer to rout a PCB than a true PCB router with a top speed of 100 mm/s. The maximum speed is a secondary consideration for PCB routing; the acceleration and deceleration characteristics of the machine and the computation algorithms that are used are much more important. This is because the machine can never reach its top speed when routing a PCB, since the motions are much too small.

The controller for the PCB Prototyper is built around an ARM7 32-bit RISC microcontroller and an FPGA. This usually provides sufficient

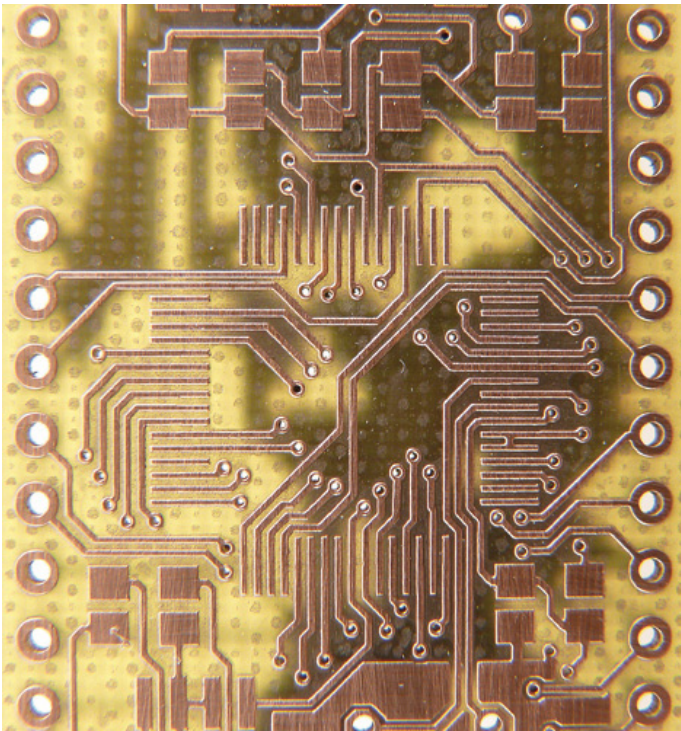


Figure 1. Detail of a PCB milled by the PCB Prototyper. Some of the isolation tracks are only 0.15 mm wide.

processing power to allow the machine to operate independently, but not always. For this reason, the PCB Prototyper controller is able to hand off specific tasks to the connected PC, which opens up unprecedented possibilities.

The built-in microcontroller allows the machine to calculate all of its motions without being dependent on the operating system running on the PC, but at the same time it can make use of the high

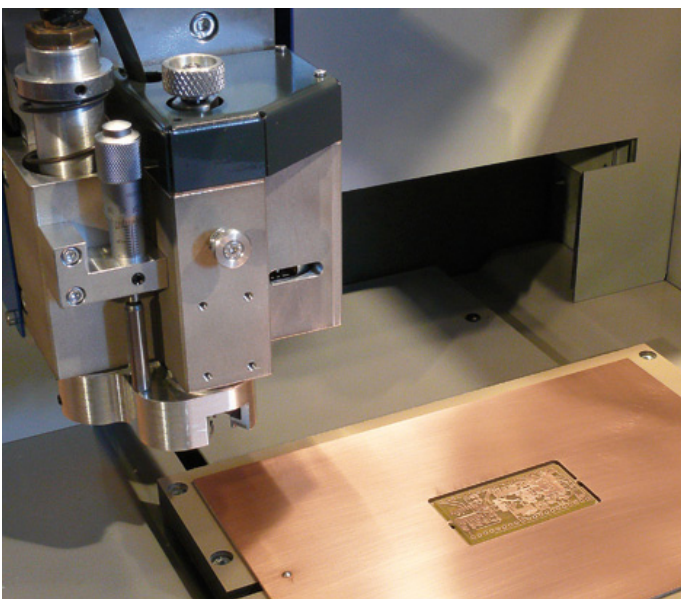


Figure 2. The engraving module with a PCB mounted on the table below. The entire table slides for motions along the X axis.

processing power of the PC. This approach utilises the advantages of both systems and eliminates their disadvantages.

### Multifunctional head

The multifunctional head is mounted on the Z axis of the PCB Prototyper. This module houses a high-precision spindle motor with air feed and dust extraction lines, a micrometer for depth adjustment, and a precision engraving module with a cyclone chamber. It also has provisions for mounting a camera, dispenser or other accessories.

The operating speed of the high-speed spindle motor can be adjusted under software control, with a maximum speed of 40,000 rpm. A handy tool lock knob and pivoting engraving module make tool changing easy. This considerably simplifies working with very fine drills and routing bits.

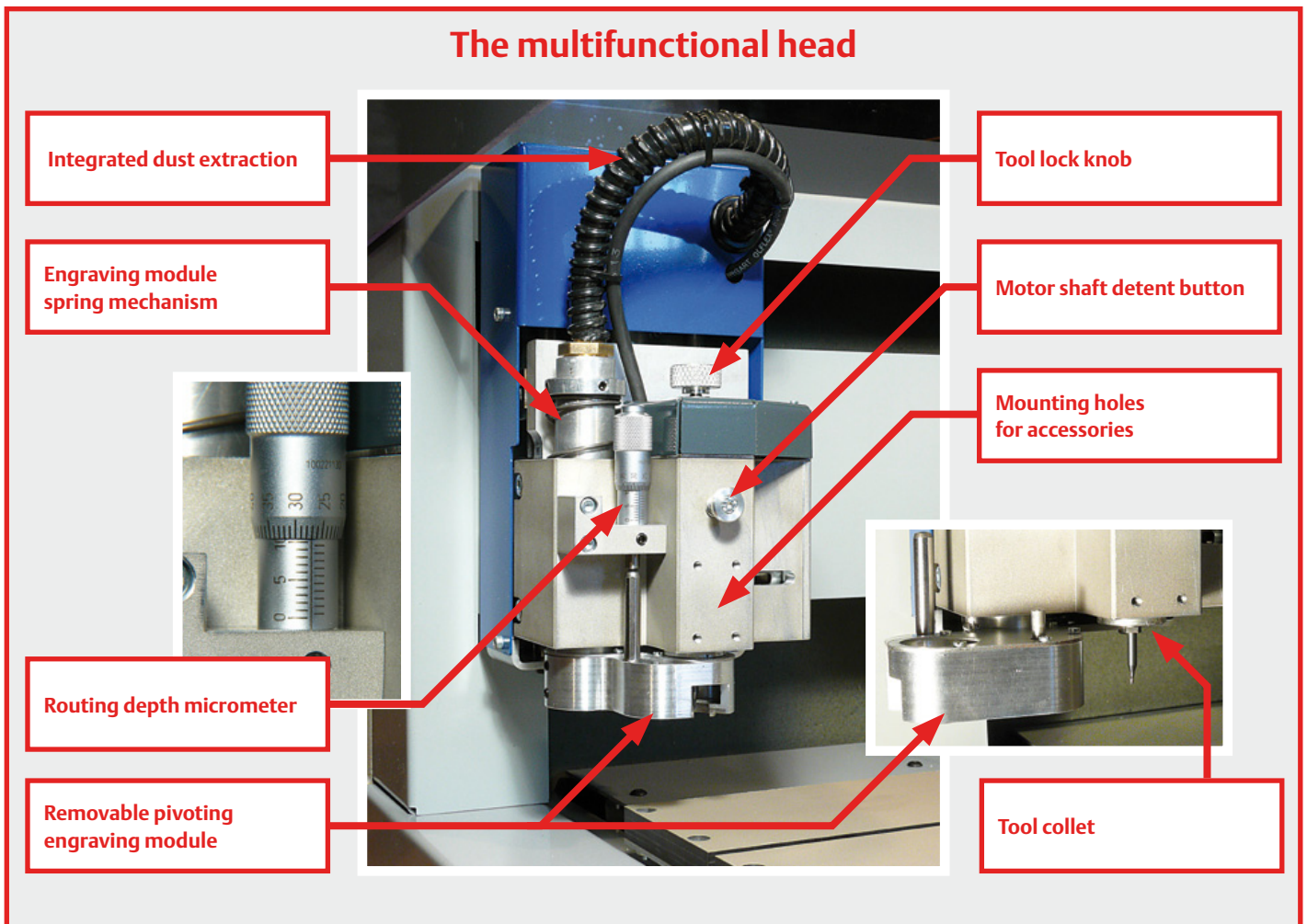
The dust extraction pickup is integrated into the engraving module. The major advantage of this is that the engraving module can be pivoted aside without disconnecting any hoses. The combination of a cyclone chamber and direct suction through the motor block effectively removes even the smallest dust particles.

The routing depth is set by a micrometer. This makes it possible to rout perfect isolation tracks, even with a conical routing bit. If you use the PCB Prototyper for other tasks, the micrometer can also be used for very precise adjustments or making measurements.

### A versatile machine

As already mentioned, the PCB Prototyper is more than just a PCB router. It can easily be adapted for performing other tasks. This applies not only to the mechanical aspects of the machine, but also the included software. The biggest challenge in developing a machine with this versatility was maintaining the necessary precision, since any time you can fiddle with a machine there's a chance of making mistakes. Several innovative solutions have been devised to achieve this:

- Like most PCB routers, the standard version of the PCB Prototyper is equipped with a flat table having a T slot in the middle. This slot holds sliding blocks with small pins for securing the PCB material. This is perfect for making double-sided PCBs, but it is not suitable for making other types of objects, such as 3D workpieces. The PCB Prototyper design allows the standard work table to be replaced by an aluminium table with T slots, a vacuum table, or a customer-specific table.
- The engraving module has an exchangeable depth sensor. The standard version of the machine is supplied with a depth sensor for routing the most common types of PCBs. For routing HF PCBs or very soft materials, it may be helpful to replace the standard depth sensor by a more suitable type.
- Almost all PCB routers have a fixed engraving module. This is ideal for routing PCBs, but it is entirely unsuitable for other types of jobs. The PCB Prototyper is equipped with the unique 'Pivo' system, which allows the engraving module to be swung aside. In addition to simplifying the fitting of delicate routing bits, this allows the engraving module to be removed easily. When it is removed, the dust extraction connector is exposed



and a different suction nozzle can be fitted if desired. This ensures that adequate suction is available, even with complex routing or milling jobs.

- The PCB Prototyper multifunctional head is designed for especially easy fitting of accessories such as a camera, measuring device or dispenser. The workspace of the machine is specifically adapted to this, so the spindle motor and fitted accessories can cover the full working area.
- A handy hatch door at the rear of the machine allows users to mount workpieces that are longer than the worktable. This enables users to machine specific locations on long objects without difficult manipulations, or to machine an entire object by marking reference points and sliding the object through the machine.
- It is even possible to remove the complete multifunctional head and use the machine for entirely different purposes. Thanks to handy quick-release couplings, the air lines built into the machine as standard can still be used for air supply and suction.

### Included software

The software included with a PCB router is very important. Users must be able to import files from their favourite PCB layout programs and have them converted into PCBs ready for assembly, all without any difficulties. Even highly complex designs should be processed smoothly. The PCB software module included as standard

with the PCB Prototyper is able to do this and much more. As already mentioned, the PCB Prototyper comes with ColiBri, a versatile software shell that holds all of the software modules for operating the machine. The idea behind this approach is that the user simply clicks a file, and ColiBri ensures that the right work environment is opened. For making PCBs, the PCB module is selected, and for making 3D objects the 3D module would be selected. This gives users a clear overview of all of their files, and each file is linked automatically to the right software module for the task concerned.

The PCB Prototyper is supplied with ColiBri and the PCB module as standard, which means that the PCB Prototyper is a full-fledged PCB router as delivered. If you need other modules, you can write your own (the entire command set is available to users) or purchase them for seamless integration with ColiBri.

### PCB module

The PCB module is a software package that complies with the latest software standards. The 'Office Fluent' user interface with Windows 7 look and feel makes working with the machine intuitive. The machine control software and CAM package are integrated seamlessly in the PCB module, which eliminates the need for manually transferring files from one environment to the other. This makes everything a lot simpler, since every modification made

## ELEKTOR PCB MILLING MACHINE

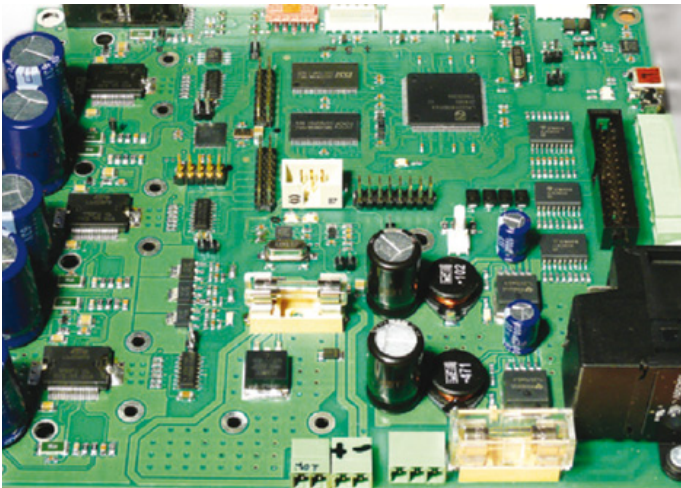


Figure 3. The PCB Prototyper controller board is built around a 32-bit RISC processor and an FPGA.

in the CAM environment is copied automatically to the control environment, and vice versa. Despite this coupling, you can process other PCBs in the CAM environment and generate contours for them without interrupting the routing activities of the machine.

The PCB module is free of the restrictions usually encountered with comparable packages. Capabilities that manufacturers often restrict in their basic packages, such as multilayer, residual copper removal, spike removal, different contour strategies for different tools, design rule checking, and a choice of metallised or non-metallised holes, are all standard features of the PCB module.

With the PCB Prototyper, routing PCBs is easy and errors are rare, but as with any mechanical process it's always possible for something to go wrong. The 'selective remake' function of the PCB module comes in handy here. Suppose a drill or routing bit breaks while a PCB is being made. You can select the poorly routed or unrouted area or feature and have this area, track, hole or whatever be remade, with everything else left alone. Without this function, your only choice would be to make a new PCB from scratch.

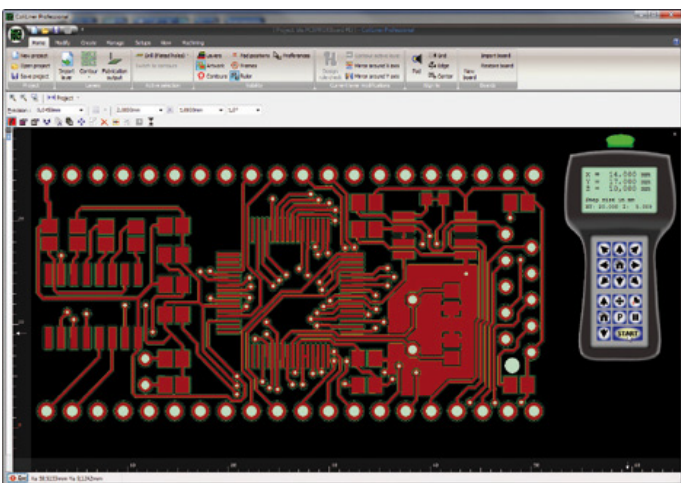


Figure 4. PCB contours computed using the new ColiBri program with the integrated PCB software module.

To see just what this PCB module can do, we used four similar CAM packages to generate contours for ten different PCBs, consisting of several HF boards requiring only residual copper removal, a few complex multilayer boards, and a couple of analogue and digital boards. In most cases (but not always) the PCB module took the least time to do the job, and it was able to generate routing files for all of the PCBs — which was not the case with the other packages.

There's not enough room here to describe all the functions and features of the PCB module. If you want to know more about what it can do, visit the Colinbus website at [www.colinbus.com/pcbprototyper](http://www.colinbus.com/pcbprototyper) for a detailed description.

### Ordering

The Elektor PCB Prototyper is supplied as a fully assembled and aligned machine with an integrated high-speed spindle motor. The included control software consists of the ColiBri shell with the PCB module. Please use the order form on the Elektor website to place your order ([www.elektor.com/PCB Prototyper](http://www.elektor.com/PCB Prototyper)).

The price is € 3500 / £3100 / US\$4900 plus taxes (if applicable) and shipping charges. The shipping charges depend on the country and are stated on the website.

The machine is delivered and invoiced directly by Colinbus.

Various software and hardware extensions for the PCB Prototyper are currently under development. They will be announced in *Elektor* and on the website when they are available.

### The proof of the pudding

Of course, it's not possible to give you a full picture of the capabilities and features of the Elektor PCB Prototyper with text and photos alone. What you really need is to inspect the results with your own eyes and a good loupe.

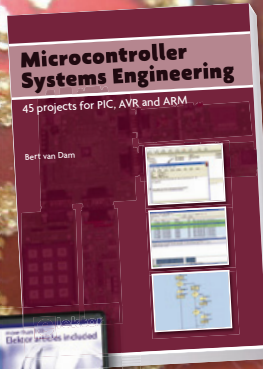
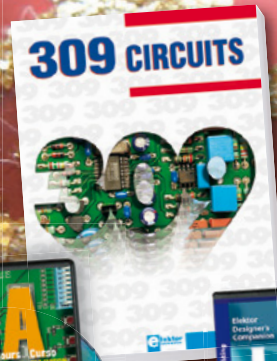
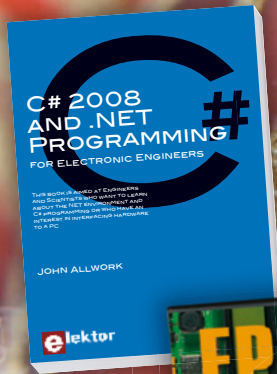
Unfortunately, we cannot invite every reader to a demo session, but we can report that our Elektor design staff are completely convinced after examining several PCBs routed by the PCB Prototyper — and they're very exacting when it comes to the quality of their boards. We're certain that the Elektor lab will soon boast a PCB Prototyper for making PCBs that need to be ready right away.

(100619-1)

**P.S. We're doing our best to arrange for a live demonstration of the PCB Prototyper at the ElektorLive! event on 20 November next, so everyone there can see what outstanding results this machine can deliver. This is provisional at present; check [www.elektorlive.nl](http://www.elektorlive.nl) for the latest news.**

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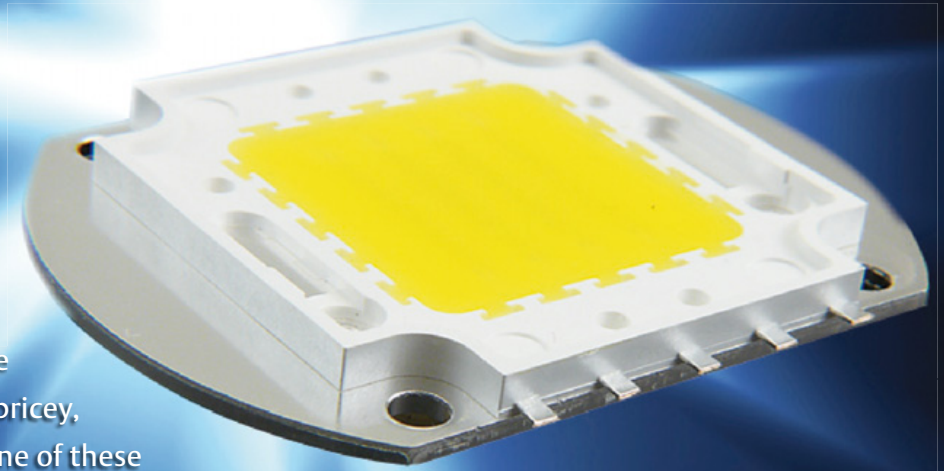


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# LED the Sun Shine

## 50-watt power LED with dimmer circuit

By Ton Giesberts (Elektor Labs) and  
Thijs Beckers (Elektor Netherlands Editorial)



Power LEDs are getting more and more powerful. Although they are still a bit pricey, we wanted to see for ourselves what one of these modern ‘heavyweights’ can do. One of most powerful LEDs we found that is available to normal consumers is the H50WA CWS from Huey Jann Electronics, an LED module that weighs in at a strapping 50 watts.

LED technology is advancing in leaps and bounds. We had to rub our eyes recently when we saw a high power LED rated at no less than 50 watts in some mail order catalogues including that of Reichelt [1]. That’s a lot of light, and we naturally wanted to see it with our own eyes. Reichelt was kind enough to provide two samples to us for our experiments. All we still needed was a power supply.

At first we had the idea of designing our own supply (preferably a switcher), but we quickly discovered that we would just be reinventing the wheel. When we found a Mean Well supply in the Reichelt catalogue that was virtually tailor-made for the power LED and with an almost unbelievable price, we realised that this was a better choice. However, we did develop a dimmer circuit to allow the LED brightness to be varied; it diverts some of the power from the supply to a shunt resistor.

### Power to the LED

The ready-made LPC-60-1750 power supply from Mean Well (Figure 1) is very well suited to the 50-W high power LED from

Huey Jann Electronics Industry Co. Ltd [2]. It could just about be made specifically for this purpose. The output current of the supply is exactly 1.75 A DC, which according to the data sheet of the power LED is the absolute maximum rated continuous current of the LED module. The supply can also handle an input voltage range of 90 to 264 V AC. The power supply is short-circuit proof and has protection against excessive constant output current and excessive output voltage. As expected, the LED produces a beastly flood of light. The stream of visitors who came into the lab had to shield their eyes to protect them from the intense brightness. Even viewing the lit-up LED from the corner of your eye was extremely irritating. Of course, we had it lying fully exposed on the lab bench (mounted on a heat sink, of course), but after being carefully fitted in a suitable fixture it would be a good deal more tolerable.

### Dimmer circuit

Up to this point, connecting the power LED to a power source was easy, but we also wanted to be able to adjust the brightness.

Our first idea for this was to simply build a circuit with a load in parallel with the LED (using a power resistor with a MOSFET or a PWM controller) that could divert a variable amount of current from the LED, since our selected power supply acts as a current source. Not exactly a ‘green’ solution, since this would cause power consumption without generating light from the LED. However, it could be less than what the LED consumes at full power because the current source has a specified regulation range of 9 to 34 V. If the LED is fully dark, in principle only 16 W has to be dissipated ( $1.75 \text{ A} \times 9 \text{ V}$ ). Shorting the output or overloading it in order to consume even less power was not an option in our view, since we didn’t know whether the supply could handle this over the long term.

The thought that power would still be dissipated even when the LED was dark stimulated us to come up with a more efficient solution. The component that (under ideal conditions) does not have any power dissipation with a DC current is an inductor. Our first idea was to connect a PWM load to the power supply and divert a variable amount

**Power LED specs**

Maximum continuous current: 1.75 A  
 Operating voltage: 27–28 V  
 Light flux: 2925–3735 lumen, depending on colour  
 Beam angle: 120 degrees  
 Colour temperature: 3300–8000 °K  
 LED junction temperature: 135 °C

**Power supply specs**

Output current: 1750 mA  
 Output voltage: 9–34 VDC  
 Input voltage: 90–264 VAC  
 Maximum power: 59.5 W  
 Efficiency: 87%  
 With overload protection and short-circuit protection



Figure 1. The output current (1.75 A) and current-source configuration make this Mean Well power supply ideal for use with the 50 W power LED.

of current from the LED in order to dim it (See **Figure 2**). The PWM frequency should be high enough to allow the inductor to be kept reasonably small (we chose approximately 100 Hz and a 40 μH inductor rated at 2 A).

Unfortunately, this idea didn't work. The problem with this approach is that a certain amount of power must always be drawn from the supply, and it has to go somewhere. This 'excess' power is normally converted into heat. Here we attempted to avoid this by converting the excess energy into a magnetic field. Our simulation showed that the magnetic field strength rose higher and higher and never returned to zero. Of course, a magnetic field that increases indefinitely is impossible in practice. Unfortunately, a flyback diode was not enough to dissipate the energy in the time when the inductor was not acting as a load. Even with a low duty cycle, after a few switching cycles the current would rise so high that it would cause the MOSFET to fail, and perhaps the inductor as well if the power supply could deliver enough current. In the case of our current source, which has a maximum output of 1.75 A, the LED would go dark even with a low duty cycle. All in all, not an especially practical circuit.

**Another idea ...**

One way to prevent the inductor from becoming saturated is to reverse the polarity of the magnetic field with each switch-

ing cycle. For example, this could be done by using two MOSFETs in a circuit configured as a push-pull converter with a centre-tapped transformer. In our case, we could take a standard interference suppression choke and add a second winding with the same number of turns as the existing one. However, we would still have the problem that the inductor constantly absorbs energy and must give it back somehow. We didn't see any sense in pursuing the idea of using an inductor for controlling the LED brightness any further. However, we still secretly wonder what would happen if we drove the

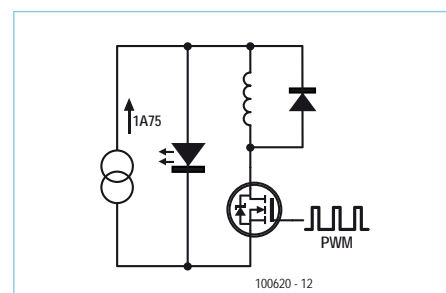


Figure 2. The basic design of our first idea for a dimmer circuit has a few pitfalls.

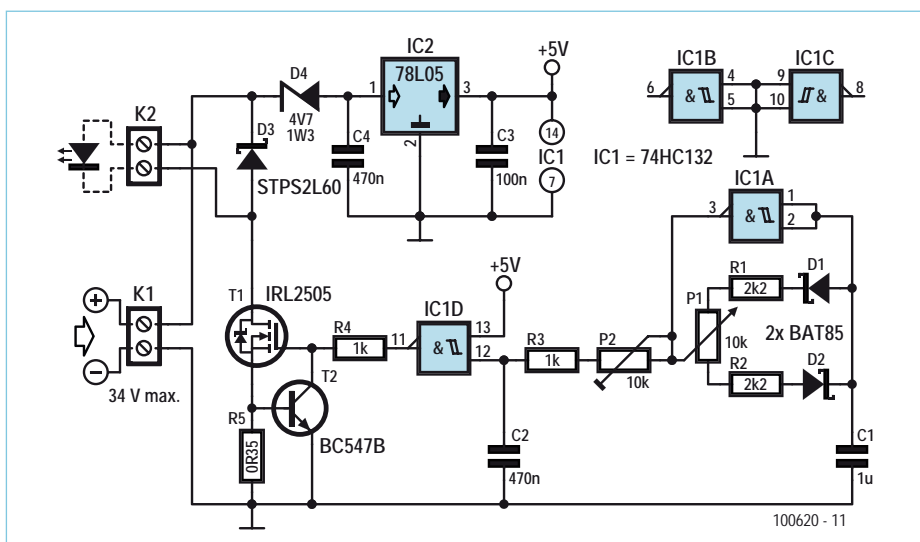


Figure 3. The schematic of the dimmer control circuit we ultimately came up with shows the simplicity of the design.

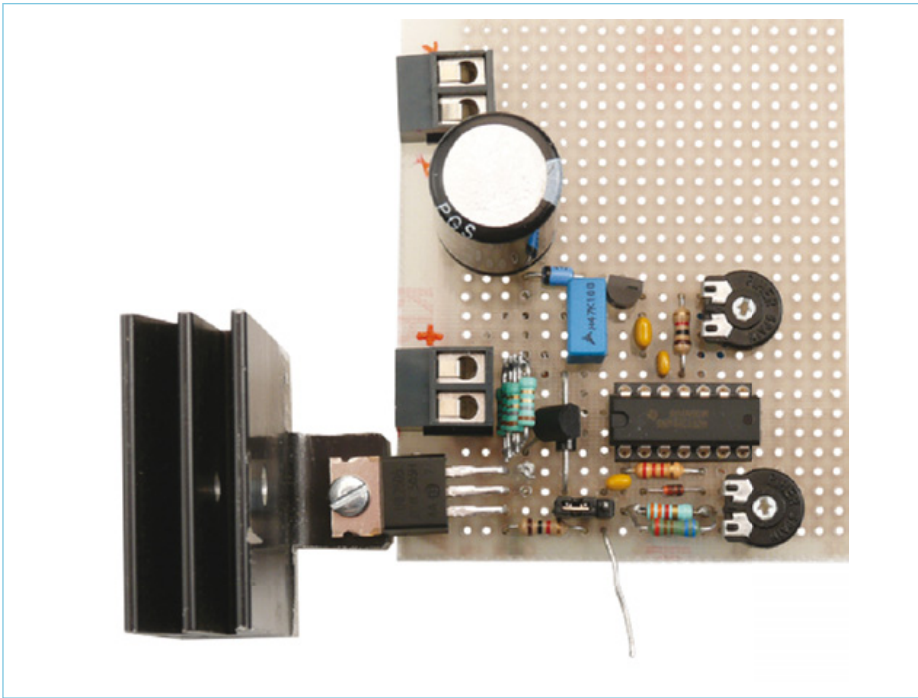


Figure 4. We didn't design a PCB layout for the dimmer circuit. Our experimental version was built on a prototyping board.

inductor with a symmetric current (pure square wave) at a variable frequency.

### ... and yet another

Another fairly obvious solution is to switch the LED itself at a relatively low frequency, such as 150 Hz. To be on the safe side, we first tried operating the power supply with a

switched resistor as a load. It's a good thing we did this first, because the power supply turned out to operate as a constant current source only with a constant load. Our test showed that the internal control circuit of the power supply has a very long response time. With a pulse-shaped load, the output voltage rises to the maximum level of 34 V.

The supply delivers distinctly more than 3 A during the pulses (we didn't pursue this experiment any further), which would be far too much for the LED.

### A workable solution

The right solution for switching the LED is simple. Instead of using the MOSFET only as a switch, we have it act as a current source as well. This only requires a sense resistor to measure the current and an additional transistor (T2 in **Figure 3**). The sense resistor is wired in series with the source of T1 and provides the base-emitter voltage for T2. The collector of T2 is connected to the gate of T1. If the voltage across the sense resistor rises to level where T2 starts to conduct, the gate voltage of T1 is pulled to ground.

This is a very simple constant-current source. One disadvantage of this circuit is the temperature dependence of T2. This causes the current to decrease as the temperature increases, which can be regarded as a form of protection. If you build this circuit yourself, it's a good idea to put T2 further away from the sense resistor than we did (see **Figure 4**), since the resistor can dissipate more than 1 W. When the controlled current through T1 is lower than the current delivered by the power supply and the duty cycle of the PWM signal generated by IC1a is 100%, the maximum dissipation of T1 can be more than 11 W. This means that T1 must be cooled by mounting it on a heat sink with a thermal resistance  $R_{th}$  of 3 K/W.

The MOSFET drive circuit is based on the 'Light Therapy Box' (a.k.a. Bluesbraker) design published in the November 2009 issue. In this case we used a 74HC132 for the Schmitt-input NAND gate. A 5-V signal is more than enough to properly drive the logic-level MOSFET T1. A simple oscillator is built around IC1a. Its duty cycle can be adjusted with P1 over a range of approximately 16% to 84% (nearly symmetrical around 50%). IC1d causes the PWM signal to the MOSFET to be always low or always high at the minimum or maximum duty cycle setting (respectively) of the signal from IC1a. This allows the LED to be adjusted to full on or full off, despite the limited range of the control circuit. It might be possible to

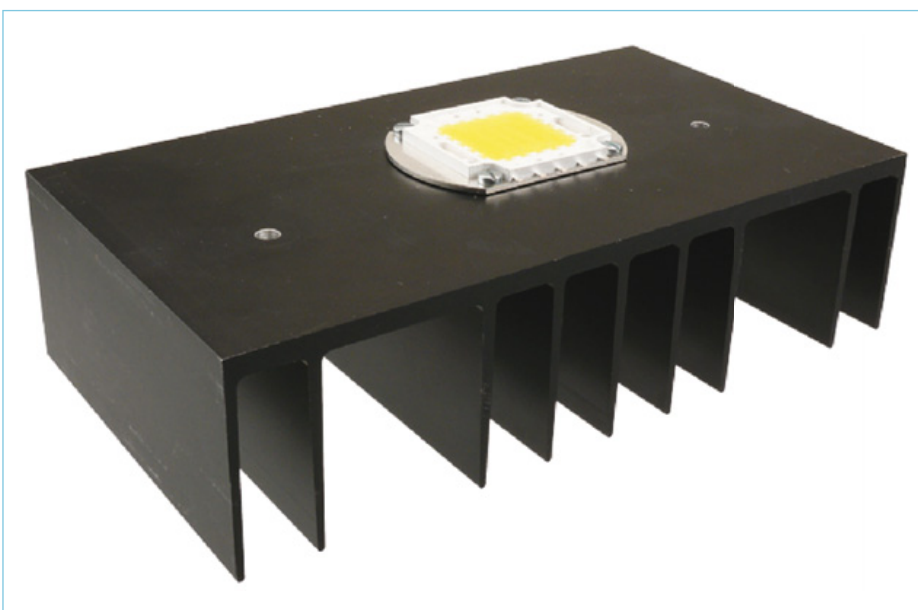


Figure 5. This LED module obviously requires cooling. Following the motto 'better safe than sorry', we drew a somewhat oversized heat sink from stock for our circuit.



extend the adjustment range of P1 by modifying the time constants of the two gates. With the component values shown in the schematic diagram, the minimum current before the LED goes dark is approximately 150 mA.

Power for IC1 is supplied by an 78L05. The maximum input voltage of the control circuit is 30 V; Zener diode D4 ensures that it stays in bounds. The current consumption of the control circuit built around IC1 is so low that the power dissipation of IC2 does not increase significantly at high input voltages. Diode D3 limits any inductive voltages generated by parasitic inductances in the wiring.

### Toasty

If you want to build the LED and power supply into a lighting fixture, you'll have to devise something that allows sufficient cooling. The data sheet warns that the surface temperature of the LED can be as high as 150 °C, and that the aluminium mounting plate to which the LED is attached is far from adequate for dissipating the heat from the LED.

The heat sink shown in **Figure 5** is a bit exaggerated. The data sheet is not entirely clear on the amount of cooling required. It states for example that for use with horizontal orientation a surface area of 550 cm<sup>2</sup> is necessary for adequate cooling of the LED, but we wanted to be on the safe side during our experiments. The light output of the high-power 50 W LED is around twice that of a standard 100 W incandescent lamp (no longer available to consumers in most of Europe), with only half of the power consumption. When the LED is highly dimmed, you can see the individual points of light. It appears that Huey Jann Electronics constructs the modules by placing four strings of LEDs side by side, with eight LEDs in each string. This is consistent with the voltage obtained by multiplying the average voltage over a white LED (3.3 V) by 8. The resulting value (26.4 V) is very close to the rated forward voltage of the power LED module (27 V).

These LED modules are available from Reichelt in several colours, including warm, cool, natural and pure white. On the manufacturer's website and the data sheets you can see that the modules are also available in other colours, but at the time of writing they still haven't found their way to the electronics retail market. Fingers crossed — eyes wide open.

(100620-1)

We wish to express our thanks to Reichelt Elektronik, Germany, for providing the power LEDs and the Mean Well power supply.

### Internet Links

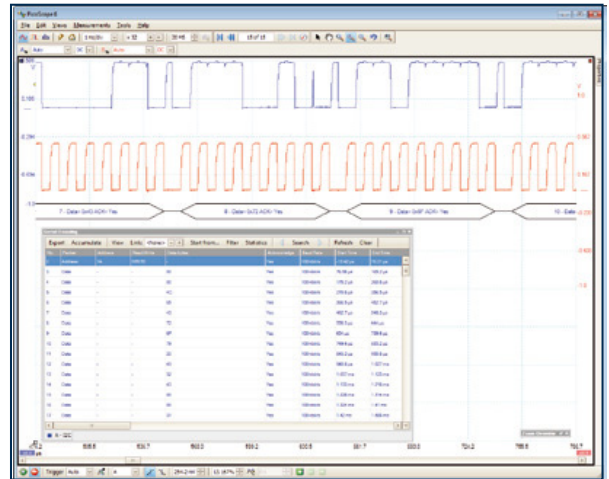
[1] [www.reichelt.de](http://www.reichelt.de)

[2] [www.hueyjann.com.tw](http://www.hueyjann.com.tw)



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# NetWorker

## An advanced web server with a micro

By Sven Schlender (Germany)

An Internet connection would be a valuable addition to many projects, but often designers are put off by the complexities involved. The 'NetWorker', which consists of a small printed circuit board, a free software library and a ready-to-use microcontroller-based web server, solves these problems and allows beginners to add Internet connectivity to their projects. More experienced users will benefit from features such as SPI communications, power over Ethernet (PoE) and more.

There are three key elements in connecting a device to an Ethernet network: the Ethernet connection hardware itself, the software library (called the 'stack') responsible for handling the various protocol layers, and finally the top-level firmware functions. For example, to allow access to a device from anywhere in the world, it is possible to use a small web server running in a microcontroller.

Compact ready-made modules are available on the market to cover the first two of these elements. They allow you to connect a microcontroller to a network without having to get involved in the gritty details of its protocols. However, programming against the libraries provided can be a daunting task for the beginner; and more experienced users often find it necessary to 'work around' the firmware provided with the module to enhance or modify it.

The solution provided here hides the complexity of the network protocols from the application programmer, and is simple to extend and very versatile. The circuit is based around a Microchip PIC18-family microcontroller which includes a built-in Ethernet transceiver. The author has added a few new functions to the free C software library available from the manufacturer that implements the TCP/IP stack. The final element of the project is a web server running on the microcontroller which can communicate with other hardware via the I/O pins of the device. Using this design it is possible to assemble a small system in just a few minutes, capable of being controlled at will over the Internet. Beyond that, the module can be used as a 'network modem' for another

microcontroller. Extra advanced features such as PoE round out the project.

Printed circuit boards and ready-programmed microcontrollers are available from *Elektor*, as well as the complete ready-made module. And of course the accompanying software is also available as a free download from the *Elektor* website.

Now let's see what makes the module tick.

### The circuit

**Figure 1** shows the circuit of the module. At the heart of the unit is a Microchip PIC18F67J60. This device is one member of a range of microcontrollers that include a 10BASE-T Ethernet transceiver. Most of the circuitry required is provided in the device and only a few external components (including a connector!) are needed to connect to a network.

The Ethernet PICs require a 2.5 V core voltage supply, which can be derived from a higher voltage (3.3 V is recommended) using the voltage regulator included in the PIC. Pin ENVREG determines whether the voltage regulator is enabled. A 10  $\mu$ F capacitor (C112) provides smoothing and capacitors C101 to C106 positioned around the microcontroller decouple the supplies. A 25 MHz crystal (Q101) provides an external clock for the microcontroller, and the Ethernet transceiver clock is also derived from this source.

The project includes a bootloader which allows new firmware to be uploaded over the Ethernet interface. Alternatively the device can be programmed via the solder pads MCLR, VCC, GND, PGD and PGC which form the standard Microchip in-circuit

serial programming (ICSP) interface. This interface is needed for debugging software problems or if the module gets into a state where it no longer responds to being rebooted. A dedicated programmer (such as the ICD2) is required for debugging and programming over this interface.

The reset circuit comprises R102, R103 and C107. R102 is a pull-up resistor, and R103 and C107 filter the reset signal to prevent spurious resets. C107 can interfere with the operation of the ICSP interface, and so should be removed if it is to be used.

The EEPROM stores configuration data. It also includes a 48-bit ID code, called the MAC address, required for Ethernet communication. The proprietary Microchip UNI/O bus protocol allows the EEPROM to be accessed over a single wire.

### Ethernet interface

The connection to the Ethernet network comprises four signals, TPOUT+, TPOUT-, TPIN+ and TPIN-. These signals are passed via the Ethernet transformer TR1, which galvanically isolates the main part of the circuit from the network. On the far side of the transformer is an RJ45 socket J1, into which a standard Ethernet cable can be plugged. A special feature of the transformer we have chosen is its compatibility with the IEEE 802.3af power over Ethernet (PoE) standard. Under this standard a 48 V supply is provided on the network and a powered device (PD) can draw current from this supply. There are two alternative arrangements possible:

1. using the spare conductor pairs (on J1 these are pins 4 and 5 and pins 7 and 8); or
2. phantom supply over the signal pairs

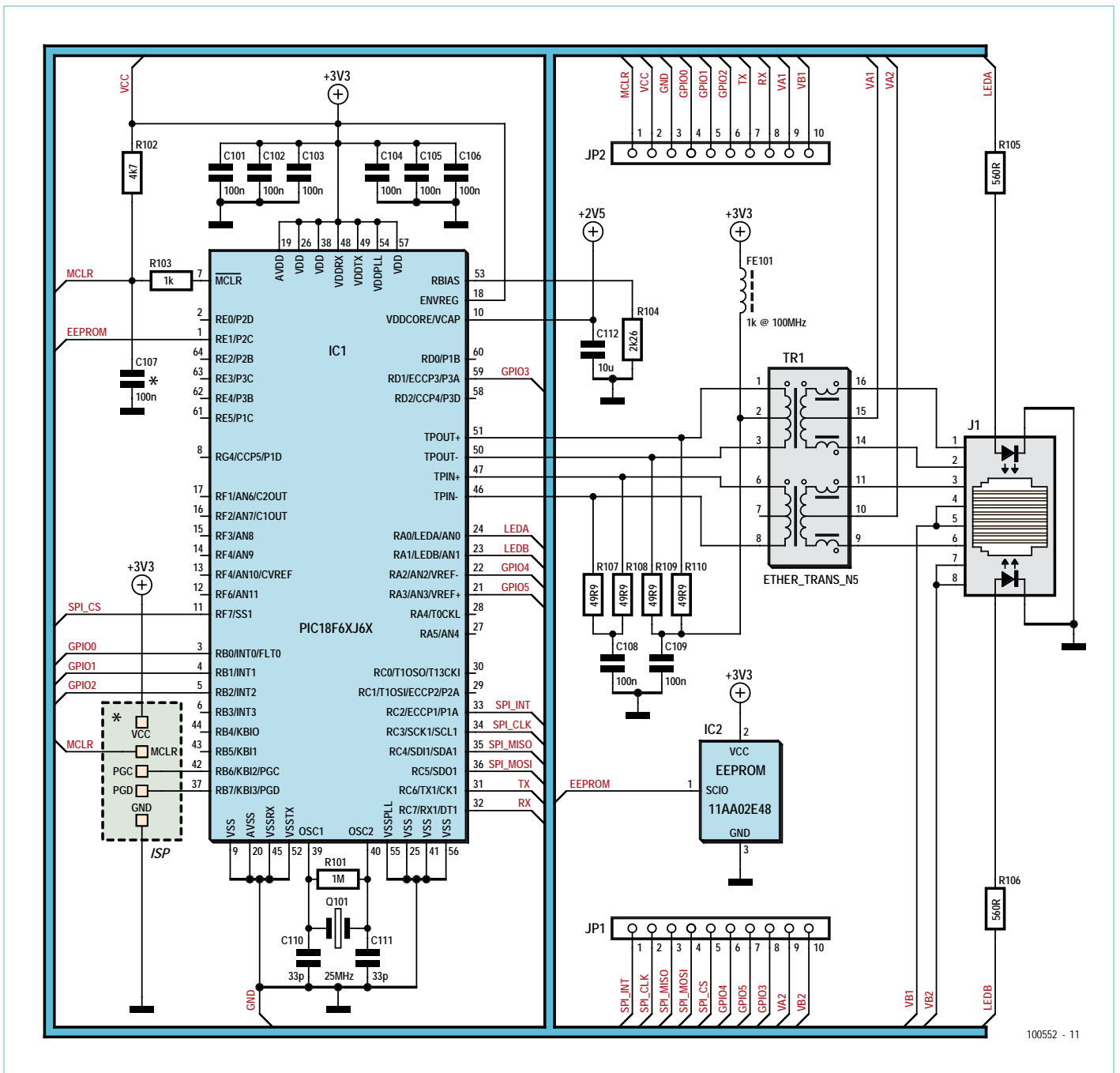


Figure 1. Circuit diagram showing the PIC microcontroller, transformer and network socket.

(pins 1 and 2 and pins 3 and 6).

A PoE-standard device must support both possibilities. To take advantage of the phantom supply a special transformer is needed with centre taps to the windings on the network side.

Implementing both power options means that a total of four wires have to be brought to headers JP1 and JP2, which form the user-side interface to the module. A suitable PoE

regulator circuit can be connected to these headers to derive a supply for the module from the 48 V DC provided over the network (see below).

Resistors R107 to R110 provide impedance matching, and C108, C109 and FE101 help reduce the effect of interference spikes on the network connections. R104 is a bias resistor that provides the Ethernet transceiver circuit with a known reference current (hence its bizarre value). This

in turn determines the signal amplitude on TPOUT+ and TPOUT-.

There are two LEDs mounted inside the Ethernet socket. LED1 lights when the link is up (in other words, when there is a connection between the module and at least one other network device), and LED2 indicates network activity. The LEDs are driven from the PIC via series current-limiting resistors R105 and R106.

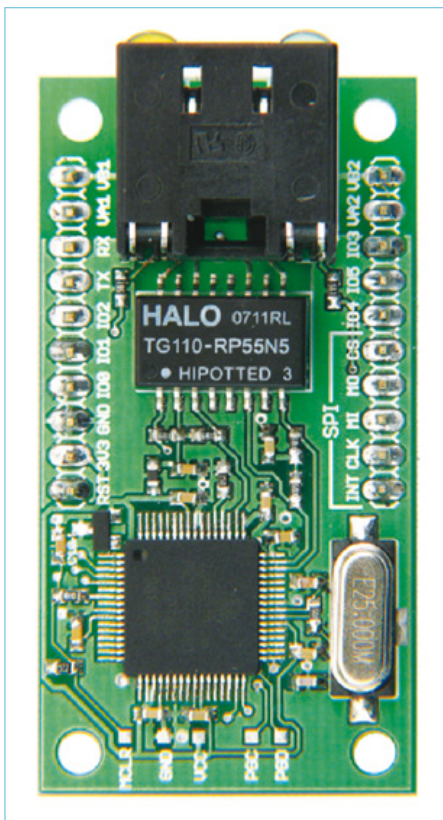


Figure 2. The printed circuit board is also available ready-assembled.

### User-side interface

The user-side interface consists of two 10-way 0.1 inch pitch headers. As well as carrying the PoE connections and the module’s power supply, the headers are also directly connected to certain pins on the microcontroller. On the author’s printed circuit board design (see **Figure 2**) the two headers are mounted 0.1 inch apart, which allows the module to be mounted easily on

ordinary prototyping board. Pins VCC and GND form the power supply to the module. The supply voltage should be between 3.1 V and 3.6 V. Pins VA1, VA2, VB1 and VB2 allow the module to be used in conjunction with a power over Ethernet regulator, sometimes called a ‘PD module’, such as the Silver Telecom Ag9000 series [2]. **Figure 3** shows an example circuit using the Ag9033, which provides a regulated 3.3 V output from the PoE DC supply.

The active-low MCLR pin allows the module to be reset. It is also pulled low briefly when power is applied to the module. The other pins on the user-side interface are for use either to control external circuits or to sense their state, or for more general communications (by UART or SPI). Pins GPIO0 to GPIO2 can be configured as digital inputs or outputs; those configured as inputs can be used to generate an interrupt to the microcontroller. Used as an output, each pin can sink or source up to 25 mA. Pin GPIO3 is also configurable as a digital input or output, but can only sink or source up to 8 mA. A future software version may allow a PWM signal to be generated on this pin. GPIO4 and GPIO5 (which can be configured as inputs or outputs) can sink or source up to 2 mA. A future software version may allow these pins to be used as analogue inputs with 10 bit conversion resolution.

### Communications

Pins TX and RX are connected to a UART that can support speeds of up to 115200 baud. Alternatively, these pins can be configured as ordinary digital inputs or outputs; as outputs, they can each sink or source up to 25 mA.

An SPI interface is available on the pins with labels starting ‘SPI’. The interface can operate in master mode or in slave mode, and the function of the pins depends on the mode selected.

1. In master mode SPI\_INT is not used, SPI\_CLK is the clock output, SPI\_MOSI the data output, SPI\_MISO the data input. The active-low SPI\_CS output is used to enable the connected slave device.
2. In slave mode SPI\_INT is used to indicate when an event has occurred in the module

that needs the attention of the SPI bus master. SPI\_CLK is the clock input, SPI\_MOSI the data output, and SPI\_MISO the data input. The active-low SPI\_CS input is used to enable reception of a bus message by the module.

Again, these pins can alternatively be configured as digital inputs or outputs. As an output, SPI\_CS can sink or source up to 2 mA, while the other pins can each sink or source up to 25 mA.

A future software version may allow SPI\_MISO and SPI\_CLK to be used as an I<sup>2</sup>C interface. In this case SPI\_MISO would be the SDA (data) signal and SPI\_MOSI the SCL (clock) signal.

### Software library

A ‘stack’ is a collection of software implementations of protocols and drivers, usually arranged in a hierarchy of layers. At the bottom end of the stack are the hardware drivers which are responsible for getting data bits transferred onto the network wires. At the top end of the stack is a simple interface for data exchange.

In theory, the layered protocol model makes it relatively easy to make modifications to one layer (such as the hardware driver) without affecting the others. In practice however, when implemented on a microcontroller, the hardware and the stack are very closely tied together, and lots of tricks need to be used to keep memory usage low. Nevertheless, TCP/IP stack implementations are available for a wide range of microcontroller families, often for free and direct from the manufacturer.

The author’s first tentative steps towards building a TCP/IP stack for a PIC microcontroller were in assembler. Over time, however, as the code grew, maintenance became harder and harder, and an alternative solution was needed.

Microchip offers a TCP/IP stack for its PIC18, PIC24, dsPIC and PIC32 microcontroller families written in ANSI C. It is free and can be extended and modified as long as it is only used in Microchip devices. It contains a rich collection of hardware drivers, low-level protocol implementations (ARP, IP, TCP and so on) and a couple of important appli-

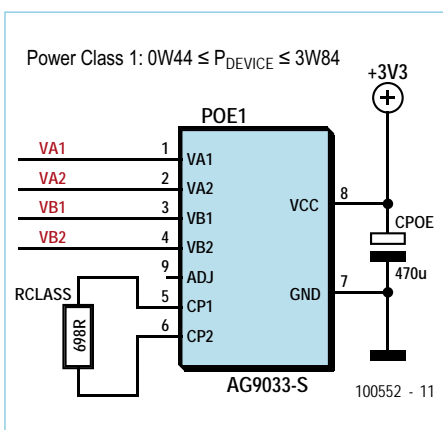


Figure 3. A PoE regulator can be used to provide power for the module.

cation-level protocol implementations such as DHCP and HTTP. The simple MPFS file system is also included to allow storage of web page source data. Example applications, a bootloader, tools and comprehensive documentation of all stack functions complete the package.

The author evaluated and extended this protocol stack for the project in the light of his experience designing the 'eWicht' handheld model railway controller [3]. For example, the DHCP module was extended to include an AutoIP mechanism (see glossary). An mDNS server was incorporated so that the module could autonomously make its presence known on a network (see below).

A feature was added to check values entered on web forms for type and range errors, and the MPFS tool provided by the manufacturer was extended to use a Huffman code to obtain a saving in memory footprint of up to 50 %.

## Application software

The module has an integrated bootloader that allows a new version of its firmware to be uploaded over the Ethernet connection for installation at any time: suitable hex files are available on the project's web pages [1]. More details on this process can be found in the text box 'Bootloader'.

The author developed the application software for the module using the MPLAB IDE. It is written entirely in ANSI C and can be compiled using the free version of the Microchip C18 compiler.

The application consists of three modules, called Main, Web and Appl. The bootloader jumps directly to Main, where the TCP/IP stack, the EEPROM driver and the Appl module are initialised. Then Appl and the TCP/IP stack receive processing time alternately in an infinite loop.

The Web module implements the web interface (web server and web pages). When a client, such as a browser running on a PC, requests a page the relevant information is prepared. If a completed web form is received from the client, its contents are checked and passed on to the relevant module. Since most data are stored in EEPROM,



Figure 4. The 'Bonjour' browser plug-in scans the network for devices (on the left of the picture). This allows access to the module without having to know its actual IP address.

they are still available after a reset or loss of power.

The Appl module forms the main part of the application. Within it there are three further sub-modules: Bootup, GPIO and Serial. Each of these is initialised by Appl and then called in round-robin fashion. The Bootup module makes sure that the GPIO and Serial modules are accessible if a network connection exists: that is, when an IP address is avail-

able and unambiguously registered on the network.

The GPIO module is responsible for reading and writing the I/O pins of the device. The module communicates with the web interface to allow the levels on the pins to be read and written via a web page. However, the possibilities go well beyond simple manual operation. The unit also makes a kind of web service available (on a port configura-

## Bootloader

The bootloader used is the one included in the TCP/IP software package provided by Microchip for its PIC18F97J60-series devices. This includes a footprint-optimised implementation of the TFTP server and ARP protocols (see glossary), as well as a hex file parser and flash programming routines: everything needed to program new code into the chip.

There are two ways to access the bootloader. If the microcontroller has not been programmed with an application hex file, or if there has been an error programming the hex file, the bootloader is automatically invoked. This will always be the case with a 'virgin' microcontroller. Alternatively, if an application hex file has been successfully programmed, the bootloader will be active for just the first two seconds or so after power is applied. The bootloader's IP address is fixed at 192.168.97.60, and its MAC address is 00-04-A3-00-00-00. A connected PC must have an address on the same network (such as 192.168.97.61) or it will not be possible to upload a new file. The microcontroller is then programmed by simply sending a hex file using TFTP.

If you wish to upload a new hex file while the device is in operation, you simply need to start a TFTP upload to its current IP address. The bootloader will be invoked automatically and the programming operation will start. (For this to work the running application must make use of the 'Reboot' module, which is part of the Microchip TCP/IP stack.)

TFTP clients are available for almost all operating systems. A typical invocation of the client on a Windows system looks like this:

```
tftp 192.168.97.60 put "file.hex"
```

After a short wait a message resembling the following should appear:

```
Transfer successful: 203557 bytes in 8 seconds, 25444 bytes/s
```

The device will then automatically reboot into the new version of the firmware.



Figure 5. The home page for the module’s web interface. The ‘Blinking’ button comes in useful when more than one module is used simultaneously.

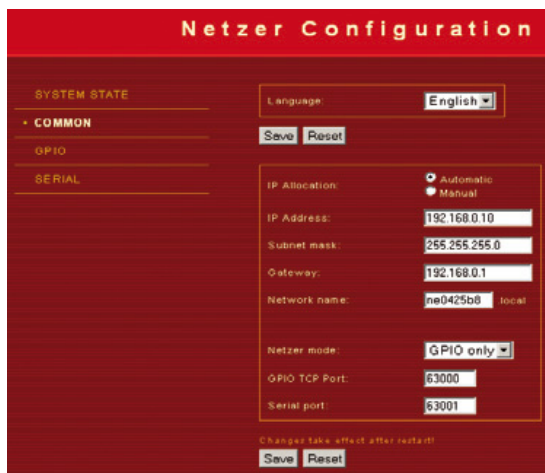


Figure 6. Using this web form you can (among other things) specify the ports on which the module will listen.

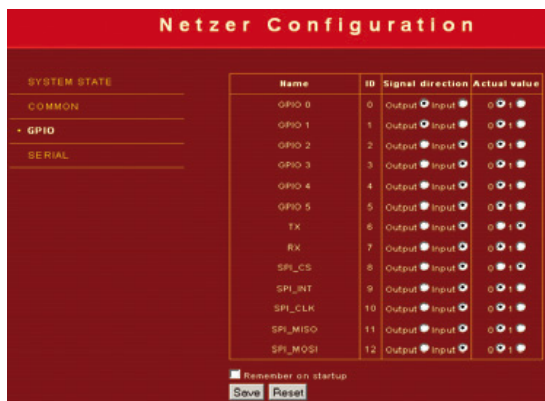


Figure 7. The radio buttons indicate the state of each pin.

ble via the web interface) called ‘GPIO Service’. Another device on the network can use this service to control and read the GPIO pins using a simple protocol (see below).

As already alluded to, the unit includes serial interfaces. Data can be transferred from these ports to the network using a separate TCP connection, or in the opposite direction: more details later on. Initialisation and data handling are done in the Serial module. A further service (‘Serial Server’) is responsible for listening on a (configurable) port for requests and data.

### Using the module

For first experiments with the module it should be connected to a PC using a crossover patch cable. When power is applied the application program starts up, with the link LED lighting and the network activity LED blinking irregularly. The module will first try to obtain an IP address. By default this happens over DHCP, but if no DHCP server is found, AutoIP is used (see glossary). If a network error should occur during this phase, the link LED will start to blink rapidly.

How do we know what IP address the module has acquired? A simple way to find out is to use Bonjour, a program developed by Apple which is now also available for Windows (most simply installed as a browser plug-in, for example for Firefox [5]).

An mDNS service runs on the module, which advertises the device’s presence to the rest of the network. Bonjour scans the network for devices running this service and displays the results in the browser (see Figure 4, left-hand part of the screen image). One click later and the web server responds by sending its home

page. This can all be done without the user having to know the IP address of the device. The web server can serve up a variety of pages. The main page gives information on the device itself (version, IP information, network name and so on). There are also buttons to reset the module, stop it, and reset its settings (Figure 5).

Under the ‘General’ menu it is possible (among other things) to change the operation mode of the module (Figure 6).

### GPIO mode

In GPIO mode the pins listed above can be configured as inputs or outputs via a web page, with the default setting being ‘input’. Unconnected pins should be prevented from floating either using pull-up or pull-down resistors or by configuring them as outputs. When the GPIO web page is loaded the radio buttons indicate the state read from the GPIO pins (see Figure 7), and then when the form is submitted the values are sent to the GPIO module. If required, the initial values of pins configured as outputs can be stored in the EEPROM.

The GPIO server module is active independent of the operation mode chosen, and other devices on the network can connect to it at any time using its simple text-based protocol. A tool such as Hyperterminal can be used to communicate with the server (using a Winsock connection specifying the network name or IP address as the host, and port number as configured). The GPIO web page gives each pin an ID code: this code is used in commands to the server in the form ‘ID=value’, terminated by a character code in the range from 0x00 to 0x20. The ‘value’ can be ‘0’, ‘1’ or ‘?’, the question mark representing a command to the server to request the status of a port pin. The server replies to requests and commands with a string of the form ‘ID=0’ or ‘ID=1’. The special wild-card ID ‘x’ indicates that all GPIO pins are to be read or written by the request or command. For example, a request of the form ‘x=?’ will receive a reply of the form ‘x=1234’, where ‘1234’ is a hexadecimal value in little-endian format, that is, to be interpreted as bits in ID code order from right to left. Write commands work in an analogous way.

### Serial modes

In UART mode the TX and RX signals form an asynchronous serial interface and are thus not under the control of the GPIO module; nevertheless, the GPIO module can still be used to read the state of these lines. The baud rate can be adjusted via the web page that is reached by clicking on the ‘Serial’ menu item (Figure 8). The asynchronous interface can, with suitable level conversion, be used to connect to devices with an RS232 port.

The serial server is active in this mode. Characters can be sent to the device over the configured port, and these are echoed over the serial port in 8N1 format. Likewise, characters received over the serial port can be sent to another device on the network.

SPI is an interface that can be used to connect to a wide range of storage, display and other devices. When a suitable network connection is established with the serial server data can be sent using TCP/IP to the unit. In this mode it acts as an SPI bus master, which means that it initiates all SPI communications. When data arrive, it asserts SPI\_CS (in other words, takes the signal low). Each data byte is then sent out bitwise SPI\_MOSI, accompanied by a clock on SPI\_CLK. Data are read back from a connected slave over SPI\_MISO using the same clock for synchronisation. Bytes read in are then sent out over the TCP/IP connection. A zero byte in the data stream is used as a terminator. When the terminator byte is received over TCP/IP, the unit deactivates SPI\_CS (by taking it high); the terminator byte itself is not sent out over the SPI bus. A zero byte that is to be transmitted to the SPI slave must be escaped by prefixing it with a backslash character ('\'); the backslash character itself is represented by two backslashes. No special escaping is applied to zero bytes received from the SPI slave.

The web page for the serial interface allows a choice of clock frequencies (650 Kbit/s, 2.5 Mbit/s and 10 Mbit/s) and of SPI clock polarity (Figure 9).

When operated in slave mode, the unit can work as a network ‘modem’ for another microcontroller. This microcontroller can, with the help of the unit, create and destroy

TCP/IP connections (as client or server) as well as transmit and receive data. Further details on the additional protocols required for operation in this mode can be found in a supplementary document downloadable from the *Elektor* website.

(100552)

### Internet Links

- [1] [www.elektor.com/100552](http://www.elektor.com/100552)
- [2] [www.silvertel.com](http://www.silvertel.com)
- [3] [www.mobacon.de/eWicht](http://www.mobacon.de/eWicht)
- [4] [http://en.wikipedia.org/wiki/Bonjour\\_%28software%29](http://en.wikipedia.org/wiki/Bonjour_%28software%29)
- [5] [www.bonjourfoxy.net](http://www.bonjourfoxy.net)

### Ideas for future expansion

- Extensions to existing functionality
- Changes to format and content of embedded web pages
- Special functions for use in control applications
- Contact the author: [schlender@mobacon.de](mailto:schlender@mobacon.de)

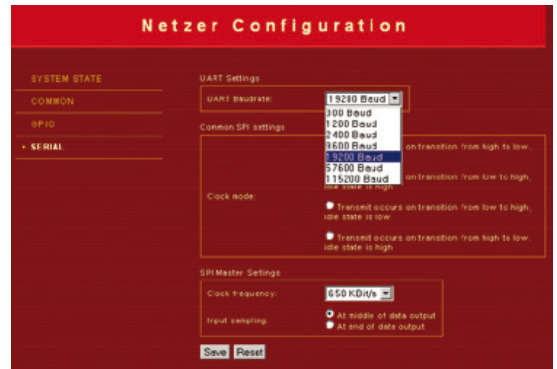


Figure 8. Setting the UART’s baud rate.

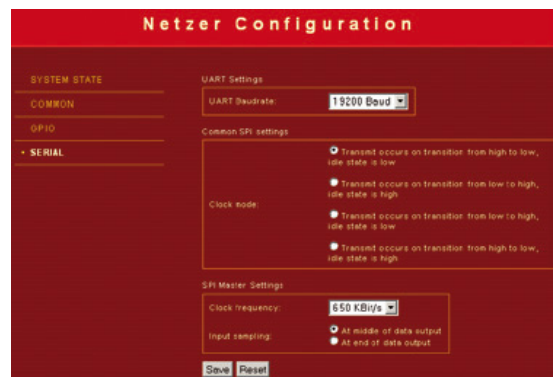


Figure 9. SPI settings are also found under the ‘Serial’ menu.

## COMPONENT LIST

### Resistors (SMD 0603)

- R101 = 1M $\Omega$
- R102 = 4.7k $\Omega$
- R103 = 1k $\Omega$
- R104 = 2.26k $\Omega$
- R105,R106 = 560 $\Omega$
- R107–R110 = 49.9 $\Omega$  (1%)

### Capacitors (SMD 0603):

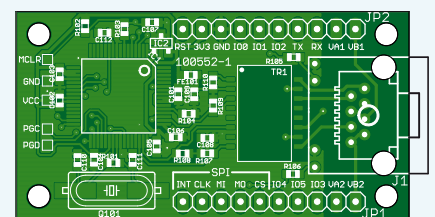
- C101–C109= 100nF
- C110,C111= 33pF
- C112= 10 $\mu$ F

### Inductors (SMD 0603):

- FE101 = 1k @ 100 MHz

### Semiconductors

- IC1= PIC18F67J60 (TQFP64), programmed, Elektor # 100552-41 [1]
- IC2= 11AA02E48 (SOT23)



TR1= 10/100Base-TX transformer, Halo N5 (SMD), PoE to IEEE 802.3af

### Miscellaneous

- J1= 8+2+2 pin RJ45 socket, w. 2 integrated LEDs
- JP1,JP2= 10-pin SIL pinheader (lead pitch 0.1 in.)
- Q101 = 25 MHz SMD quartz crystal, HC49UP case
- PCB, Elektor # 100552-11 [1] or NetWorker module, ready built and tested, Elektor # 100552-91 [1]

# LEDs and Illumination

## How much light does that LED give?

By Harry Baggen (Elektor Netherlands Editorial)

LEDs are used increasingly for lighting applications. The manufacturers of LEDs outdo each other every week with announcements of ever increasing light output or efficiency. What use are all these numbers in practice and how can you measure, using only simple means, the amount of light produced by an LED cheerfully connected to a power source you just developed?

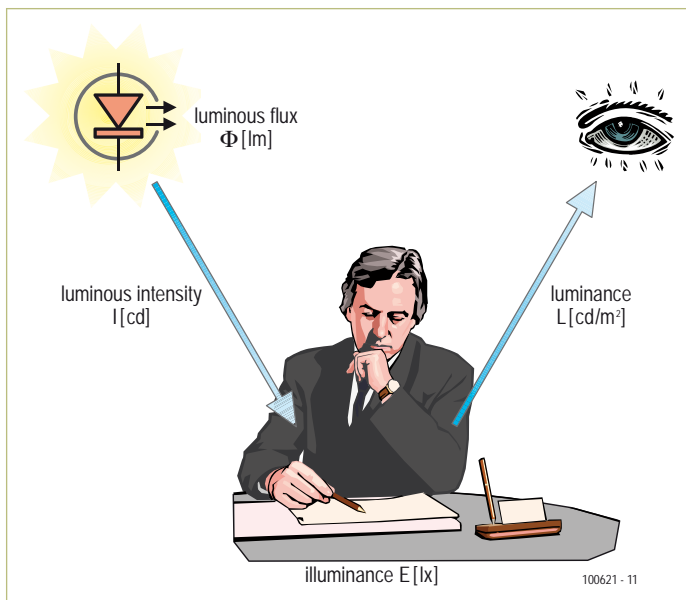


Figure 1. This drawing shows the relationships between the various light units.

Table 1. Colour temperature of various light sources.	
1200 – 1800 K	candle light
2000 – 2500 K	sunrise / sunset
2800 – 3000 K	incandescent lamp
3200 K	halogen lamp
3500K	1 hour after sunrise
5600K	standard daylight
6000K	sunlight without clouds
6500K	neutral white (standard setting for a PC-monitor)
7000 – 10.000 K	heavily overcast without direct sunlight

Despite all that generated light the world of LEDs is not very transparent. It is not at all easy to establish whether LED from brand X is really better than that from brand Y for a particular application.

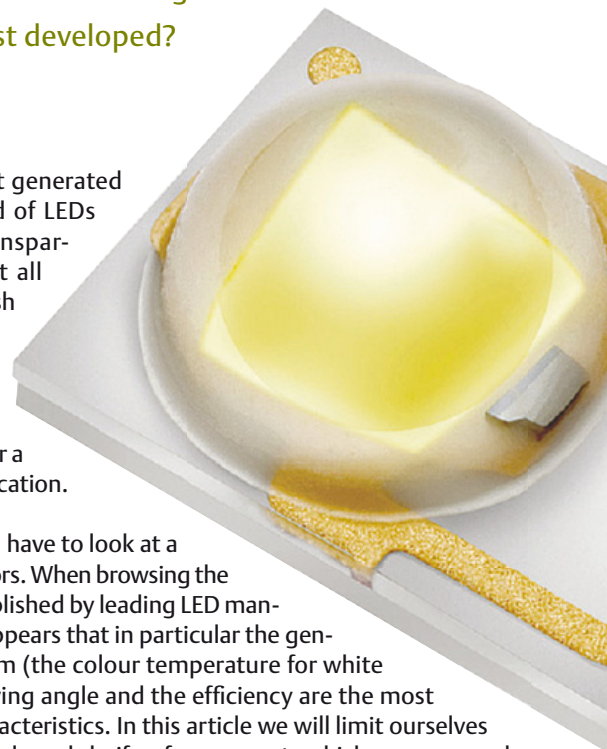
For this you will have to look at a number of factors. When browsing the data sheets published by leading LED manufacturers, it appears that in particular the generated spectrum (the colour temperature for white LEDs), the viewing angle and the efficiency are the most important characteristics. In this article we will limit ourselves to white LEDs only and clarify a few concepts which are commonly used in the world of lighting technology.

### Concepts

The total amount of radiated light from a light source is expressed in **lumen**. One lumen is the luminous flux of a point light source of one candela across a solid angle of one steradian. Expressed as a formula:  $1 \text{ lm} = 1 \text{ cd sr}$ .

The **luminous intensity**, expressed in **candela** (cd), is the amount of radiated light in a particular direction ( $1 \text{ cd} = 1 \text{ lm/sr}$ ). This value is particularly important with LEDs and halogen lamps, because those are often fitted with a reflector or lens. The number of candelas is equal to the number of lumens per steradian. When a light source is fitted with a lens with a smaller viewing angle, then the light intensity will increase considerably.

The **luminance** is a measure for the brightness of an object (expressed in  $\text{cd/m}^2$ ) and has nothing to do with the light source, but depends on the structure of the object that is illuminated. An object with a darker surface therefore has a lower luminance than one with a lighter surface.





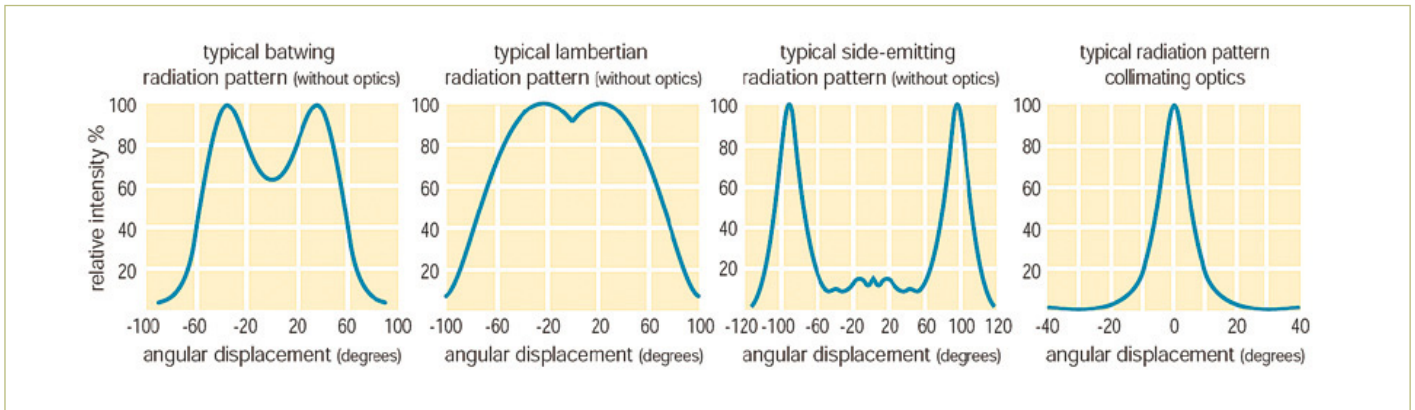


Figure 2. LED's are available with different radiation patterns (here are a few examples from Luxeon Star LED's, ill. Philips Lumileds).



Finally, **illuminance** is an important value. This is expressed in **lux** and indicates how many lumens strike a particular surface ( $1 \text{ lx} = 1 \text{ lm/m}^2$ ). The light intensity is important in offices, schools and other places of work, because there are legal guidelines for the illumination of such spaces. For example, the light intensity of a work space has to be at least 500 lux.

**Figure 1** shows the relationships between these units based on a desk which is illuminated by an (LED) lamp.

Another important consideration when selecting a light source is the **colour temperature** of the light that is produced. The colour temperature has a real influence on the mood of a space. White light with a higher proportion of red appears warmer and white light with a larger proportion of blue feels colder. Warm-white gives a cosier (some say, homelier) ambience, while cool-white is more appropriate for office work.

The colour temperature of a light source is determined by comparing it to a black (platinum) body at a certain temperature. The colour temperature is expressed in kelvin (K). **Table 1** shows the colour temperature of various light sources.

When selecting a particular type of LED, the designer has to balance a number of different considerations. How big is the surface that has to be illuminated? What is the distance from the light source to the object to be lit? What is the minimum light intensity that is required? And what is the purpose of the light (mood or work lighting)? Based on these considerations it is already possible to make a good choice. What has not yet been considered is the efficiency. But here applies in general: the higher, the better. However, cost will play an important role here. In addition, when using the selected LEDs, any appropriate cooling requirements will have to be taken into account. In particular with the power LEDs presently available,

a sizeable heatsink is often required to ensure that the operating temperature remains within acceptable values (see also the article about the 50-watt LED).

### Measuring light intensity yourself

To measure the light intensity it is best to use a so-called light intensity meter or lux meter. These are equipped with a sensor which measures incident light across a solid angle of nearly 180°. For this purpose the sensor is usually fitted with a milk-white spherical cap. The sensor is simply placed on the surface to be measured and the



Figure 3. A lux meter measures the amount of incident light across a hemisphere. (photo: Testo).

## LIGHT MEASUREMENT

**Table 2. Conversion from shutter speed / aperture value to lux (at ISO 100)**

Aperture value									Lux
1.4	2	2.8	4	5.6	8	11	16	22	
1/2	1	2	4	8	15	30	60	120	10
1/4	1/2	1	2	4	8	15+	30	60	20
1/8	1/4	1/2	1	2	4	8	15	30	40
1/15	1/8	1/4	1/2	1	2	4	8	15	80
1/30	1/15	1/8	1/4	1/2	1	2	4	8	160
1/60	1/30	1/15	1/8	1/4	1/2	1	2	4	300
1/125	1/60	1/30	1/15	1/8	1/4	1/2	1	2	650
1/250	1/125	1/60	1/30	1/15	1/8	1/4	1/2	1	1,300
1/500	1/250	1/125	1/60	1/30	1/15	1/8	1/4	1/2	2,600
1/1000	1/500	1/250	1/125	1/60	1/30	1/15	1/8	1/4	5,100
1/2000	1/1000	1/500	1/250	1/125	1/60	1/30	1/15	1/8	10,200
1/4000	1/2000	1/1000	1/500	1/250	1/125	1/60	1/30	1/15	20,500

meter indicates the light intensity in lux at that location. Such a device is very handy to establish whether there is sufficient light at a work place, but also to find out how bright that DIY torch with that super-LED shines.

It does not make a lot of sense to buy a special lux meter (such as in Figure 2) for this purpose if you're only going to use it a couple of times a year. An alternative for such a lux meter is something almost everybody already owns, namely a digital camera. These have, after all, a light meter built in (a real light sensor in an SLR and the CCD sensor in a compact camera, which also makes the image).



Figure 4. You can also approximate the light intensity with the aid of a digital camera and Table 2.

The light meter in that camera can also be 'abused' to measure the light intensity in a roundabout way. A prerequisite is that your camera allows you to set the sensitivity manually and that the camera displays the selected exposure time and aperture on the display or in the viewfinder.

With the aid of a few formulas you can calculate a light intensity value (expressed in EV = exposure value) from the shutter time/aperture combination and then convert that into a lux value. We have already done all this work for you in **Table 2**. Along the top row, look up the aperture value indicated by your camera, then go down the column to the measured shutter speed and you will see the corresponding lux value on the right.

For example, if you would like to measure the light intensity at your desk, then point the camera at the desk and look at the values indicated by the camera (don't forget to fix the sensitivity to ISO 100, since with many cameras the sensitivity is often automatically changed depending on circumstances). Also make sure that you are not measuring a bright white surface on the desk, because a camera is calibrated for measuring a neutral grey level, which means that the object to be measured reflects about 18% of the incident light. In the past, photographers would use a so-called grey card. You could put this in place of the object to be photographed and note what the light meter indicates. Unfortunately grey cards are seldom used any more and are also no longer being made. If you ensure that there are several different types of objects in the field of view, without too much white paper then the measurement will be quite close. As we already noted, this measurement gives a good approximation but not an exact value, a real lux meter is required for this. But you will nevertheless get a good indication of the light intensity. And that is already very useful in many cases!

(100621-I)

Introduction photo: LUXEON Rebel from Philips Lumileds

# PIC<sup>32</sup> USB Starter Kit II

By Luc Lemmens (Elektor Labs)

Starter kits come in all shapes and sizes, although in the last few years the boards have become quite small and are powered and programmed/debugged via a USB connection. As you may gather from the title, this board also falls into this category: a small and relatively simple microcontroller system with three pushbuttons and LEDs to help you create your first 'Hello World' experience.

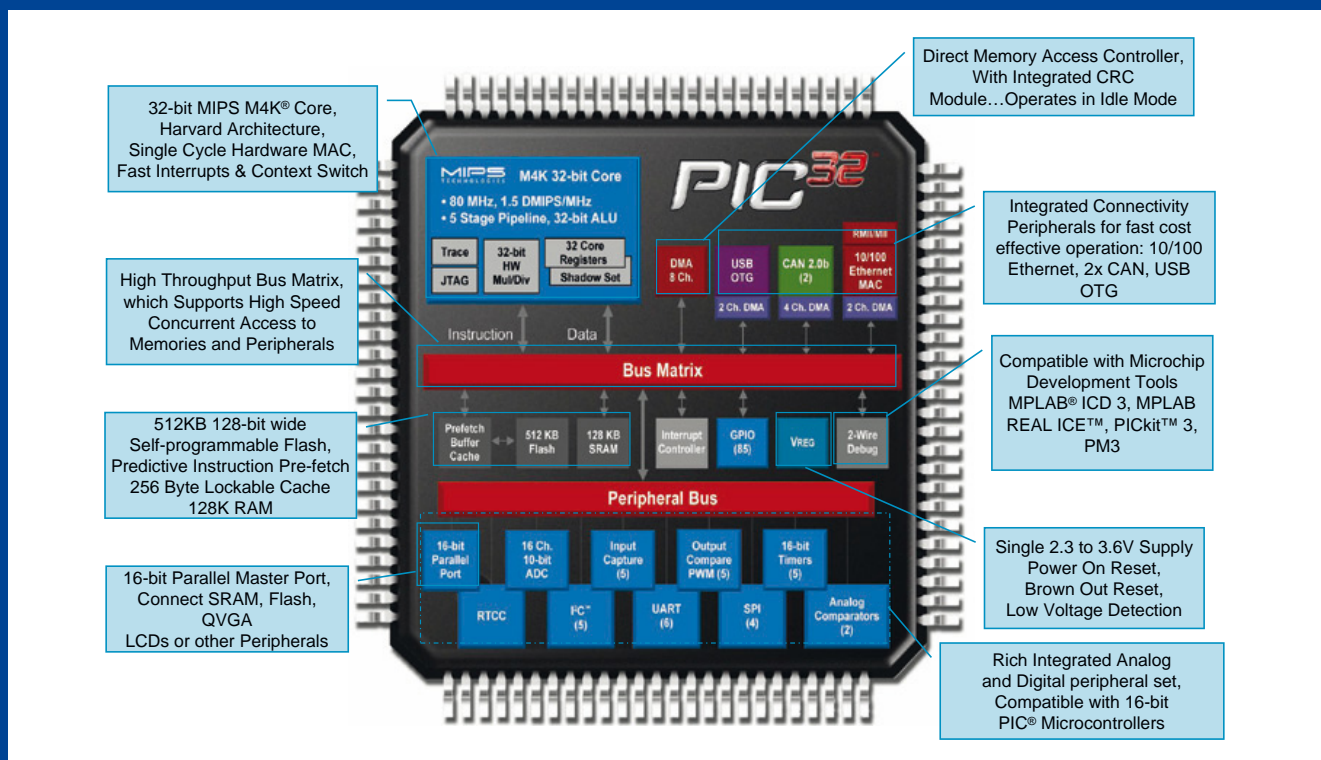
There is one big difference that makes this kit stand out from its contemporaries: a 120-pin connector is provided to make this board function as a processor module with a debug interface in a larger system. Microchip itself offers various boards to expand their starter kits, such as the I/O Expansion Board and the Multimedia Expansion Board, which makes it possible for these small experimenter's boards to offer much more than several happily flashing LEDs.

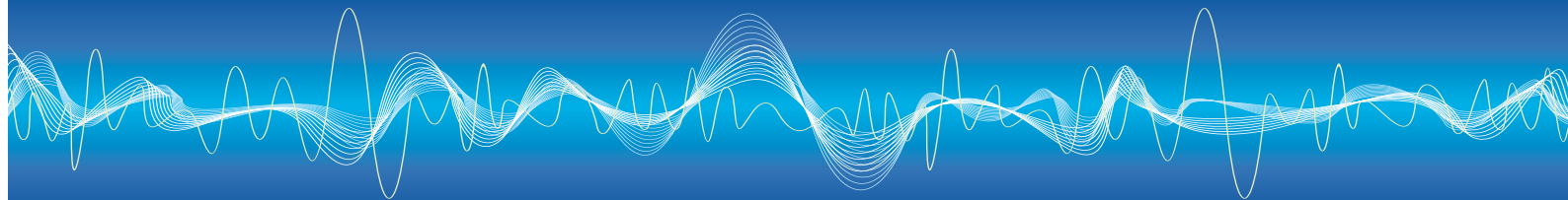
The PIC32 family is designed around a MIPS32 RISC core. After extensive analysis by Microchip this architecture was found to be the most suitable type of core for these 32-bit microcontrollers.



Apart from the microcontroller board the kit also contains a CD with all required documentation and PC software for the development of applications. However, we'd recommend that you download the most recent versions of MPLAB C32 and MPLAB IDE from Microchip's website. The MPLAB development environment is the same for all Microchip microcontrollers, which makes the move from their 16-bit or even 8-bit families so much easier.

There is a free version available of the above-mentioned C compiler, which remains fully functional for 60 days. During this period there are no restrictions on the size of the code you can develop. After this period the compiler remains fully functional although several code optimisation routines are turned off. This may not sound very drastic, but it can





have an enormous effect on the speed at which the compiled applications run.

There are free C libraries available for all peripheral blocks, which are fully compatible with the libraries for the PIC24 and dsPIC33 families.

Apart from the CD, the starter kit also includes two USB cables; microcontrollers in the PIC32 family support USB On-The-Go (abbreviated to USB OTG), which means that they can behave as a USB host as well as a slave. For example, as a host it can read and write information from/to a standard USB memory stick, which makes it possible to upgrade the firmware without the need for a programmer or computer. Hence the two cables: one is used to connect to the JTAG/debug interface and the other is used to connect USB slaves to the processor board.

In the block diagram for the PIC32 you can see how extensive and powerful this microcontroller family is. There is a choice of several peripheral blocks, the amount of memory and the package. The 32-bit processors from Microchip are pin and software compatible with their 16-bit family, which makes the migration to these new microcontrollers very straightforward. The modest price of about \$55 (approx. £37) for this starter kit certainly makes it worthwhile to give these 32-biters a go.

(100614)

### Internet Link

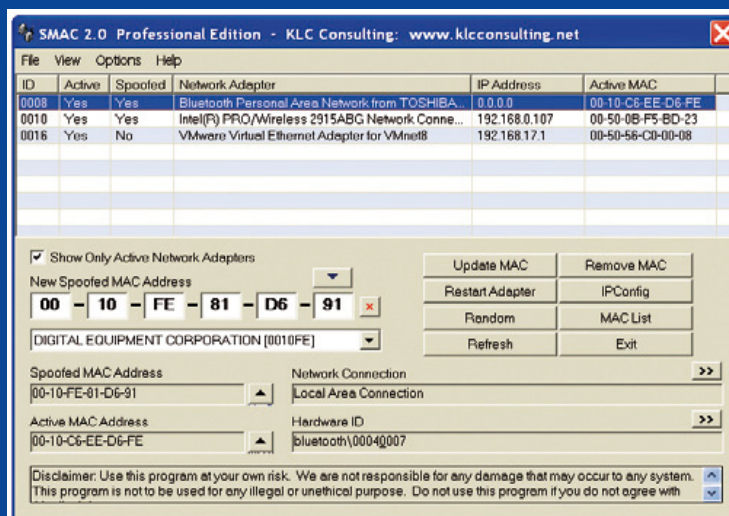
[www.microchip.com/stellent/idcplg?IdcService=SS\\_GET\\_PAGE&nodeId=2615&dDocName=en535536](http://www.microchip.com/stellent/idcplg?IdcService=SS_GET_PAGE&nodeId=2615&dDocName=en535536)

# MAC Addresses

By Luc Lemmens  
(Elektor Labs)

Network interfaces all have a Media Access Control (MAC) address, a unique code which allows them to be recognised on the network. The MAC address is usually shown in hexadecimal form, for example 0A:12:50:E3:2F:E8. In this numbering system (MAC-48), as defined by the IEEE-802 standard, there are 281,474,976,710,656 (256<sup>6</sup>) unique addresses.

There is already a new standard because there is the expectation that sooner or later this series of unique numbers will run out. Originally it was the intention that this code would be unique and permanent for every interface, but these days it is usually possible to change the MAC address in firmware (so-called MAC spoofing). Although it is, in principle, very easy to use any arbitrary address, this is certainly not the intention and entirely inappropriate for applications outside a local network. The IEEE records and distributes these MAC addresses worldwide and in this way ensures that no two addresses are the same. The first three bytes of an address indicate the manufacturer of the interface, these bytes are called the Organisationally Unique Identifier (OUI). The remaining three (in the case of the MAC-48 and EUI-48) or five bytes (EUI-64) are unique serial numbers allocated by the manufacturer. If you ever design a device with a network interface then



you are not allowed to just make up a MAC-address or 'borrow' one from another application. A company or organisation can purchase an OUI from the IEEE for \$1650, but it can also be done for less money by requesting an Individual Address Block (IAB) for \$500. In the latter case you will only have 4096 addresses at your disposal, instead of the 2<sup>24</sup> of an OUI. The allocation of OUIs and IABs is public knowledge, which

means that, based on the first three bytes, anyone can find out what company or organisation produced the device. IABs can also be anonymous, which means that the IEEE collects an additional \$1000 per annum.

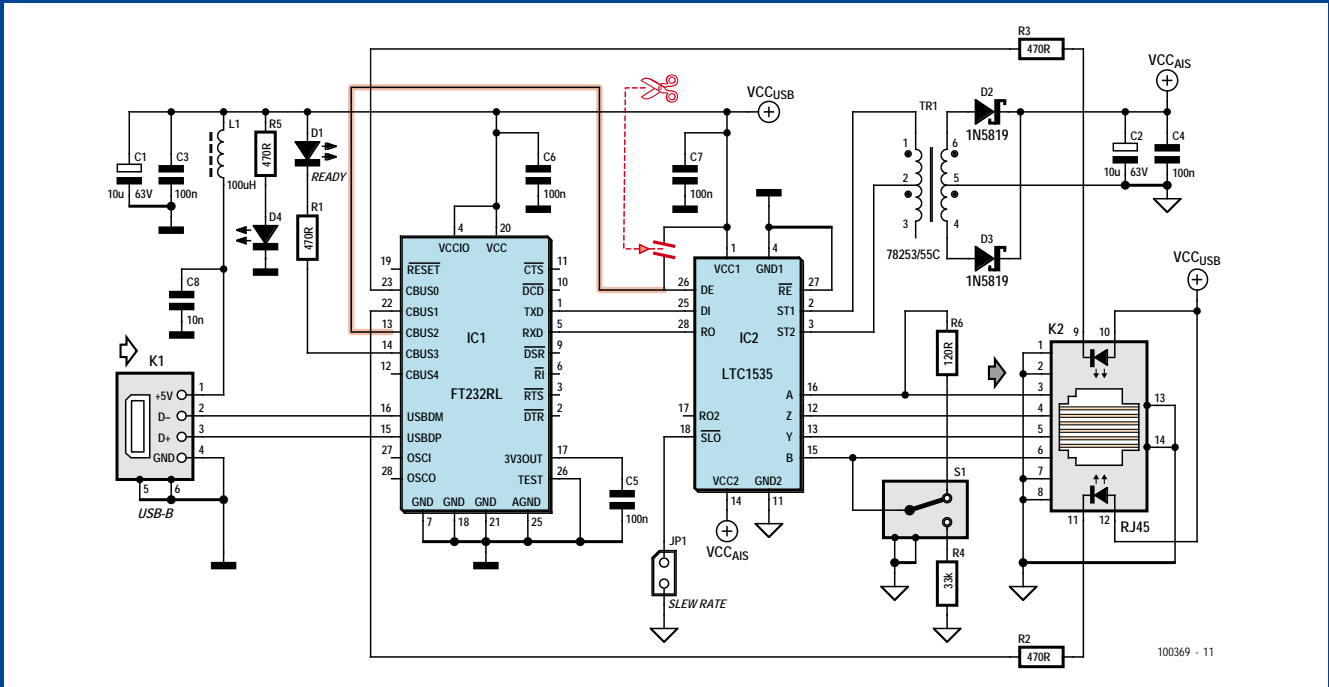
For the network interface that presented elsewhere in this issue we used a much cheaper and simpler solution: a small EEPROM from Microchip, which already contains a MAC address, whereby the manufacturer passes all administration and rights to the end-user. These memories are extremely useful for both small as well as large production volumes. Finally, there are also Ethernet controllers available which already have their own MAC-address built in.

(100719-I)

### More information:

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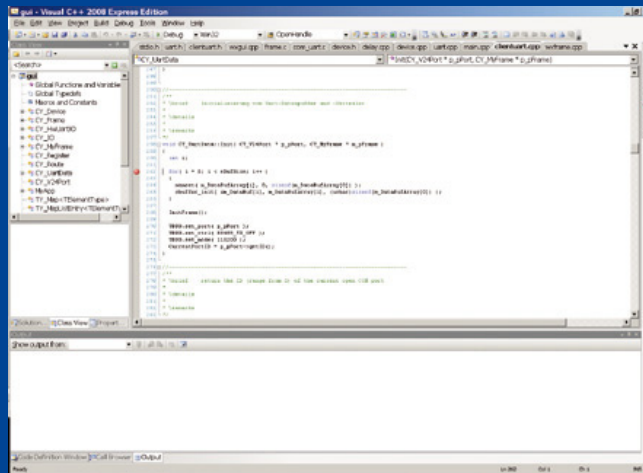
# RS485 Interface Extension



By Jens Nickel (Elektor Germany Editorial)

The central heating meter described elsewhere in this issue is a clever device that can help you keep on top of your fuel bills by measuring the number of kilowatt-hours actually delivered by the heating system. As described in the article, it does this using just four temperature sensors attached to the central heating pipework. The signal from the sensors is conditioned by an analogue circuit and then digitised using an A/D converter in a microcontroller; PC-based software then does the necessary calculations and provides a display of the instantaneous system heat output [1].

It should go without saying that the wires from the temperature sensors to the conditioning circuitry should be kept short. However, there could easily be a distance of up to several tens of metres separating the microcontroller from the host PC. Designer Falko Bilz therefore decided to use an RS485 interface which, because of the symmetrical signal levels employed, enjoys particularly good noise immunity even at high data transfer rates. In addition, he implemented a digital protocol to allow temperature data to be sent over the cable to the PC at up to 115 kbaud and to allow the PC to send commands back to the temperature sensors. (The RS485 standard only specifies

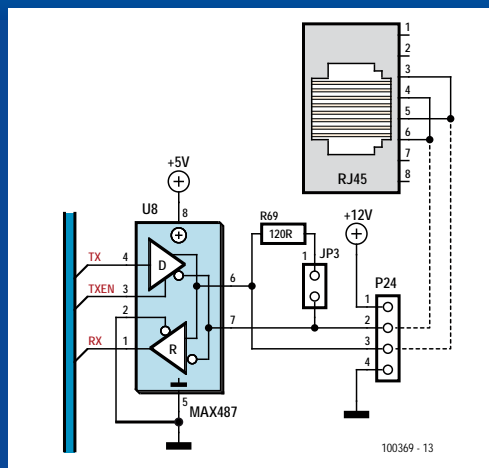


signal levels, not protocol details nor even a connector pinout.) This meant that there was still one piece missing: on the PC side some kind of adaptor was needed to take the RS485 signal levels and convert them into bits to send over a USB interface. Good news, then, that this issue also happens to contain a USB to RS485 converter (see 'USB to RS485/RS232 Converter' and [2])? Not so fast: it soon became apparent that the two circuits were not compatible with one another.

Juan Canton from Mexico, who designed the adaptor, had assumed that an RJ45-type cable would be used to carry the RS485 signals, and so equipped the device with a suitable socket. These cables have enough conductors in them to allow full-duplex communication using two transmitter pairs and two receiver pairs. Economising on the use of these pairs was not the designer's primary concern.

In contrast, the central heating meter uses just two data lines which are used alternately to communicate temperature data and commands (half-duplex operation). Elektor designer Ton Giesberts, who shepherded the project through our labs, faced a problem: how could he make the RS485 adaptor (for which a printed circuit board had already been prepared) support half-duplex operation? Looking at the circuit diagram (see the 'USB to RS485/RS232 Converter' article to follow

for yourself), Ton realised that connecting together the A and Y and the Z and B signals on the LTC1535, the device in the adaptor responsible for sending and receiving RS485 data, should not cause any problems. Ton needed to add an RJ45 socket at the heating meter end anyway, so that he could use a standard cable (the circuit diagram and printed circuit board just provided for a simple pinheader), and so it would be easy to make the extra connections between the data lines at that point. This possibility is shown in the circuit diagram of the heating meter: the figure here shows the relevant part.



However, this is not the complete solution. Somehow the LTC1535 needs to know whether data are being sent or received: the DE pin on the device must be taken high when transmitting [3] and low otherwise. Fortunately the other device in the circuit, an FT232R from Glasgow-based company FTDI, comes ready-equipped with a suitable output [4]. When the USB-TTL converter receives data from the PC to be passed on by the UART, it takes its TXDEN output high. In the device's default configuration this function is on pin CBUS2. A few board modifications later (cut the track between VCC and DE on the LTC1535, add a wire link from CBUS2 on the FT232R to that pin instead) and the USB serial converter works in half-duplex mode!



We have shown the modifications in blue in the circuit diagram. It is a pity that the board design for the converter had already been completed, or else we would have added a couple of jumpers (for the A-Y and Z-B connections too) to make it easy to switch between full- and half-duplex modes. Of course, we needed to test these modifications. Ton plugged in the cable, powered up the central heating meter, started up the PC software *et voilà...* nothing happened. What was wrong? Had we missed something or made a mistake in the configuration? The oscilloscope confirmed that communication was going on in both directions, but nevertheless the heating meter software steadfastly refused to plot a temperature graph.

Time was pressing, as we were only three weeks before the copy deadline for this the December 2010 edition. We quickly wrapped up the heating meter prototype and modified converter, put them into a box and sent them back to the designer in Falkensee, near Berlin.

The reply from Falko Bilz was, to put it mildly, surprising: for him, the two devices worked perfectly together. Were we looking at a timing problem, which happened to have made itself known only in our lab? The FTDI chip takes the TXDEN pin high exactly one bit period before transmission starts, and according to the datasheet this tight timing is not configurable. Had we used the wrong FTDI driver software?

In any case, the only way to proceed was to investigate the problem on Ton's computer. Two days later the prototype and adapter were back in our hands. We connected everything together and again, on starting the PC software, no temperature graphs appeared on the screen. The next step was to check the situation with the FTDI driver. We called on our colleague Antoine Authier, connoisseur of all things Scottish from silicon to single malts, and with a few deft clicks of the mouse this possibility was eliminated. He then turned to testing the communications in more detail and fired up Tera Term, a terminal emulator program popular in our labs because of its robustness. In order to see anything, he needed to configure (virtual) COM port COM4, which Ton had selected for use with the heating meter, to run at 115 kbaud.

And in another window, as if by magic, a temperature graph appeared!

Antoine's curiosity was piqued. He knows a bit of C++, and soon had the source code of the PC software up on the screen. It didn't take long to find the problem: when changing the COM ports in the menu the program did not then call the function to initialise the settings for the new port: the settings were only initialised when the program started up, with the port set to its default value of COM1. And Falko Bilz had still been working on the software while we were running our tests, and had only used COM1 in his test environment.

Sometimes life can be so simple!

(100369)

- [1] [www.elektor.com/090328](http://www.elektor.com/090328)
- [2] [www.elektor.com/100372](http://www.elektor.com/100372)
- [3] [cds.linear.com/docs/Datasheet/1535fb.pdf](http://cds.linear.com/docs/Datasheet/1535fb.pdf)
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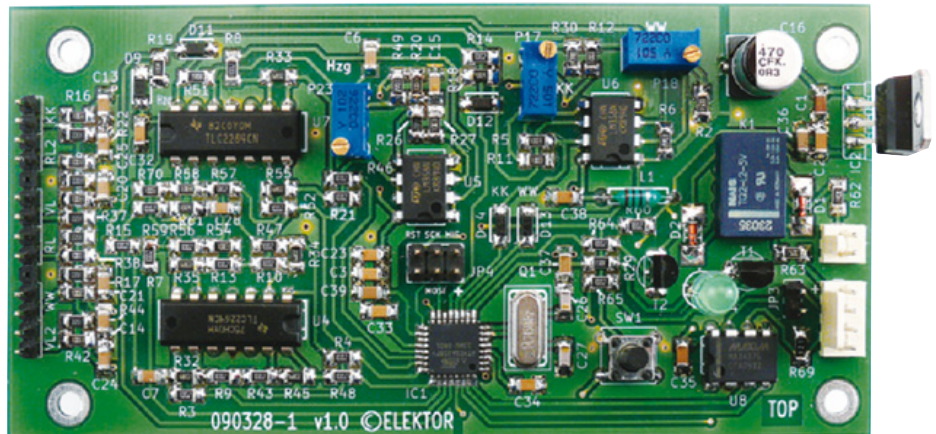
# Heating System Monitor

## Add-on for thrifty consumers

By Falko Bilz (Germany)

Usually you can tell how much energy your heating system has consumed by checking your utilities bill, but what if you want to know how much heat it actually delivered? This clever design from one of our readers measures the actual heat output and

doesn't require any modifications to your central heating system. It also has a built-in control function for the circulation pump, which helps you reduce your environmental impact and keep your bank balance healthy.



Heating bills often present unpleasant surprises. Despite your best efforts to economise on heating, they list tidy sums for electricity or gas consumption. In this article we describe a relatively easy way to check these values and monitor your consumption almost continuously. All you need in order to determine how much heat your system delivers is four temperature sensors, a bit of wiring, and a microcontroller. There's no need to delve into the electrical or hydraulic components of your system or modify any of them.

### A bit of theory

As many readers probably remember from their physics lessons, it's easy to calculate the amount of heat transferred to a medium such as water. It is given by the product of the temperature change  $\Delta T$ , the volume  $V$  of the medium, and the specific heat capacity  $C_V$  of the medium. The power  $P$ , which is amount of energy transferred per unit time, is:

$$P = \Delta T \times C_V \times V \div \Delta t$$

With a fluid medium, the term  $V \div \Delta t$  can be interpreted as a volumetric flow  $V/\Delta t$ . This value can be calculated directly from the flow velocity  $v$  of the medium and the inner

diameter  $r$  of the pipe. In a central heating system, the temperature difference  $\Delta T$  is simply the difference between the supply (S) and return (R) temperatures. This yields the formula:

$$P = (T_S - T_R) \times C_V \times v \times \pi r^2$$

The temperatures can easily be measured with suitable sensors. Flow transducers are available for measuring the flow velocity, but installing a flow transducer always requires drilling a hole in a pipe or opening up the piping to insert a fitting.

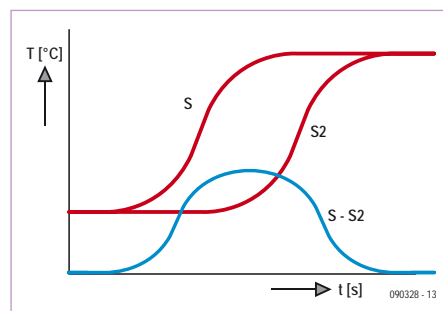


Figure 1. Signal level versus time for two temperature sensors mounted on the heating system supply line some distance apart.

### Measuring principle

Here we used a different method to determine the flow velocity. We make use of the fact that the supply and return temperatures always vary by at least one to two degrees due to the operation of the control system. If pairs of temperature sensors separated by a few metres are mounted on the supply and return lines, the flow velocity can be determined from the time offset of the variations measured by the two sensors. **Figure 1** illustrates the measuring principle, using a temperature increase as an example. As the water flows through the pipe with a

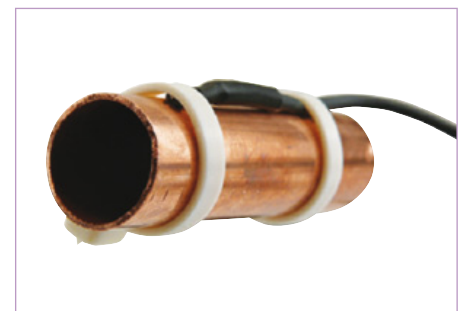


Figure 2. Cable ties or other means can be used to attach the sensors to the heating system pipes.



speed of only a few metres per second, the temperature at sensor position S2 rises somewhat later than the temperature at sensor position S, which is closer to the boiler. An ATmega microcontroller constantly acquires temperature data from the two sensors. The time delay between the signals from a pair of sensors is determined by a correlation algorithm in the signal processing software, which shifts the signal waveforms from the two supply line sensors relative to each other until they virtually overlap. The temperature signals from the sensors on the return line are correlated in the same manner, and ideally the time offsets obtained for the supply and return lines should be the same.

To increase the sensitivity of the system, the return line sensor signals are applied to the inputs of a differential amplifier, and the resulting difference signal is amplified. This difference signal is also logged as a function of time. The area under the curve of the difference signal is a measure of the time offset of the temperature variations.

Various means can be used to attach the temperature sensors to the heating pipes (see the 'Sensors' inset), including cable ties (see **Figure 2**). The accuracy of the measurements can be improved by applying some thermal paste between the sensor

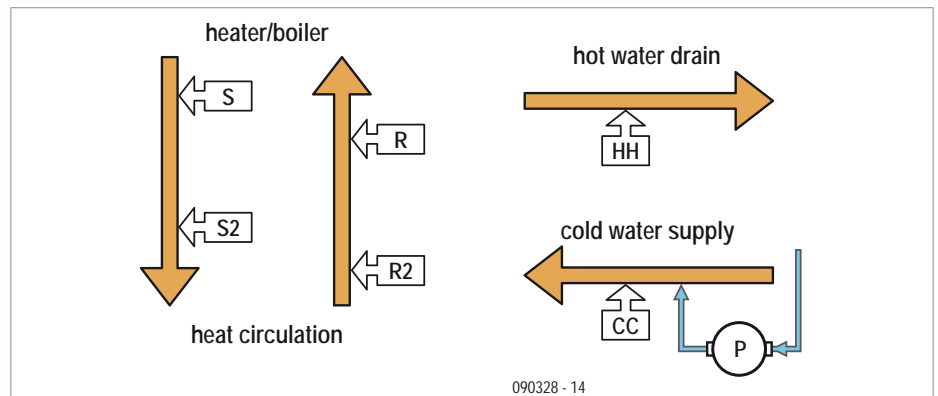


Figure 3. Sensor locations in the heating system. S = Supply, R = Return.

and the heating pipe. When you relocate, the system can be removed without leaving any traces behind.

### Hot water please

If the heating system is also used to supply hot water for domestic use, additional pipes are used for this purpose. For this reason, the PCB designed by the author includes inputs for additional temperature sensors. It also has a switched output for driving a relay that can control a circulation pump. Under certain conditions, controlling the circulation pump can save you a lot of money and significantly reduce CO<sub>2</sub> emissions. This is because some systems have constant hot water circulation so users can draw hot water from the tap immediately. This costs electricity to power the pump, and energy is also lost through the pipe walls. This can be remedied by the author's

circuit, which switches on the circulation pump for only a short time after the hot water tap is opened. This is detected by the temperature difference between the hot water and cold water supply lines.

**Figure 3** shows where the six temperature sensors should be fitted. It is important to ensure that there are no active branches between sensors S and S2 on the supply line or between sensors R and R2 on the return line (German *Rücklauf*, RL). By contrast, three-way valves between the two sensor locations are not a problem as long as they are closed while measurements are being made.

### Circuit description

The easiest way to understand the schematic diagram (**Figure 4**) is to follow the signal path. It starts at the temperature sensors connected to the circuit board, which are NTC silicon devices. Their resistance var-

## Sensors

The sensors should have the smallest possible time constant so the temperature variations on the outside of the heating system pipes can be measured as accurately as possible. Several suitable sensor types are listed in the table. The stated time constants assume good thermal contact and indicate the time required for the sensor to reach the 63% level of a step change in temperature.

Type	Time constant	Package
KT130, KT230	1.0 s	SOT-23
KTY13, KTY23	1.0 s	SOT-23
KT110, KT210	1.5 s	TO92-mini
KTY11, KTY21	1.5 s	TO92-mini
KTY 81-210	3.0 s	TO92



The sensor resistance should be as high as possible, since this allows the impedance of the voltage dividers to be kept high and thus reduces the self-heating of the sensors. All of the listed types have a resistance of around 2 kΩ at 25 °C (77 °F). They are also less expensive than other varieties of sensors, such as Pt2000 platinum sensors, while offering comparable long-term stability (which is what matters here).

The disadvantages of silicon temperature sensors – a nonlinear characteristic and an absolute error of up to 3% – can be circumvented by a one-time calibration process. The effects of all other non-varying sources of errors in the circuit are also eliminated by calibration.

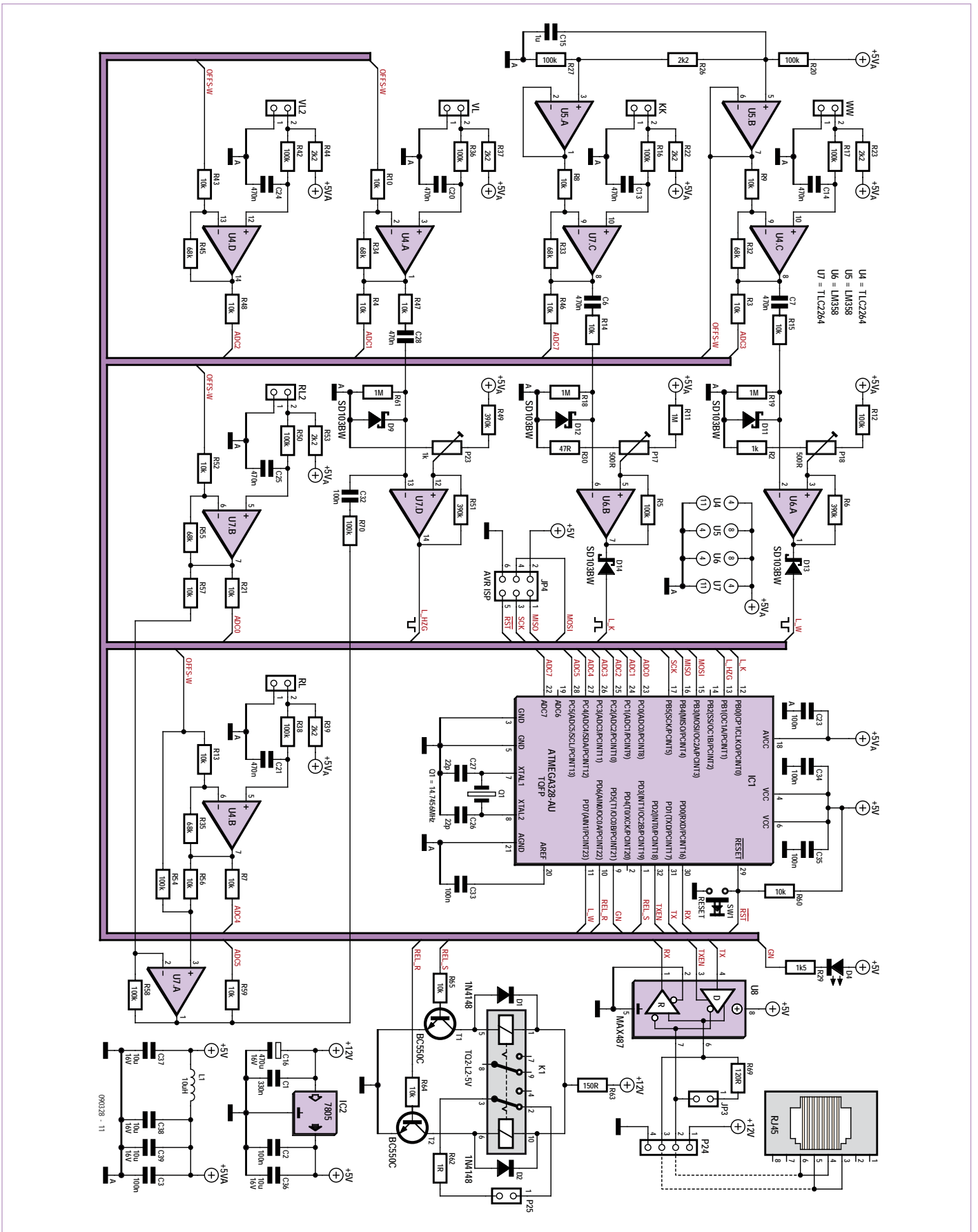


Figure 4. Schematic diagram of the system. The opamps are used as comparators, impedance converters and differential amplifiers.

ies by around 0.7–0.8% per degree K change in temperature. For example, the resistance of a KT110 sensor is approximately 1.7 k $\Omega$  at 5 °C and approximately 2.8 k $\Omega$  at 70 °C. The sensor for supply temperature S (German: VL) forms a voltage divider with resistor R37. This is followed by a simple low-pass filter formed by R36 and C20, which filters out induced AC hum. U4a amplifies the sensor signal by a factor of approximately 8. The TL2264 used here is a rail-to-rail opamp, so the output voltage can assume almost any value within the supply voltage range. This increases the absolute measurement accuracy, since the full output signal amplitude is used. U4a naturally needs a reference voltage on its inverting input. This is provided by the combination of R20, R26 and R27. U5b acts as an impedance converter to minimise the load on the voltage divider.

The input stages for the other temperature sensors have a similar structure. The component values have been chosen to yield a measuring range of approximately 8 to 70 °C for five of the sensors. The reference voltage for the sixth sensor, which is attached to the cold domestic water line (cold-cold, CC), is somewhat lower and is buffered by U5a. The measuring range of this temperature sensor is approximately 2 to 70 °C.

The analogue signals are fed to the A/D converter of the ATmega328. The converter's reference input is connected internally to AVCC, which means that all analogue signals are reference directly to the supply voltage. Consequently, the supply voltage does not require elaborate stabilisation. If you want to know more about factors that may affect the measurement accuracy, you will find a worksheet in the download file for this project.

The R (German RL, *Rücklauf*) and R2 (German RL2, *Rücklauf2*) sensor signals are also applied to the inputs of a differential amplifier built around U7a, and the resulting difference signal is amplified by a factor of 10. This allows temperature differences as small as approximately 10 mK to be measured.

Opamp U7d is wired as a comparator and triggers an interrupt in the ATmega microcontroller via pin PB1 when the supply line temperature rises. Here C28 and R61 form a high-pass filter that more or less allows only changes in the signal level to pass. R47 is

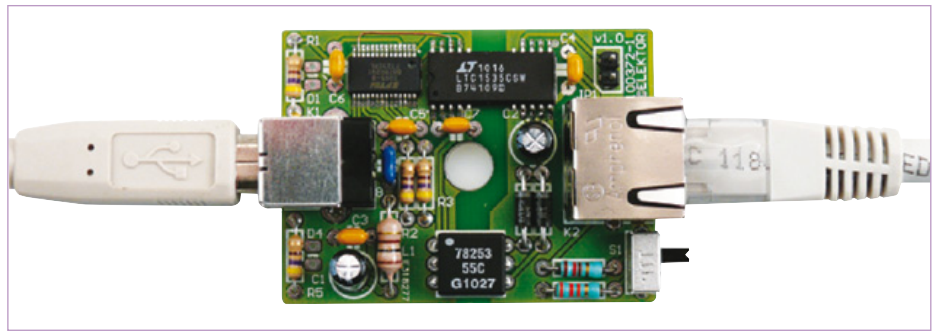


Figure 5. The USB to RS485 converter described elsewhere in this edition can be used to connect the board to a PC. See the 'E-Labs Inside' section for information on converting the adapter to half-duplex mode.

necessary to stabilise U4a with a capacitive load. Schottky diode D9 prevents unallowable negative input levels on U7d when the circuit is not connected to a power source. U6a and U6b are also wired as comparators for signals from the temperature sensors for hot and cold domestic water. The maximum output level of the inexpensive LM358 opamps is always approximately 1.5 V below the supply voltage. These two opamps can pull port pin PD7 or PB0 (respectively) to approximately 0.8 V (corresponding to a logic low level) via D13 or D14. Internal pull-up resistors in the microcontroller generate the high level.

The advantage of this approach is that the microcontroller does not need to constantly sample the signal levels, but instead only has to examine them when something 'interesting' happens. This means that the ATmega can spend most of its time in power-down mode. This is also beneficial in terms of EMC because the clock is stopped in this mode.

The bistable relay K1 is driven by T1 and T2. It is rated for only relatively low voltages and currents. If you want to switch a circulation pump, you will need a suitable power relay or contactor, which in turn is driven by K1. In case of circuits connected to the AC powerline, the usual safety regulations must be observed. Never allow this circuit to come in direct contact with the AC power voltage.

### PC connection

The circuit does not have its own display unit, but instead delivers its readings to a PC via an RS485 bus. Its functions can also be controlled from the PC. IC U8 looks after signal level conversion between the TTL transmit and receive lines of the ATmega microcontroller's integrated UART and the differential RS485 bus. As the bus protocol

allows several connected (peer) devices to transmit data on the bus, transmit mode must be selected actively via pin 3. Jumper JP3 must be fitted if the circuit is connected to the end of the RS485 bus. This causes the bus to be terminated in 120  $\Omega$ , which matches the characteristic impedance of a twisted-pair line.

The advantages of the RS485 bus system are its robustness and immunity to interference. A twisted-pair cable (preferably shielded) is all that is needed to transmit data over distances up to 1,000 metres at a rate of 1 kbaud.

An RS485 to USB converter such as the one described in the Embedded Special Insert with this edition (see **Figure 5**), can be used to connect the bus to the PC. The 'E-Labs Inside' article in this issue describes how the adapter can be modified to operate in half-duplex mode for this circuit. See reference [2] for more information on RS485 to USB adapters.

The ATmega can be programmed via JP4, and if you have an ICE Mk 2, AVR Dragon or similar device available, you can also debug it via this port. JP4 has yet another function: one or more type DS18B20 digital temperature sensors can be connected to this port. These factory-calibrated sensors (absolute error  $\pm 0.5$  °C) are ideal for aligning the circuit and calibrating the silicon sensors. However, these digital temperature sensors have a response time of approximately 700 ms, which is too slow for measuring the flow velocity.

### Construction and initial use

**Figure 6** shows the component layout (the PCB layout drawings can be downloaded from the Elektor website [1]). Fit and solder the components according to the usual rule of 'lowest profile first'. Soldering the microcontroller, which comes in a TQFP package, should also be possible with the aid of surgi-

## COMPONENT LIST

### Resistors (SMD 1206)

R2 = 1k $\Omega$   
 R3, R4, R7, R8, R9, R10, R13, R14, R15, R21, R43, R46, R47, R48, R52, R56, R57, R59, R60, R64, R65 = 10k $\Omega$   
 R5, R12, R16, R17, R20, R27, R36, R38, R42, R50, R54, R58, R70 = 100k $\Omega$   
 R6, R49, R51 = 390k $\Omega$   
 R11, R18, R19, R61 = 1M $\Omega$   
 R22, R23, R26, R37, R39, R44, R53 = 2.2k $\Omega$   
 R29 = 1.5k $\Omega$   
 R30 = 47 $\Omega$   
 R32, R33, R34, R35, R45, R55 = 68k $\Omega$   
 R62 = 1 $\Omega$   
 R63 = 150 $\Omega$   
 R69 = 120 $\Omega$   
 P17, P18 = 500 $\Omega$  (trimpot type 64Y)  
 P23 = 1k $\Omega$  (trimpot type 64Y)

### Capacitors (SMD 1206 except C16)

C1 = 330nF  
 C2, C3, C23, C32, C33, C34, C35 = 100nF  
 C6, C7, C13, C14, C20, C21, C25, C24, C28 = 470nF  
 C15 = 1 $\mu$ F  
 C16 = 470 $\mu$ F 16V  
 C26, C27 = 22pF  
 C36, C37, C38, C39 = 10 $\mu$ F 16V

### Inductors

L1 = 10 $\mu$ H

### Semiconductors

U4, U7 = TLC2264 (DIP14)  
 U5, U6 = LM358 (DIP8)  
 U8 = MAX487 ECPA (DIP8)  
 IC1 = ATmega328-20AU (TQFP32-08), programmed, Elektor no. 090328-41 [1]

IC2 = 7805 (TO220)  
 T1, T2 = BC550C (TO92-EBC)  
 D1, D2 = 1N4148 (SOD106-R)  
 VL, VL2, RL, RL2, WW, KK = KT110, KT210, KTY11, KTY21, KT130, KT230, KTY13 or KTY23 (SOD23 or TO92-mini, resp.)  
 D4 = LED (5 mm)  
 D9, D11, D12, D13, D14 = SD103BW (DO-214BA)

### Miscellaneous

Q1 = 14.7456MHz quartz crystal (HC49U-S)  
 K1 = relay, bistable (TQ2-L2-12V)  
 SW1 = micro pushbutton (lead pitch 5mm)  
 JP4 = 6-pin (2x3) pinheader (lead pitch 2.54mm)

JP3 = jumper (2.54mm)  
 P24 = 4-pin pinheader and plug (lead pitch 2.54 mm)  
 P25 = 2-pin pinheader and plug (lead pitch 2.54 mm)  
 VL, VL2, RL, RL2, WW, KK = 14-pin pinheader and plug, gold-plated (lead pitch 2.54mm) (see text for English labels S, S2, R, R2, CC, HH)  
 Microphone cable = ML108 (1 x 0.08 mm)  
 Heat shrink sleeve (1.6mm and 3.2mm)  
 G1 = Aluminium enclosure, like Teko type B4 (143x72x43mm)  
 PCB standoff (M3)  
 Nuts (M3)  
 LED clip (5 mm)  
 PCB, no. 090328-1 [1]

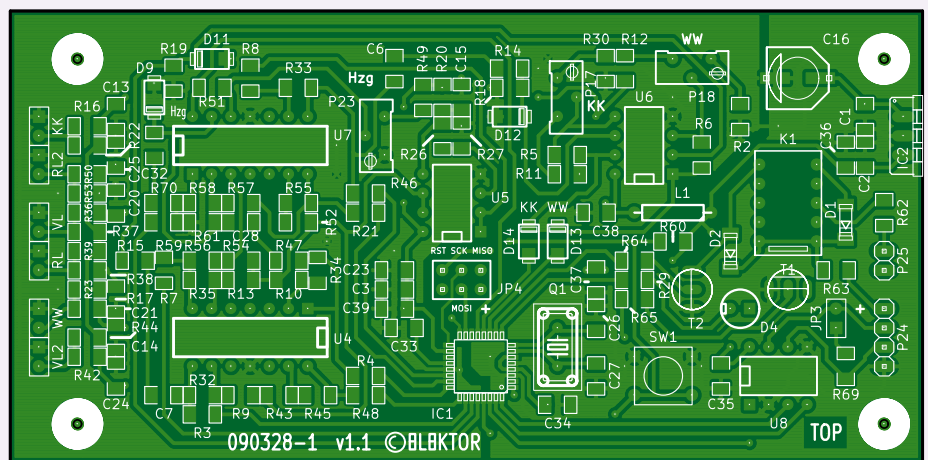


Figure 6. With a bit of practice, all of the components can be soldered by hand.

cal/dental loupes. Use a soldering iron with a fine tip (approximately 1 mm) and—especially important—ESD protection. After all, you're working with sensitive electronic components.

Always use headers with gold-plated contacts for the sensor connections, as otherwise the circuit will do a good job of measuring any significant mechanical vibration. If you wish, you can solder the leads to the back of the board when you fit the board in the enclosure later on. If you fit the board in the enclosure so the LED and the trimpots are visible or accessible through openings in the front, there will be enough room at the rear for the sensor cables.

The best technique for soldering the leads of the sensor cables is to clamp the cable somewhere and use tweezers to position the pre-tinned ends of the leads.

When applying the supply voltage for the first time, connect a resistor with a value of 100  $\Omega$  or so in series with the supply voltage. If the current consumption is around 21 mA, the board assembly can be assumed

to be correct and you can connect a power supply (voltage range 10–12 V) directly to the board.

The next task is to load the boot loader software into the microcontroller via the ISP port. The boot loader can be downloaded from the Elektor website [2]; alternatively, you can purchase a pre-programmed microcontroller from the Elektor Shop. After this the LED should start blinking. Reprogramming a few fuses is necessary to enable the boot loader to work properly, but first you should study the microcontroller data sheet carefully. Up to now the author has always had good results with programming the fuses individually and in sequence. This way you can see exactly which function is involved if a problem arises.

Next connect a RS485 adapter [2] to the two middle pins of four-way connector P24. Naturally, the corresponding driver must also be installed on the PC before you can use the adapter.

The next step is to launch the PC program *termgui.exe* (located in the *wgui* folder),

which is also included in the download package [1]. If the Verify and Write buttons are not active after you press the Bootload button on the Maintenance tab, swap the two lines of the RS485 bus. After this you should be able to download the application program code to the microcontroller's flash memory by pressing the Write button. The author wrote the software for the ATmega328-AU (boot loader and application program) in C, and the source text can also be downloaded. The author used C++ for the PC program. This requires Visual Studio 2008 SP1 for C++ [3] to be installed on the PC. After the sensors have been connected to the board, the initial temperature curves (as yet uncalibrated) should appear in the PC program. Now you need to attach the sensors to the heating system pipes as shown in **Figure 3**.

### Alignment and calibration

The first task is to adjust the three trimpots that set the voltage thresholds for interrupt triggering. During this process the tem-

perature of the heating system supply line should remain constant and no domestic water should be drawn from the taps.

The LED is lit constantly when an interrupt pin is active; otherwise it blinks or is dark. Start by rotating trimpot 'KK' (CC) fully anti-clockwise and trimpots 'WW' (*warm warm*; English: HH) and 'Hzg' (*Heizung*; English: heater) fully clockwise. The LED should go dark after 5 seconds.

Next rotate each of the trimpots in turn fully in the opposite direction; the LED should light up. Then rotate the trimpot back in the other direction until the LED starts blinking or goes dark.

You can follow all of this on the 'Temperature Curves' tab of the PC program (*thermgui.exe*) by means of corresponding messages shown the bottom left corner. A volt-

meter connected to the input pins of U6a, U6b or U7d (respectively) is also helpful.

Use the PC software to calibrate the temperature sensors. A software user guide (with a brief description of the method) is available in the Zip file that can be downloaded from the Elektor website [1]. If you wish to modify or extend the PC software, you will also find the source code and information on recompiling the code in the download.

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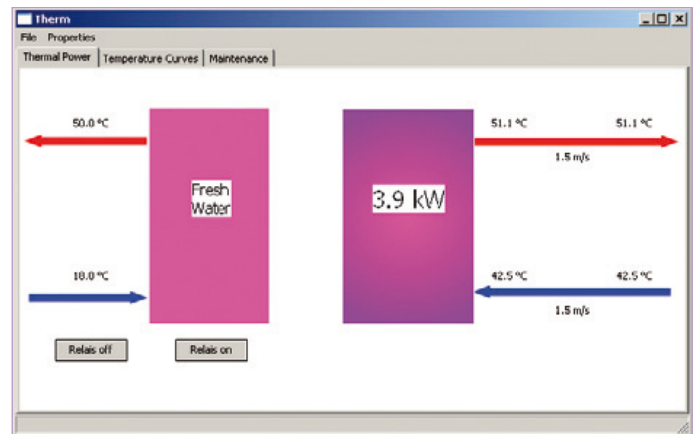


Figure 7. A PC program written by the author provides a convenient user interface.

### Internet Links

- [1] [www.elektor.com/090328](http://www.elektor.com/090328)
- [2] [www.elektor.com/100372](http://www.elektor.com/100372)
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As a special treat for this holiday season, we have made an overview of a number of useful, handy or just plain interesting gadgets, all of which make use of LEDs. Enjoy reading, wondering and finding out about them. And make sure you show these pages to family and friends, if you would really like to receive any of these items as a gift.

### Samurai watch

You do not wear a watch just to know what the time is; it is also a piece of jewellery and a fashion accessory. If you are looking for a watch with an unusual shape then you have plenty of choice. But what do you think of



6:48



wearing a bracelet, that is until you press one of the buttons and the time or date appears. The watch is easily adapted to different wrist sizes by removing one or more links.

More information: UK: [www.chinavasion.com/product\\_info.php/pName/iron-samurai-japanese-inspired-red-led-watch/](http://www.chinavasion.com/product_info.php/pName/iron-samurai-japanese-inspired-red-led-watch/)

### LED vehicle lights

LED replacements for incandescent lamps at home are already well known. But now there are also LED replacements for the light bulbs in your car. While these lights come in many different types and shapes, the manufacturers of LED replacements have been resourceful enough to figure out how to make a replacement for nearly all of them. Only for the headlights they haven't (yet) succeeded. You just need to find the correct type and replace with an LED version that has the same terminals and equal light output. After that you will probably never have to replace any lights again, the life expectancy is given as 50,000 operating hours!



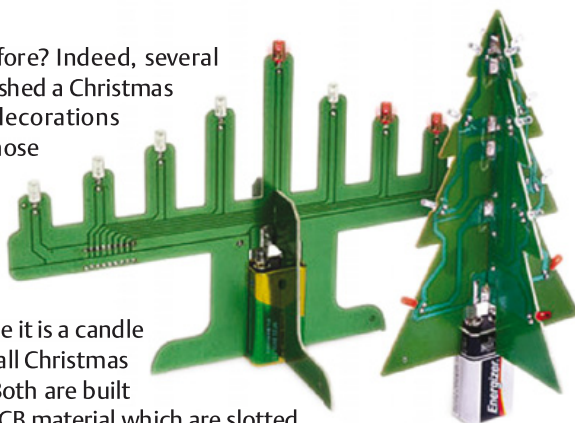
More information: [www.go-greener.eu/shop/index.php?main\\_page=index&cPath=1](http://www.go-greener.eu/shop/index.php?main_page=index&cPath=1)

this sturdy watch that, according to the manufacturer, is made from the same steel as that used in Japan to make the legendary Samurai swords. Well, we probably should take that with a substantial pinch of salt, but it nevertheless looks quite nice! This watch indicates the time using red or blue LEDs, where the LED segments are hidden between the links. So it appears that you are just

### Christmas boards

Where did we see these before? Indeed, several years ago now, Elektor published a Christmas tree and other Christmas decorations using LEDs and even sold those as kit sets.

It is still a very nice idea to put something together from a couple of circuit boards, which is decorative and gives off light. In this case it is a candle holder with 9 LEDs and a small Christmas tree with 16 flashing LEDs. Both are built from two pieces of (green) PCB material which are slotted together. A 9-volt-battery is inserted in the base and functions as the power supply and also gives it some additional mass for increased stability. With the candle holder you have a DIP-switch so you can set which LEDs are turned on. The Christmas tree is a little more expensive than the candle holder, but you do get a few more LEDs.



More information: [www.thinkgeek.com/homeoffice/lights/b25a/](http://www.thinkgeek.com/homeoffice/lights/b25a/)

### Box shaped time

There are unusual clocks, not only based on their shape and appearance, but also with regard to the manner in which they display the time. Digital clocks with numbers are nothing special, of course, but there are always the inventive types who forever dream up new methods of indicating time. This TIX LED-clock is not of the type that displays the time in binary code, but just uses the decimal system with the aid of a number of illuminated boxes (the photo shows 12:34). A nice feature is that the boxes will illuminate in a different pattern each time. In addition, we like the beautiful tight styling, a very nice present for the holidays!

More information: [www.thinkgeek.com/interests/giftsforher/7437/](http://www.thinkgeek.com/interests/giftsforher/7437/)

## Programmable jewellery

The PIX is a type of pendant that can display various kinds of pictures and texts on an LED matrix consisting of 177 red LEDs. You can program the text and pictures yourself using a computer and also add various effects, you can even write messages in the air by swinging it. The programmed images can be uploaded to the PIX using a serial connection. The PIX is, however, more than just a little LED screen, you can even exchange information via an infrared connection with friends and acquaintances who also have a PIX. There is now also a PIX Sports, specifically for the active types among you.

More information: [www.ilovepix.com/en/htm/main.htm](http://www.ilovepix.com/en/htm/main.htm)



## You have e-mail

E-mail notifiers are handy programs which display an indicator in the system task bar or on the desktop when new mail has arrived for you. Now there's also a hardware version available, the USB Webmail Notifier, which makes it even more obvious that new electronic mail is waiting for you. The semi-transparent block in the shape of an envelope is



connected to the PC via a USB cable and lights up when new mail has arrived. Depending on the type of mail you can make it turn blue, red or green. The gadget works with pop3 mail servers, Outlook, Outlook Express and web-based e-mail from Yahoo and Gmail.

More information:

UK: [www.usbgeek.com/prod\\_detail.php?prod\\_id=0922](http://www.usbgeek.com/prod_detail.php?prod_id=0922)

## Illuminated chess board

Chess is of course the ultimate mind game. But you don't necessarily have to be able to play chess to appreciate a nice chess board. There are elaborately decorated chess pieces and boards that could easily become a nice ornament in a room. The special feature of this handsome glass chess game are the LEDs that are housed inside the chess pieces and are illuminated when they are in the vicinity of the chess board. It's very nice to look at, both during the day and at night. The board is powered from a mains adapter or four AA-batteries.



More information:

[www.epartyunlimited.com/led-glow-chess-set.html](http://www.epartyunlimited.com/led-glow-chess-set.html)



## Smiley for car drivers

Are there times when you would like to communicate with other motorists when you're on the road? And no, we do not mean gesturing with a finger when something doesn't quite go right... This is very easy with the Drivemocion and a lot more civilised. This LED-display can be attached to the rear window with a suction cup and using a wireless remote control you can select the desired symbol from the driver's seat. No, everything remains quite clean. The adjacent photo shows the five symbols that can be displayed. The display is powered from batteries, so an additional power supply connection is therefore not required. Note: this unit may not be road legal in all countries.

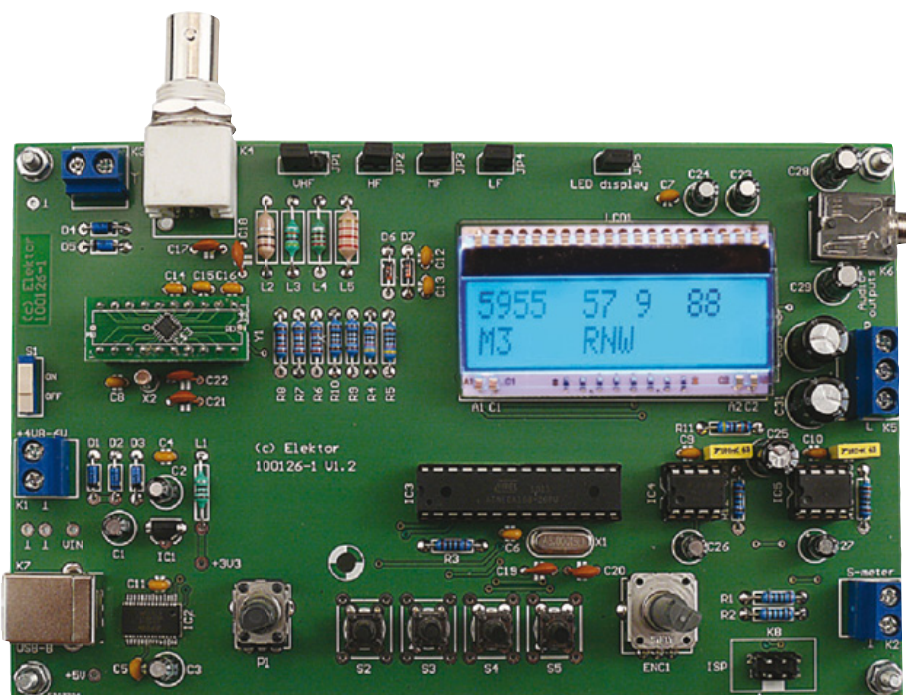


More information: UK: [www.find-me-a-gift.co.uk/drivemocion-led-car-sign.html](http://www.find-me-a-gift.co.uk/drivemocion-led-car-sign.html)

# Elektor DSP Radio Scanner Monitor, Log and Scan

By Burkhard Kainka (Germany)

Anyone with an interest in radio DX-ing whether it be long wave, VHF or anywhere in between are faced with the same questions: which aerial is best? What time of day can I best receive a particular broadcast station and where did all that noise come from? The versatile Elektor DSP radio is supremely suited to answer these questions especially with this new PC based scanning software.



**Table 1. Band scan data:  
Frequency, signal strength (RSSI)  
and SNR.**

11600	32	0
11605	28	0
11610	35	0
11615	60	25
11620	37	0
11625	28	0
11630	32	2
11635	28	0
11640	28	0
11645	34	2
11650	31	0
11655	42	11
11660	28	0

The successful DSP radio project featured in the July & August 2010 edition of Elektor lends itself easily to adaptations of its operating mode. The DSPscan software presented here runs on a PC and controls the DSP radio, using it as the front end to a rudimentary RF spectrum analyser. It plots band occupancy showing received signal strength (RSSI) and signal to noise ratio (SNR) of signals in the band selected and can be pre-programmed to scan at scheduled times. The scanned band width can be set at say 500 KHz or 3 to 23 MHz. Medium wave and VHF bands can also be scanned. The DSPscan program (Figure 1) writes the measurements to files (Table 1), which can then be archived. The information includes time, date and start frequency of the scan. The band start frequency can be entered

by hand or press the appropriate band scan button. Although the band from 3 to 23 MHz can be scanned the process takes over an hour to run. It may be more convenient to set the scan width to just 500 KHz around an area of interest. Clicking on the 'AutoScan SW' button begins an automatic sequence of measurements on all bands from 75 to 16 m with the scans starting on the hour. The program can be set to run the whole day long if necessary so that later you can come back and analyse the captured data.

### Anyone there?

Tuning in to shortwave broadcasts can at times be a little frustrating; often there is so much noise that hardly any stations are intelligible. At other times you can pick up

stations loud and clear from the other side of the world. The variation can be enormous and it makes you wonder whether this is due to poor propagating conditions, aerial setup or your receiver. The Elektor DSP radio is helpful here because it shows the received signal strength and SNR along with the received station frequency. Don't be too disappointed if when you first try out a new short wave receiver there is nothing but noise to hear. You may think that the receiver has really poor sensitivity but there may in fact simply be no transmitters active on that particular band at that time of day.

Two factors are at work here; firstly the RF propagating conditions and noise levels in each band are different depending on the



time of day. Secondly the majority of stations are programmed to transmit at specific times on certain bands where experience has shown that the propagating conditions will be favourable. There is little sense in pumping a 100 kW signal into the ether if it becomes so distorted and masked by noise that no one hears it.

The radio stations forming the mainstay of short wave transmissions are mostly government controlled. In countries receiving these broadcasts they may be interpreted as unwanted propaganda and in some cases the stations are subjected to electronic countermeasures (spot jamming). The authorities responsible for the broadcasts will stress that they offer an alternative interpretation of world events. If you do happen to tune in to a broadcast in some exotic language you can be fairly sure that its source is either the BBC World Service (UK), Deutsche Welle (Germany), CRI (China) or a station sponsored by either the US or Russia. In the current economic climate government departments are under ever more pressure to cut costs and this is likely to lead to fewer radio broadcasts and reduced schedules.

The majority of shortwave activity takes place in the evening; this is when listeners are more likely to find spare time to listen in. The coverage that a transmitting station can expect to achieve depends to some extent on the wavelength of the broadcast signal. During daylight hours transmission on the higher frequency bands will achieve greater coverage, at night the lower frequency bands are better. RF noise is another important factor to consider; a large proportion of this is due to atmospheric noise and interference from unsuppressed electrical equipment. Atmospheric noise is primarily a product of all the electrical storms occurring around the world. Satellite data suggests that globally there are on average at least 30 lightning discharges per second! This noise is dominant in the lower bands and is at a minimum around 20 MHz (Figure 2). In the 49 m band a noise figure of 30 to 40 dBµV (up to 100 µV(!)) with AM broadcasts and using a long wire antenna is completely normal. The transmission

should produce a received signal strength of 60 dBµV (1 mV) for clear reception.

The receiver performance can be assessed in a simple test with the DSP radio: Disconnect the aerial; the radio will indicate a received signal strength of 0 dBµV or 1 µV inherent noise or less for most frequencies. Now reconnect the aerial and tune to an unoccupied frequency. If the noise rises by more than 10 dB then the receiver has sufficient sensitivity and the antenna length is adequate. This is true for every radio however automatic gain control (AGC) makes it difficult to get a true measurement. Practically none of the modern day receivers suffer from poor sensitivity. It is often difficult to separate the receiver performance from the received SNR. The advantage of the Elektor DSP Radio is that received signal strength is indicated on the display.

### Keep the noise down

The value of received signal strength is not as important as the received signal to noise ratio. Tuning into the 16 m band (17.480–17.900 kHz, Figure 3) during the day you will pick up quite a few stations which despite their low RSSI (30-40 dBµV using a long wire antenna) are still quite intelligible. The atmospheric noise on this band is distinctly lower. You will most likely find several China Radio International (CRI) stations transmitting on this band. On mainland China the higher frequency bands are used quite intensively because of their good propagation characteristics over long distances. The bands below 10 MHz are practically empty. In addition the upper bands suffer less fading.

Medium wave reception can be afflicted by interference especially during daylight (Figure 4) but at night things really liven up and you can pull in many distant stations with a good signal to noise ratio (Figure 5). Signals

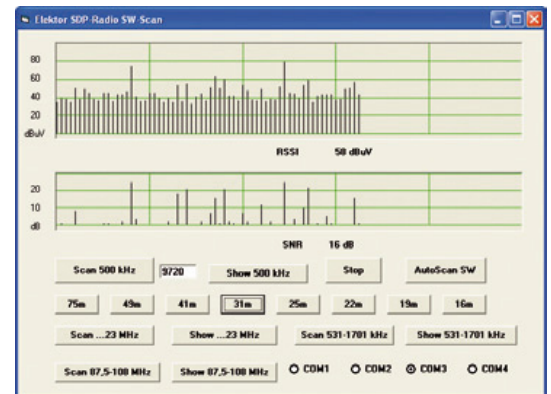


Figure 1. Scanning the 31 m band.

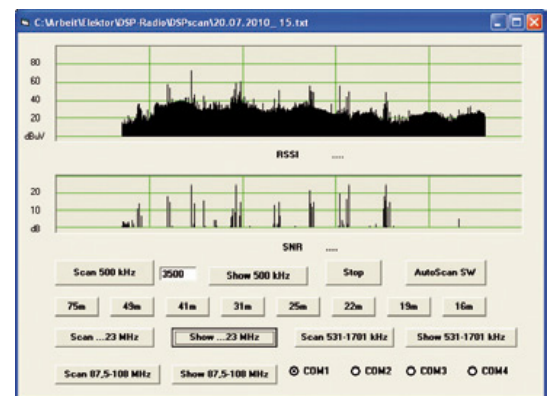


Figure 2. Antenna noise and wanted signal between 3.5 MHz and 23 MHz.

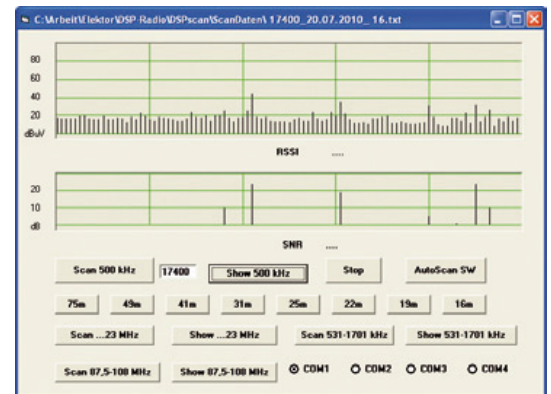


Figure 3. The 16 m band at 16:00 Hrs.

above 1611 kHz are most likely to be pirate radio stations.

A question often posed is why can't we pick up Radio Luxembourg nowadays when in the 1970s it was loud and clear? The most likely explanation is the rise in RF noise. The countless number of domestic energy saving lamps, switch mode regulators and digital electronics etc in the environment undoubtedly contribute to the levels of

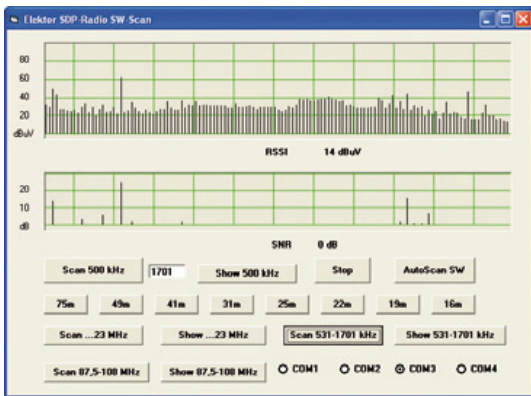


Figure 4. The medium wave band at midday.

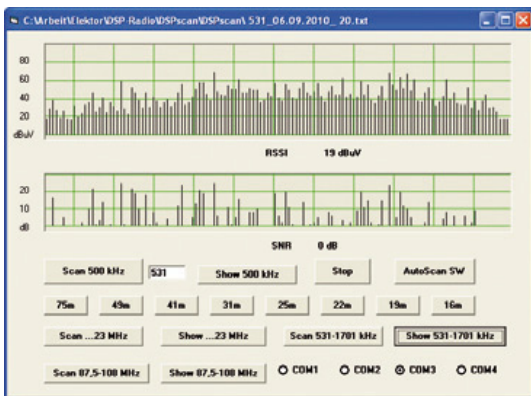


Figure 5. The medium wave band after sundown.

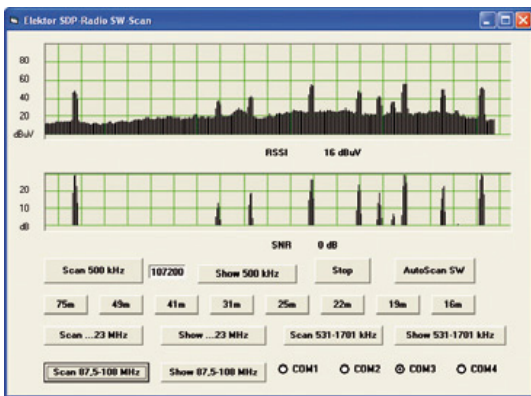


Figure 6. An indoor scan of the VHF band.

FM		AM	
1	102300 kHz	1	153 kHz
2	88800 kHz	2	543 kHz
3	95100 kHz	3	640 kHz
4	96500 kHz	4	720 kHz
5	99200 kHz	5	6075 kHz
6	101300 kHz	6	6090 kHz
7	102200 kHz	7	9995 kHz
8	102800 kHz	8	9445 kHz
9	103300 kHz	9	9540 kHz
10	105000 kHz	10	11650 kHz
11	106700 kHz	11	3975 kHz
12	97600 kHz	12	3995 kHz
13	107400 kHz	13	9920 kHz
14	97300 kHz	14	5940 kHz
15	106200 kHz	15	6055 kHz
16	92200 kHz	16	6055 kHz
17	96100 kHz	17	7275 kHz
18	94600 kHz	18	9420 kHz

Figure 7. Logging the receive data.

electrosmog. During the day it makes it practically impossible to pick up any distant stations unless you live on the top of a mountain, miles away from a connection to the national grid. Maybe that is a little bit of an exaggeration but often you can find around 10dB improvement by siting the receiver in a more rural location. Of necessity and comfort most people listen-in in an urban environment, in this case the aerial of choice should be either a ferrite rod or loop antenna, both of which often have better noise rejection properties compared to the alternatives.

**Try it at VHF**

Noise also plays a big part in FM reception. A band scan will give a good insight into what is actually going on in this band. **Figure 6** shows that the antenna and the RF input stage are in resonance for the band because the background noise shows a maximum at around 100 MHz. With the antenna sited indoors the level of interference is generally too high to be able to receive many stations with an acceptable SNR. Out in the garden the same receiver and antenna will pull in weaker and more distant stations. The situation improves even more if you go further afield, away from buildings and habitation, and best of all at the top of a mountain. Here you get the chance to pick up really faint stations. Sensitivity should not be a problem. You can confirm this by trying out

a short 10 cm stub antenna. As you might expect the received signal strength is lower but unwanted noise is also attenuated so overall the SNR does not really suffer.

**DSPscan**

The DSPscan program is a good tool to compare propagation conditions between receiver bands. It will not however show information about an individual station. The PC program written for the Elektor DSP radio (September 2010) has been modified to simplify the transfer of received signal station data. The new program is called ElektorDSP2 (**Figure 7**) and can be downloaded for free from the project page on the Elektor website [1]. Along the top margin of the program window we can see information indicating the frequency, station name, received signal strength and SNR of the signal. A click on the 'log' button saves the displayed data into the log.txt file (**Table 2**). This information can be automatically logged at intervals of 10 s or 60 s by clicking on the appropriate button. The stored data can be useful to document received signal fading, see for example figures for the short wave station Deutsche Welle (DW) in **Table 2** operating on 6075 kHz.

(100706)

**Internet Link**

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

**Table 2. Data in log.txt**

28.08.2010	19:21:57	6075 kHz	DW	52 dBuV	15 dB SNR
28.08.2010	19:22:07	6075 kHz	DW	49 dBuV	12 dB SNR
28.08.2010	19:22:17	6075 kHz	DW	42 dBuV	3 dB SNR
28.08.2010	19:25:37	9420 kHz	Thessaloniki	66 dBuV	25 dB SNR
28.08.2010	19:25:47	9420 kHz	Thessaloniki	70 dBuV	25 dB SNR
28.08.2010	19:25:57	9420 kHz	Thessaloniki	64 dBuV	25 dB SNR

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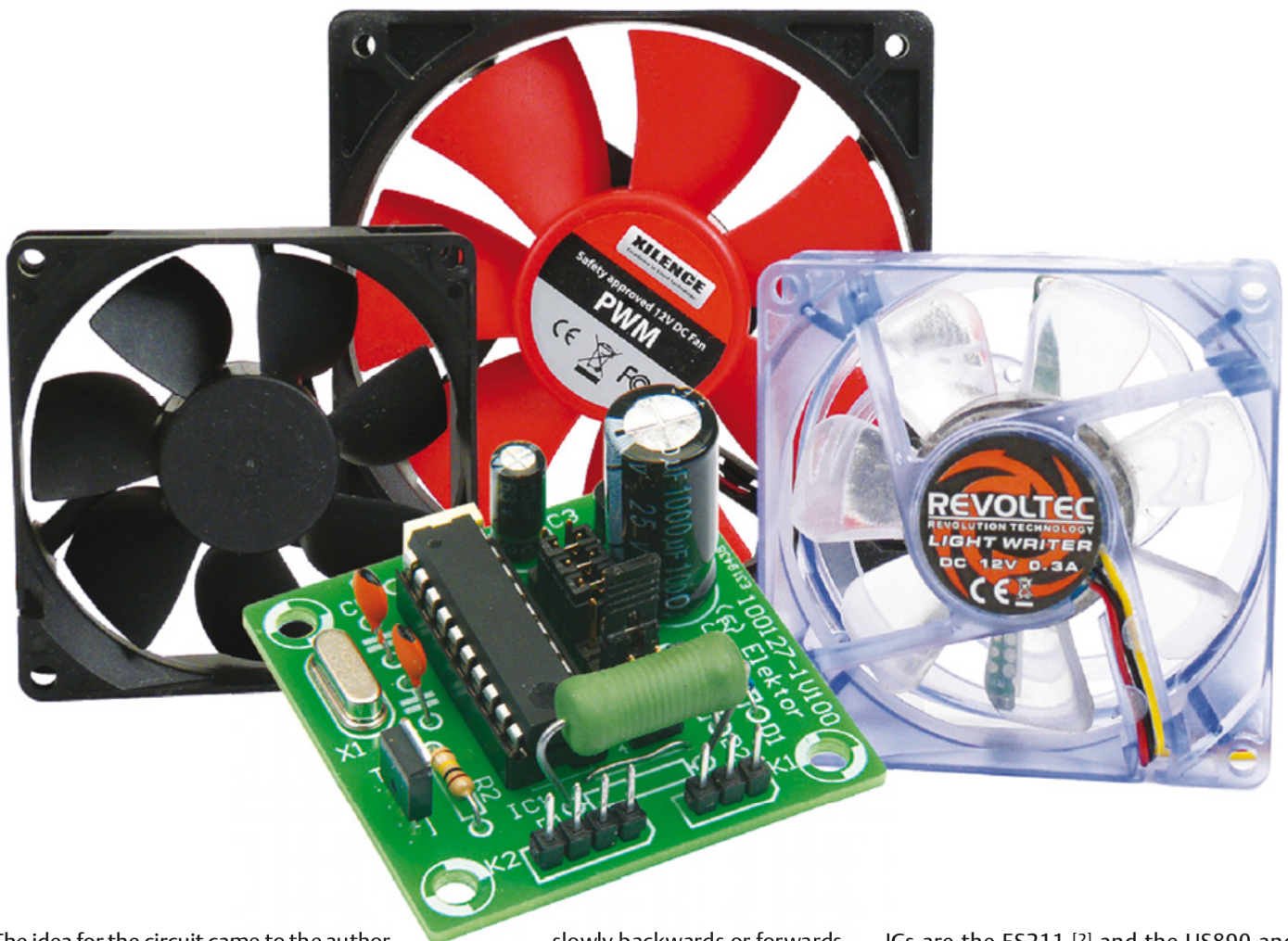


# Stroboscopic PC Fan

## No flash in the pan

A PC case with a side window gives plenty of opportunities for pimping the machine out with visual effects. Stand out from the crowd with the fan stroboscope circuit described here: based on an Atmel microcontroller, it drives an LED in such a way as to make the vanes of the fan seem to stop, turn slowly backwards or forwards, or suddenly change position.

By Martin Ossmann (Germany)



The idea for the circuit came to the author when his son bought a new computer. The case had a window in the side through which the gleaming components could be admired, but something was missing. An eye-catching centrepiece to the machine was needed, and the idea soon evolved into a plan to illuminate the CPU fan with a stroboscope using power LEDs. By flashing the LEDs with the right timing, it would be possible to make the fan appear to stop or turn

slowly backwards or forwards.

The author's YouTube channel has videos showing how effective the illusion is: search for 'Ossimodding' [1].

### All about fans

PC fans come in all shapes, sizes and colours. **Figure 1** shows the construction of the simplest modern design. Drive is by a brushless DC motor with two windings controlled by a dedicated IC. Typical driver

ICs are the ES211 [2] and the US890 and US891 [3], which also include a Hall sensor to detect the position of the rotor.

To get a proper stroboscopic effect, the flashes of light illuminating the fan must be synchronised with its rotation. For PC fans with a three-wire [4] or four-wire [5] connection, this is relatively easy, as they have a special output (called the 'tacho' output) that delivers typically two pulses per revolution. Some fans deviate from this 'Intel

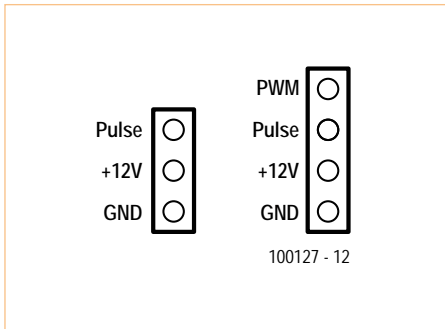


Figure 2. Pinouts of three- and four-pin fan connectors.

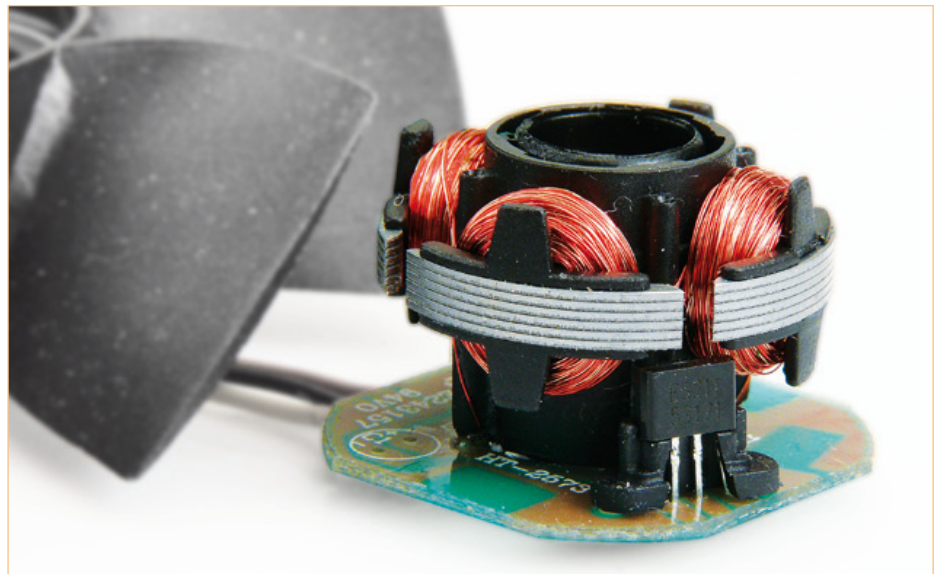


Figure 1. The secrets of a fan: two coils and a dedicated control IC.

standard' and deliver three pulses per revolution; the necessary software modification to deal with this is given in the download for this project.

**Figure 2** shows the pinouts of the three- and four-pin connectors normally used, in each case an extension of the classical two-pin design providing just +12 V power and ground. The three-pin connector adds the tachometer signal, which is an open-collector output from the fan. The PC motherboard will normally include a pull-up resistor to the +12 V rail, and this is taken into account in the design of our circuit.

The four-pin connector adds a PWM input to the fan controller. A TTL-level PWM signal provided on this input, nominally at 25 kHz, allows the fan speed to be controlled. If the input is left open-circuit, a pull-up resistor inside the fan ensures that it will run at maximum speed.

### The circuit

Using a microcontroller we can read the tachometer signal and use its timing to control one or more power LEDs accordingly. Driving the LEDs is best done via a logic-level MOSFET. The whole circuit is shown in **Figure 3**.

The clock for the microcontroller is provided by a 20 MHz crystal. A row of nine jumpers (JP1) allows the various options offered by the software to be configured: see the **Table**. The first four jumpers (on port pins PB4 to PB7) are used to tell the microcontroller the number of blades on the fan, from 0 to 15. The next three jump-

ers (on port pins PB0, PB1 and PB3) select one of eight different modes of operation. The jumper on PD6 controls the amplitude of the apparent fan movements, and the jumper on PD3 their speed.

Power is obtained from the +12 V line on the fan connector. The easiest way to connect the circuit to the fan is to make a small adaptor (**Figure 4**) which passes through

the four fan signals and brings out the GND, +12 V and tachometer wires for connection to K1 on our printed circuit board.

### Construction and LEDs

Although the circuit only consists of a few components, we have designed a small printed circuit board (**Figure 5**) in the *Elektor* lab for the project to make the project

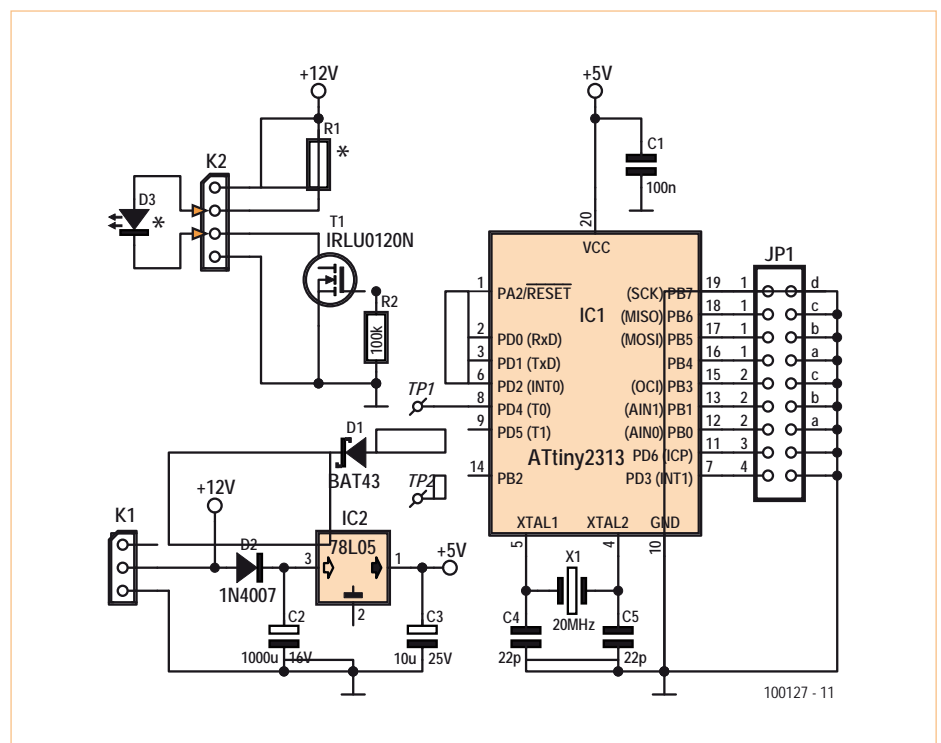


Figure 3. Circuit diagram: the jumpers allow various effects to be selected.

**Table: Jumper settings**

(PB7)	(PB6)	(PB5)	(PB4)	Blade count
1	1	1	1	0
1	1	1	0	1
1	1	0	1	2
1	1	0	0	3
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
0	0	0	0	15

(PB7)	(PB6)	(PB5)	Option N°.	Function
1	1	1	0	Stationary
1	1	0	1	Combination of various movements
1	0	1	2	Oscillation
1	0	0	3	Forwards and backwards
0	1	1	4	Movements with pauses
0	1	0	5	Sudden movements
0	0	1	6	Slow movement
0	0	0	7	Stationary

PD3 = select speed of effect

PD6 = select amplitude of effect

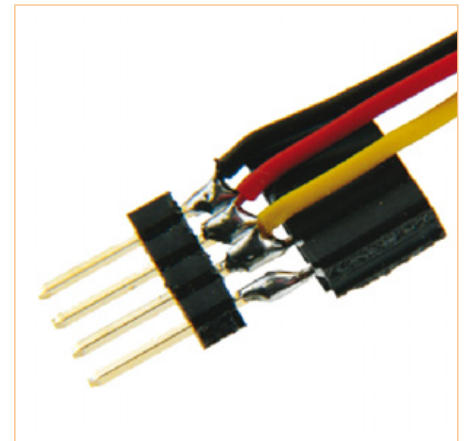


Figure 4. Adaptor for connecting to a fan cable.

## Software variants

### Version using ATtiny2313:

Source file: fan\_flash\_2313\_v01.c  
 Compiler WINAVR GCC  
 Compileroption: -O2  
 Fuses: external crystal  
 brown\_out at 4.3 V  
 no CKDIV8

### Version using ATtiny25/45:

Source file: fan\_flash\_45\_v01.c  
 Compiler WINAVR GCC  
 Compileroption: -O2  
 Fuses: external crystal  
 brown\_out at 4.3 V  
 no CKDIV8

easier for beginners to tackle. The software for the microcontroller (including source code) is available, as ever, for free download from the project web pages [6]. Compiler options and fuse settings are listed in the text box 'Software variants'. If you are not able or not inclined to program the microcontroller yourself, ready-programmed microcontrollers can be purchased, again via the project web pages. The device then just needs to be plugged (the right way around!) into its socket on the board: see Figure 6.

## COMPONENT LIST

### Resistors

R1 = see text  
 R2 = 100kΩ

### Capacitors

C1 = 100nF  
 C2 = 1000µF 16V  
 C3 = 10µF 10V  
 C4, C5 = 22pF

### Semiconductors

D1 = BAT43  
 D2 = 1N4007  
 D3 = power LED (see text)  
 IC1 = ATtiny2313-20PU, programmed, Elektor # 100127-41  
 IC2 = 78L05  
 T1 = IRLU120N (International Rectifier)

### Miscellaneous

K1 = 3-pin pinheader  
 K2 = 4-pin pinheader

JP1 = 18-pin (2x9) DIL pinheader with Jumper  
 X1 = 20MHz quartz crystal  
 PCB # 100127-1 (www.elektor.com/100127)

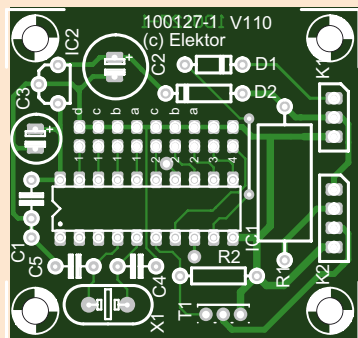


Figure 5. The printed circuit board designed in the Elektor lab.

As shown in the circuit diagram, an LED is connected between pins 2 and 3 of K2. The LED only lights very briefly, and so needs to be driven at a high current to give bright enough results. Power LEDs rated at up to 5 W are ideal. The value of series resistor R2 will depend on the type of LED chosen. In our prototype we used a value of 5 Ω; with a normal LED a value of 50 Ω would be more suitable. It is also possible to wire several LEDs with individual current-limiting resistors in parallel, as the MOSFET has plenty of drive capability ( $I_{Dmax} = 10 A$ ).

### Software

The program running in the ATtiny2313 configures timer 0 so that it generates an interrupt every 200 clocks. The interrupt rate is thus 100 kHz, and all the important functions of the system are carried out in the service routine. The routine monitors

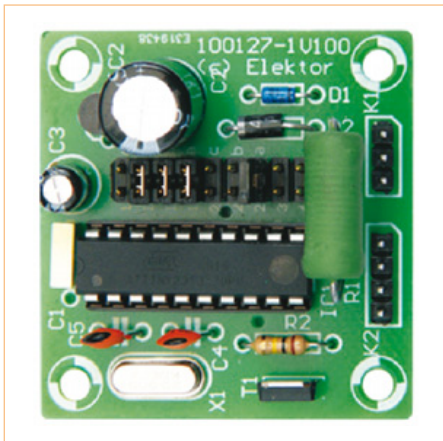


Figure 6. The assembled prototype.

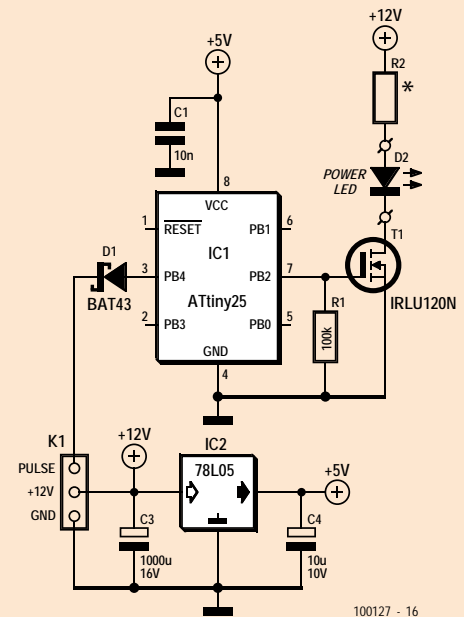
## Minimalist's version

If the ability to configure the circuit is not required, and the settings can be fixed in the software, then it is possible to dispense with the jumpers.

Furthermore, if the internal RC oscillator in the microcontroller is used, the crystal can be dispensed with too.

The result is a minimalist's version that can run in an ATtiny25 or ATtiny45.

The software can again be downloaded from the *Elektor* website [6]: see the text box on software variants. In view of the small number of components, it is easy to build this version on a small piece of prototyping board.



the tacho signal from the fan to detect edges. Two rising edges correspond to one revolution of the fan. **Figure 7** shows the timing of events during each revolution. The variable `slowTimer` is incremented by one on each interrupt and reset to 0 at the start of each complete revolution. The changing value of this variable can be thought of as a sawtooth wave synchronised with the rotation of the fan, and with a maximum value dependent on its speed. For example, if the fan is turning at 1500 rpm each revolution takes 20 ms, or 2000 interrupts. For maximum brightness, we would like to flash the LED once as each blade of the fan goes by, and to this end we generate another saw-

tooth variable, called `fastTimer`. This variable is reset at the same time as `slowTimer`, but counts up only to a limit called `fastPeriod`, which is equal to the maximum value reached by `slowTimer` divided by the number of blades of the fan. The result is that `fastTimer` varies as a sawtooth synchronised with the blades of the fan.

It is also necessary to be able to adjust the relative phase of the LED flash and the fan blade position, which is done using a further fan-blade-synchronous sawtooth variable called `PLLtimer`. The LED is flashed each time this variable is reset. The period of the variable is equal to that of `fastTimer` and a simple software PLL controls the

phase shift between the two variables. On each falling edge of `PLLtimer` (at the time indicated by the dashed line) the value of `fastTimer` is compared against a reference value. If the edge is to the left or right of the desired position the phase of `PLLtimer` is corrected by slightly increasing or decreasing the length of its next period. The **Listing 'PLL code'** shows the relevant part of the program.

The period of `PLLtimer` at any time is given by `fastPeriod` plus `PLLcontrol`. Here `fastPeriod` is the nominal period of the variable and `PLLcontrol` is the correction to cause a phase shift. When `PLLtimer` reaches its maximum value it is reset and the LED is

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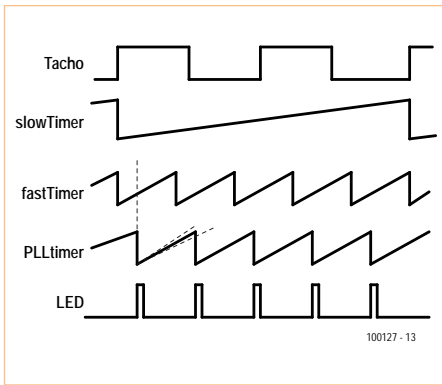


Figure 7. Timing diagram for the rotation of the fan.

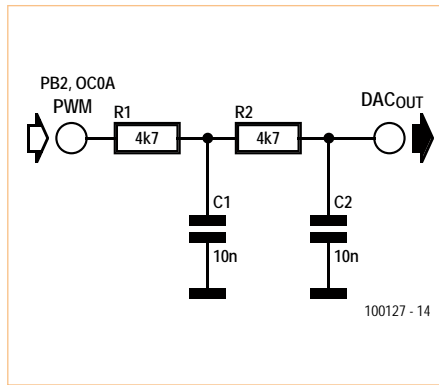


Figure 8. Low-pass filter suitable for converting the PWM test signal output on PB2 of the microcontroller into a sawtooth wave.

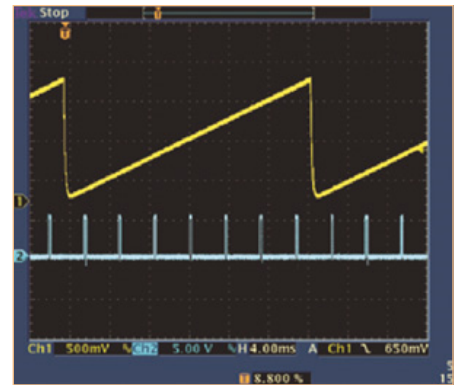


Figure 9. Oscilloscope traces showing the sawtooth waveform (filtered PWM signal) and the LED drive pulse.

flashed. At the same time the phase difference between wantedPhase and fastTimer is calculated in order to generate a new PLL-control value.

**Debugging**

If you are planning to make any modifications to the software, it will be helpful to have a debugging facility: real-time debugging is a must, as most bugs will lead to timing errors. To simplify this, pin 14 of the ATtiny2313 (TP2) outputs the current fan position in the form of a PWM signal. This can be filtered using the low-pass circuit shown in **Figure 8** and the result shown as

a sawtooth signal on an oscilloscope. The second channel of the oscilloscope can be used to monitor the gate signal to the MOSFET to see where the light pulses are being generated. **Figure 9** shows a typical picture obtained using this set-up.

(100127)

**Internet Links**

- [1] [www.youtube.com/user/ossimodding](http://www.youtube.com/user/ossimodding)
- [2] [www.eastera.com.cn/data/ES211-ENb\\_a.pdf](http://www.eastera.com.cn/data/ES211-ENb_a.pdf)
- [3] [www.melexis.com/Assets/US890US891\\_DataSheet\\_4851.aspx](http://www.melexis.com/Assets/US890US891_DataSheet_4851.aspx)
- [4] [www.nidec.com/fanpdfs/t92t200901.pdf](http://www.nidec.com/fanpdfs/t92t200901.pdf)
- [5] [www.formfactors.org/developer%5Cspecs%5C4\\_Wire\\_PWM\\_Spec.pdf](http://www.formfactors.org/developer%5Cspecs%5C4_Wire_PWM_Spec.pdf)
- [6] [www.elektor.com/100127](http://www.elektor.com/100127)

**Listing: PLL code**

```

if (PLLtimer<fastPeriod+PLLcontrol){
    PLLtimer++;
}
else {
    PLLtimer=0;
    LED_PORT |= ( 1 << LED_BIT );
    PLLcontrol=wantedPosition-fastTimer;

    if (PLLcontrol > fastPeriodHalf ) {
        PLLcontrol -= fastPeriod;
    }
    if (PLLcontrol < -fastPeriodHalf ) {
        PLLcontrol += fastPeriod;
    }

    // limit to -100..100
    if (PLLcontrol > 100 ) {
        PLLcontrol = 100;
    }
    if (PLLcontrol < -100 ) {
        PLLcontrol = -100;
    }
}
    
```



# ARM Freephone Control

## Give your microcontroller orders over the phone

By Bert van Dam (The Netherlands)

With this circuit, you can use your mobile or landline phone to send commands to an ARM microcontroller connected to the public telephone network, free of charge. That's handy when you want to close the curtains or switch on the heating while you're away.

This project is built around an ARM microcontroller connected to the public telephone network. You can send commands to the microcontroller by allowing the phone to ring a specific number of times. With the design described here, a yellow LED lights up for 30 seconds after you let the phone ring three times and then four times on two successive calls. As the microcontroller doesn't answer the phone, you can send commands to it from anywhere in the world, free of charge.

### Hardware and schematic diagram

The ECRM40 module used here houses a fast AT91SAM7S128 ARM microcontroller with 128 KB of ROM, 32 KB of RAM and an integrated boot loader, fitted on a mini PCB. This means you don't need a separate programmer; all that's necessary is a simple program on your PC and a USB cable.

The schematic diagram of the circuit (**Figure 1**) is fairly simple, and it can easily be built on a breadboard (**Figure 2**). A DC voltage of approximately 48 V is normally present on the phone line, \* and the 0.1- $\mu$ F capacitor blocks this voltage. This means that no voltage is applied to the rectifier when the line is in the idle state. When the phone number is dialled, a 20-V AC signal is superimposed on the existing DC voltage in order to ring the bell of the telephone normally connected to the line. The capacitor allows this AC signal to pass through to the rectifier, which converts it into a pulsating DC voltage.

This voltage is fed to the LED in the optocoupler via a 10-k $\Omega$  resistor. The optocoupler provides galvanic isolation between the telephone line and the ARM microcontroller. According to its data sheet, this optocoupler (type 4N25) supplies 1.6 mA with an LED current of 2 mA (80% of the LED current), which is more than enough for the microcontroller input. The 10-k $\Omega$  resistor to ground prevents the microcontroller input from floating.

The microcontroller portion of the circuit is powered from the USB port. If the circuit is used on its own, it should be powered by a well regulated 3.3-V power supply and the jumper on the rear of the ECRM40 module must be changed from 'USB' to 'EXT'. The rest of the circuit is powered from the telephone line.

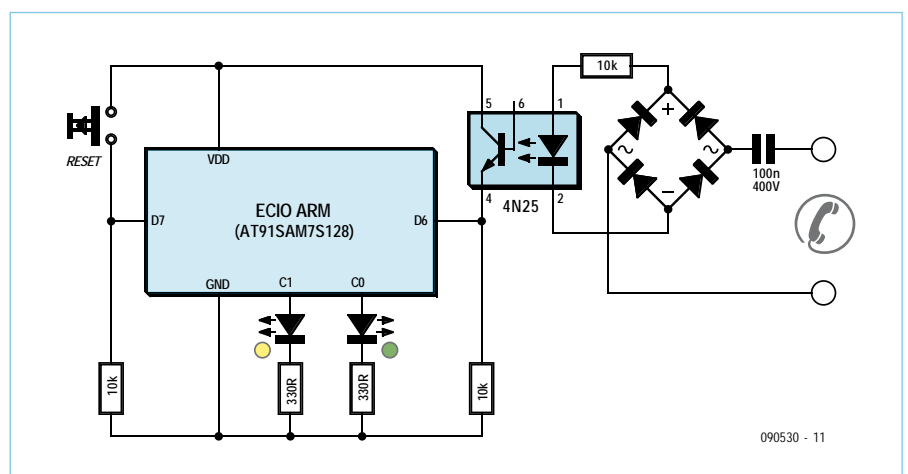


Figure 1. Schematic diagram of the hardware.

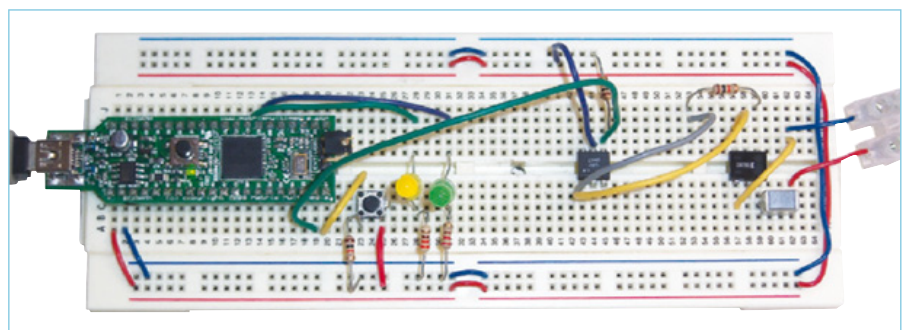


Figure 2. The circuit assembled on a breadboard.

### Software and operation

This circuit causes a yellow LED to light up after a caller first allows the phone to ring three times, hangs up, and then calls again and allows the phone to ring four times. If you use only command codes consisting of two numbers and keep the first number fairly small, you reduce the chance that someone else may send a command to the circuit by accident.

The AC signal intended to ring the bell is rectified by the bridge rectifier but not smoothed. This results in a pulsating DC voltage. You won't notice this if you connect an LED in place of the opto-

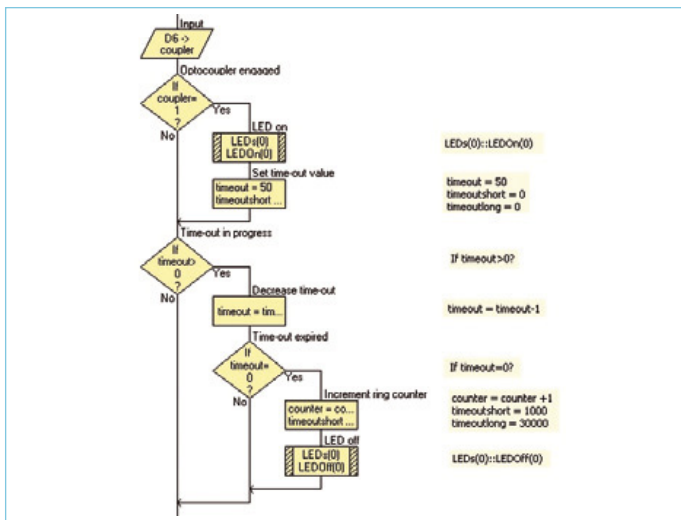


Figure 3. Flow chart of the loop for counting pulsating ring tone signals.

coupler, but the microcontroller does notice this and registers it as a series of short pulses.

The program (written in Flowcode) essentially consists of three counting loops with timeouts. As soon as the optocoupler outputs a signal, a timeout counter is started with an initial value of 50 and the green LED lights up (see **Figure 3**). This counter is decremented by 1 for each pass through the loop. The loop delay is 10 ms, so the total timeout is 500 ms. If a new pulse arrives within this interval, the timeout counter is reset. If a new pulse is not received, the timeout expires. The ring tone counter, which keeps track of how often the phone rings, is incremented by 1 when this happens, and the green LED goes dark.

The microcontroller must wait a certain amount of time for another ring tone to not be received before it knows that the caller has hung up after letting the phone ring a certain number of times (three in this case). In the Netherlands, the duration of the ring tone is 1 second and the pause between ring tones is 4 seconds. To be on the safe side, the microcontroller waits a bit longer. If no new ring tone is detected after 10 seconds, the microcontroller knows exactly how many times the phone rang (three in this case). This is handled by the second counter loop, which use the variable *timeoutshort*.

If caller does not intend to send a command code (after all, the phone line can also be used for normal purposes), the microcontroller shouldn't have to wait forever for the second number of the code. Accordingly, a third loop is used to reset the program's state machine after approximately 5 minutes. This loop uses the variable *timeoutlong*. If the phone starts ringing again before this timeout has expired, the ring tones are treated as the second number of the code. After the ring tones for this number have been counted, the received numbers are compared with the possible command codes (see **Figure 4**). The present design has only one defined code (3 – 4), but it's easy to add more. When the defined code is received, the LED lights up for 30 seconds.

### Using the circuit

Connect the circuit to the USB port of a PC, or connect it to an external power supply with a well regulated 3.3 V output. Also connect it to the telephone line. Now dial the number belonging to this line.

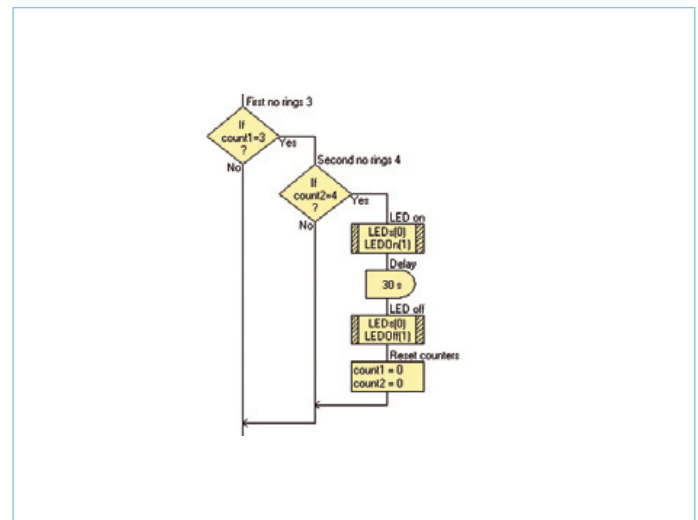


Figure 4. Flow chart for comparing the number of ring tones with the defined command code (3 – 4). Note that 'First no / Second no' should be taken to mean 'First/Second ring count'.

The green LED will light up each time the phone rings. Hang up after it rings three times and wait briefly (at least 10 seconds, at most 5 minutes). Then dial the number again and let the phone ring four times, then hang up. After approximately 10 seconds, the yellow LED will light up and remain lit for 30 seconds, which indicates that the microcontroller has recognised the command.

If you do something wrong, the circuit resets automatically after approximately 5 minutes. If you don't want to wait this long, press the reset button.

The command code used here and the yellow LED are only examples. You can define as many command codes as you wish and connect other devices, such as outdoor lighting, a coffee machine, or what have you. Bear in mind that the maximum output current of the microcontroller is 8 mA per pin and 150 mA in total, with a 3.3-V output level. If you need more current or a higher voltage, you should use a transistor, MOSFET or relay.

The Flowcode software for the ARM microcontroller and ECRM40 module are available on the Elektor website. The source code for this project can be downloaded free of charge from the project page [1].

(090530-1)

\* With an ISDN line the voltage is usually around 90 to 100 V. For this reason, an electrolytic capacitor with a sufficiently high rated voltage is specified here.

### Internet Link

[1] [www.elektor.com/090530](http://www.elektor.com/090530)

## About the author

Bert van Dam writes articles and books on microcontroller projects, including *PIC Microcontrollers: 50 JAL Projects for Beginners and Experts*; *Artificial Intelligence: 23 JAL Projects to Bring Your Microcontroller to Life!*; and *Microcontroller Systems Engineering with Flowcode: 45 Flowcode Projects for PIC, AVR and ARM*.

# Hexadoku

## Puzzle with an electronics touch

At the time of writing obviously we've no way of telling what the weather will be like in December. For sure, however, this new Hexadoku puzzle will get you through a bad afternoon or two. So how hard is the puzzle this time? Try it out for yourself! Enter the right numbers in the puzzle, send the ones in the grey boxes to us and you automatically enter the prize draw for four Elektor Shop vouchers. Have fun!

The instructions for this puzzle are straightforward. Fully geared to electronics fans and programmers, the Hexadoku puzzle employs the hexadecimal range 0 through F. In the diagram composed of 16 × 16 boxes, enter numbers such that **all** hexadecimal numbers 0 through F (that's 0-9 and A-F) occur once only in each row, once

in each column and in each of the 4×4 boxes (marked by the thicker black lines). A number of clues are given in the puzzle and these determine the start situation. Correct entries received enter a draw for a main prize and three lesser prizes. All you need to do is send us the numbers in the grey boxes.

### Solve Hexadoku and win!

Correct solutions received from the entire Elektor readership automatically enter a prize draw for one Elektor Shop voucher worth £ 80.00 and three Elektor Shop Vouchers worth £ 40.00 each, which should encourage all Elektor readers to participate.

### Participate!

**Before January 1, 2011**, send your solution (the numbers in the grey boxes) by email, fax or post to

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### Prize winners

The solution of the October 2010 Hexadoku is: 3F8B5.  
The £80.00 voucher has been awarded to: Gergely Szabolcsi (Hungary).  
The £40.00 vouchers have been awarded to: Cédric Chapé (France),  
Antonios Chorevas (Greece) and Peter Hillen (The Netherlands).  
Congratulations everyone!

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

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

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# EF50 – The Story

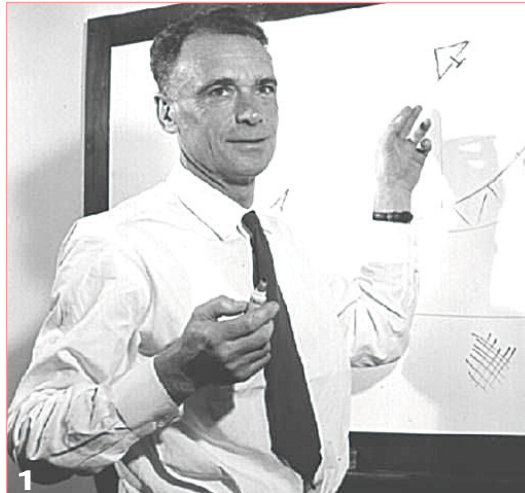
## The valve that helped win the war

By Ronald Dekker (The Netherlands)

A strangely tense mood prevailed in the Philips valve plant on the Emmasingel in Eindhoven (The Netherlands, a.k.a. Holland) on the evening of the May 9, 1940. It was clear to everyone that, in addition to the fact that the Germans were set to invade the Netherlands at any moment, the Philips workers had an unusual job to do that evening. A total of 25,000 units of their newest radio valve, the EF50, and 250,000 components for this valve, all of which had been produced in a great hurry, were quickly loaded onto a waiting lorry. The lorry left the same evening for Vlissingen (Flushing) on its way to England. The news of the start of the invasion came even before the Stoomvaart Maatschappij Zeeland ferry had slipped its moorings. Although the ferry came under fire from a German fighter plane, it reached the coast of England safely. Its unusual cargo was to play an especially important role in one of the crucial battles of World War II: the Battle of Britain.

Around five years earlier, on February 26, 1935 (the day when Hitler gave the order for the formation of the German Luftwaffe), an old lorry loaded with electronic equipment made its way to the small town of Weedon in Northamptonshire, England. It was clear at that time that a German invasion, should there be one, would be preceded by a decisive air battle for control of the British air space. The Royal Air Force (RAF) was weaker than the Luftwaffe, and for it to have a chance of winning the battle it was essential for the Air Command to be aware of approaching enemy aircraft as early as possible.

The legendary inventor Watson-Watt had proposed that radio signals reflected from aircraft wings could be detected and used for this purpose. In order to convince British Air Commander Sir Hugh Dowding, an experiment was carried out. This involved radio signals broadcast by a BBC shortwave transmitter in Daventry, with the objective of using an improvised radio



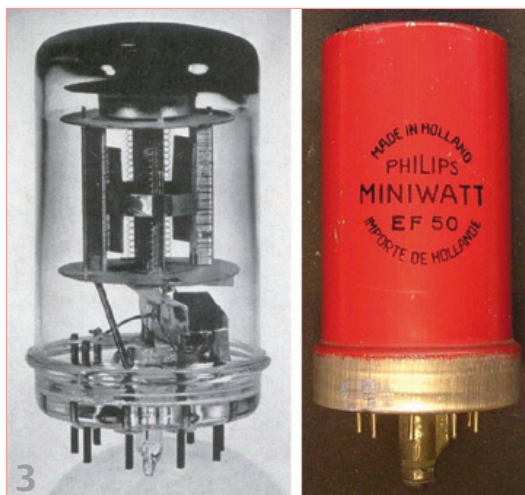
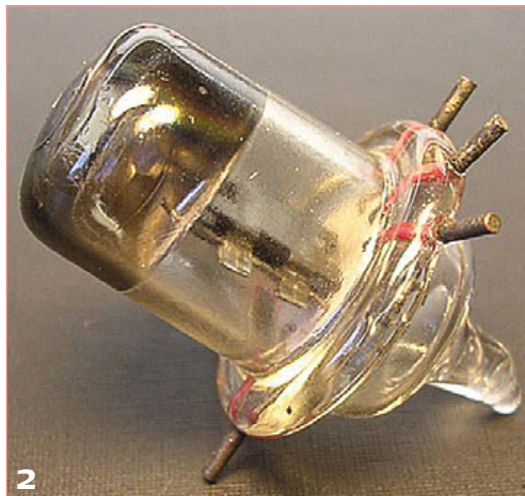
receiver in the lorry to detect these signals after reflection from an aircraft. The demonstration was so convincing that an order was issued to build a chain of radar stations along the English coast, called the 'Chain Home' system.

The brilliant scientist 'Taffy' Bowen <sup>[1]</sup> was one of the first people involved in the design and construction of the Chain Home system (Figure 1). A wavelength of 50 metres was selected (6 MHz) because it yielded maximum signal reflection from aircraft with a wingspan of 25 metres. Construction of the system proceeded very propitiously, in part because the transmission frequency used in the system was a good match to the state of technology at that time.

Near the end of 1936, when the construction of the Chain Home system was already quite advanced, there came a need for a radar system that was small enough to be installed in an aircraft. Although the Chain Home system could see a long way, its resolution was too coarse to allow individual fighter planes to be directed toward enemy aircraft at night when visual sighting was not possible. As there was no room in the small fighter planes for a large antenna, an airborne system of this sort would need to operate at a transmission frequency of around 200 MHz. This was an enormous challenge at that time.

Building a 200-MHz transmitter proved to be not especially difficult, but the receiver caused a lot of problems. The only radio valves that could still provide sufficient gain at this relatively high frequency were the 'acorn' valves (Figure 2). They were very difficult to make and certainly not suitable for mass production. Just before the situation became truly pressing, Bowen received a golden tip from his former professor Edward Appleton: the electronics firm Pye had developed an extremely sensitive 45-MHz receiver for its new television sets <sup>[2]</sup>.

The director and owner of Pye, the well-known and eccentric C.O. Stanley, was determined to make a major



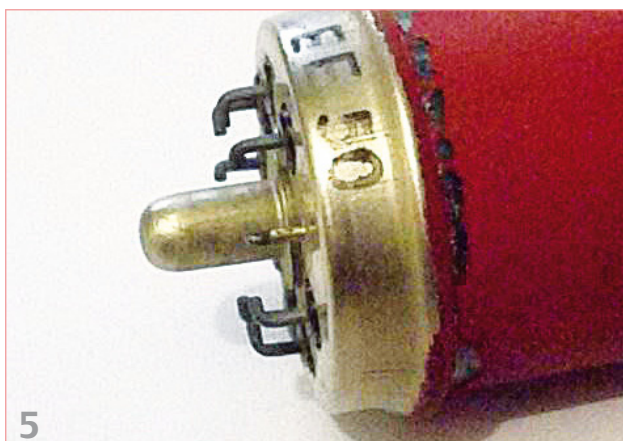
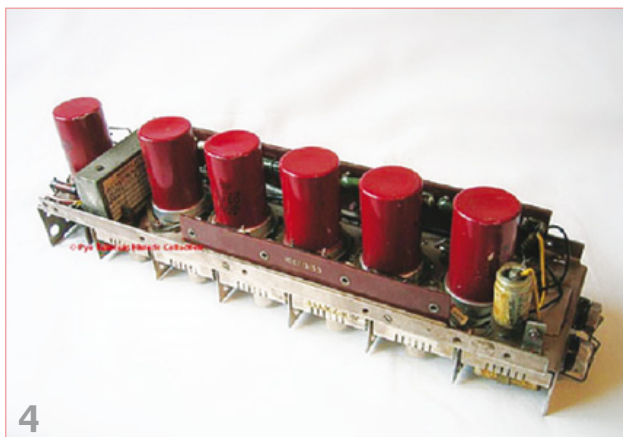
commercial success of the new medium of television. At that time, the 45-MHz television transmitter at Alexandra Palace in London was the only television transmitter in England. To maximise the coverage area of the transmitter, and thus the number of people who could receive the signal, Stanley had asked his designers B.J. Edwards and Donald Jackson to develop a sensitive television receiver. As there was only one transmitter, they chose a tuned RF receiver design for operation at a single frequency: 45 MHz. A revolutionary new valve, the EF50, was developed in order to achieve the necessary sensitivity, and it was supplied in England by Mullard, at that time a fully owned subsidiary of Philips (Figure 3).

Bowen was delighted. With a modified version of the EF50 in the mixer stage and the 45-MHz 'Pye strip' for the IF stage, he had an excellent radar receiver, which moreover could be produced in large quantities (Figure 4). It came just in time: a few months later England declared war on Germany. What made the EF50 so special?

Before the advent of the EF50, radio valves were made using the same method as incandescent lamps. The electrodes of the valve were assembled on wires passing through a small glass stem pinched off at the top. The relatively long lead wires passed from the electrodes through the pinch to the valve base. The parasitic capacitances and inductances of these lead wires made it impossible to produce good HF valves using this method.

The pressed-glass base developed by the researchers Jonkers, Alma and Prakke at the Philips Physics Lab in Eindhoven was considerably better in this regard. With this approach the electrodes are mounted directly on a number of nickel-iron pins held in a pressed glass base, and these pins also act as the contact pins of the valve. The pins were originally bent so the valve could be rotated a bit to lock it in place after it was inserted in the socket (Figure 5). This system caused quite a few problems, so after a short time the bent pins were replaced by straight pins. A metal sleeve provided suitable shielding.

At that time a major development effort was necessary to refine this method to the point that it was suitable for the automated



production of millions of valves per year. Consequently, the EF50 valves that Mullard supplied to Pye were not manufactured by Mullard, but instead came directly from the Philips plant in Eindhoven. As the people at Mullard also had no idea that the EF50 valves were used in the top-secret radar project, this did not come to light until the spring of 1940. Understandably, this realisation led to a minor panic in the British military organisation, since The Netherlands were on the verge of being overrun by the Germans.

As a result of a request at the government level, Theo Tromp, the energetic manager of the Philips valve factory, was summoned to London. There Watson-Watt asked him to produce and deliver as many EF50 valves as humanly possible without asking any questions, and to have copies of the production machines made so Mullard staff could take over production. Tromp realised that this involved something very important and did what he was asked. Working day and night, the machines in Eindhoven turned out as many

valves as possible.

The history and background of the EF50 is described in detail on the author's website [3], based on unique source material from the Philips company archive. The shipment from Eindhoven played a major role in the Battle of Britain. It is both impossible and unnecessary to estimate how important the EF50 was for the course of the war. Here it is sufficient to cite the words of Taffy Bowen: "Along with the magnetron, the EF50 was the most important valve in World War II."

(100657-1)

### Internet Links and References

- [1] E.G. Bowen, *Radar Days*, Adam Hilger, Bristol 1987; ISBN 0-85274-590-7
- [2] [www.pyetelecomhistory.org/index.html](http://www.pyetelecomhistory.org/index.html)
- [3] [www.dos4ever.com/EF50/EF50.html](http://www.dos4ever.com/EF50/EF50.html)

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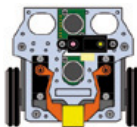
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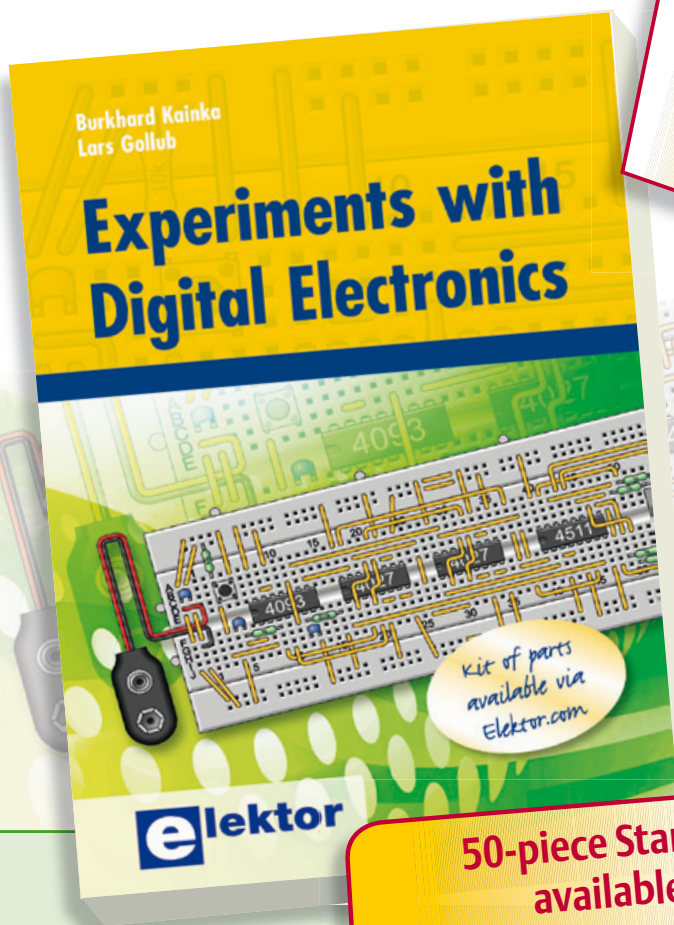
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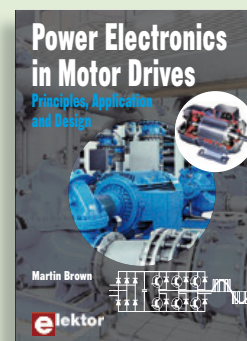


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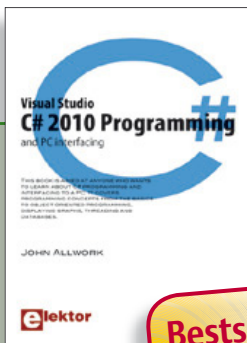
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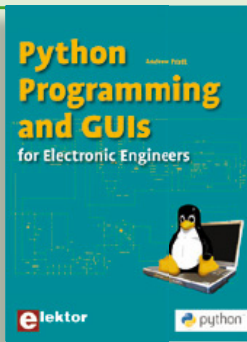
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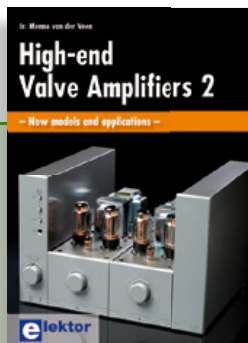


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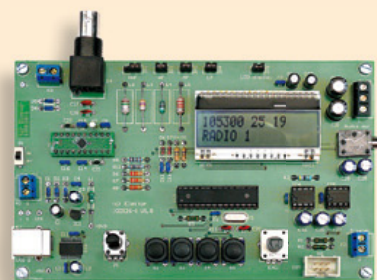
## Digital Multi-Effects Unit

(September 2010)

It's a simple fact: every recording sounds better with the right sound effects. Here we prove that it's possible to generate a variety of effects digitally, including hall, chorus and flanger effects, without having to work yourself to the bone with DSP programming. The circuit is built around a highly integrated effects chip and features an intelligent user interface with an LCD. The result is a treat for the eye and the ear.

*Kit of parts including PCBs, programmed controllers and EEPROM*

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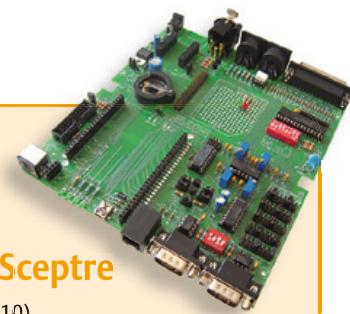
## The Elektor DSP radio

(July/August 2010)

Many radio amateurs in practice use two receivers, one portable and the other a fixed receiver with a PC control facility. The Elektor DSP radio can operate in either capacity, with a USB interface giving the option of PC control. An additional feature of the USB interface is that it can be used as the source of power for the receiver, the audio output being connected to the PC's powered speakers. To allow portable 6 V battery operation the circuit also provides for an audio amplifier with one or two loudspeakers.

*PCB, assembled and tested*

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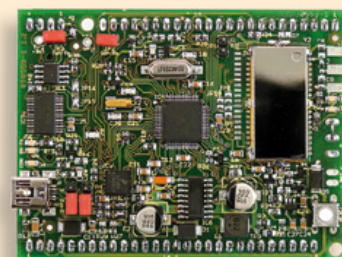
## InterSceptre

(June 2010)

In our March issue, we introduced Sceptre, a fast prototyping system fitted with a 32-bit microcontroller. Even on its own, this board will let you produce some great results, but if we add an extension board to make it easier to access all its peripherals, the Sceptre platform becomes downright powerful. What's more, if you fit this extension board into a suitable case, you'll be able right from the start to develop a prototype that you can use 'properly' in a installation, with no trailing wires or bits of sticky tape holding everything together. Now that's what you call fast, convenient prototyping!

*Kit of parts, contains PCB and components*

Art.# 100174-71 • £116.00 • US \$ 187.10



## Reign with the Sceptre

(March 2010)

This open-source & open-hardware project aims to be more than just a little board with a big microcontroller and a few useful peripherals — it seeks to be a fast prototyping system. To justify this title, in addition to a very useful little board, we also need user-friendly development tools and libraries that allow fast implementation of the board's peripherals. Ambitious? Maybe, but nothing should deter you from becoming Master of Embedded Systems Universe with the help of the Elektor Sceptre.

*PCB, populated and tested, test software loaded (excluding Bluetooth module)*

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£ US \$

+ + + Product Shortlist December : See [www.elektor.com](http://www.elektor.com) + + +

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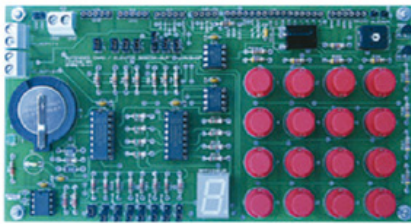
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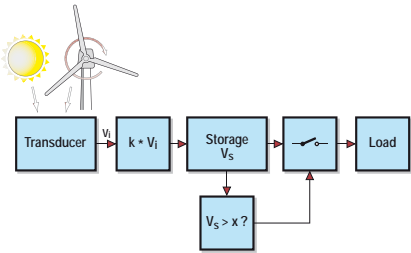


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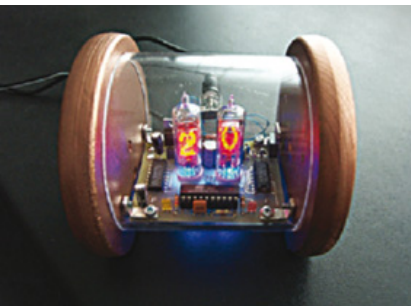
### Educational Breadboard

Many users are facing problems with microcontroller serial protocols such as I2C, SPI and 1-Wire. This project allows serial communication to be mastered with a diverse collection of components all featuring serial interfaces. Besides offering versatile serial communication the board also enables you to experiment with buttons, a buzzer, LCD, and much more. The card was originally designed for our very own ATM18, but can be used with other microcontrollers too.



### Every Little Bit Helps

In the January 2011 edition we show a few ways to power circuits from alternative energy rather than from batteries or the AC grid. We focus on solar energy, but the methods applied should be useful in combination with other energy sources too. We show that a sophisticated combination of modern and not so modern components can yield acceptable results at low cost.



### Thermometer with Nixie Tubes

Nixie tubes have a distinctive appeal, as substantiated by our recent Nixie clock in the shape of the Sputnik satellite. Here we're presenting a thermometer with two Nixie tubes, a One-Wire thermometer type DS18B20 is used for the temperature measurement, while the processing of temperature data and the control of the Nixie tubes is happily handled by an AT89C2051 microcontroller.

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

Elektor UK/European January 2011 edition: on sale December 23, 2010. Elektor USA January 2011 edition: published December 16, 2010.

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