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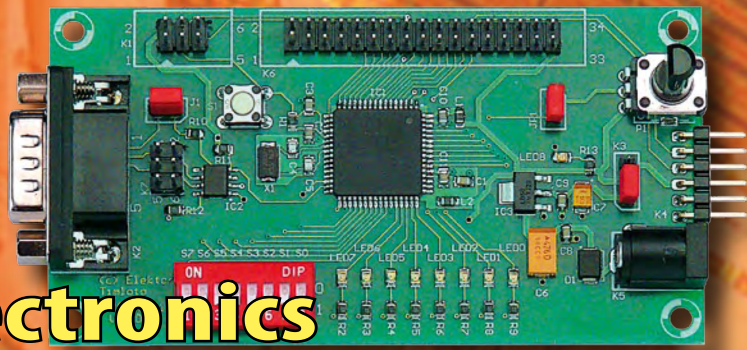
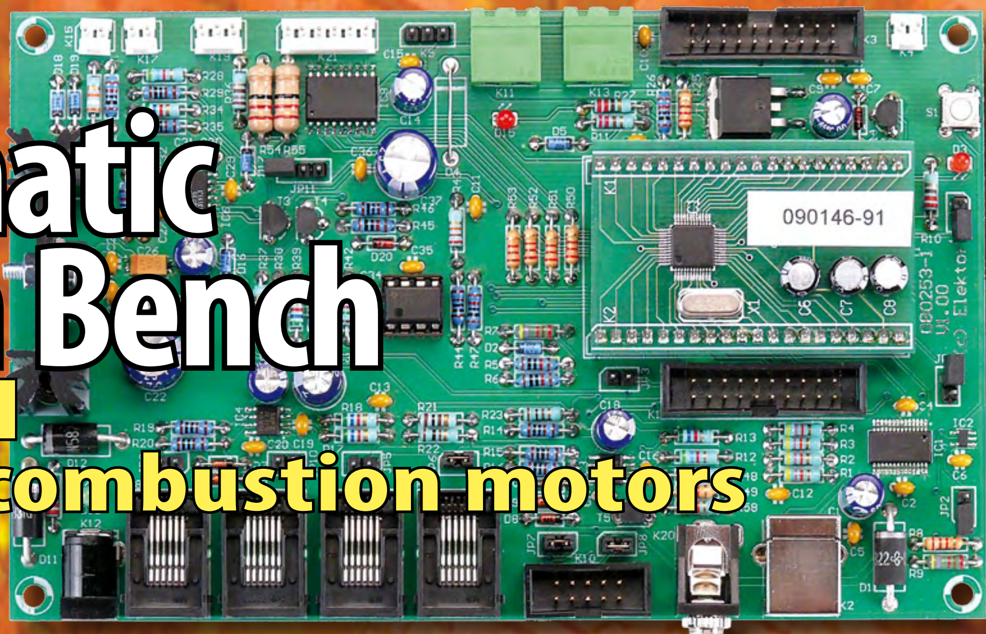
Automotive CANtroller
explore auto electronics



Automatic Run-in Bench
for model internal combustion motors



The 32-bit Machine
develop & program with our R32C starter kit

... SUPER COMPUTERS ... FM STEREO DECODER ... C DISPLAY ... LED DRIVERS SPICED ... AVR MACROS ...

04
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The Sound Strobe™

SPEAKER DIAGNOSTIC TOOL

This assembled unit comes in a durable plastic case

- Produces six selectable spectrum shape pulse signals to help you identify problems with your speakers and their interactions with your listening room.
- Quickly hear your speaker's degree of image focus, transient precision, and tonal neutrality.
- A great product for DIY speaker builders who want to tweak their designs and a must-have for anyone installing loudspeakers professionally.

***Check out Ed Simon's review at* www.audioXpress.com**

To find out more about The Sound Strobe™ contact customer service by calling 888-924-9465 or e-mail **custserv@audioXpress.com.**

The Sound Strobe™ was designed by Dennis Colin, currently working as an Analog Circuit Design Consultant for microwave radios and a frequent contributor to *audioXpress* magazine.

Available in kit or assembled versions

KT-3A	Assembled Sound Strobe............	$329.00	Sh.Wt. 6 lbs.
KT-3	Sound Strobe Kit	$275.00	Sh.Wt. 4 lbs.
PCBT-3	Sound Strobe PC-board only.....	$19.95	Sh.Wt. 1 lb.

Old Colony Sound Laboratory
PO Box 876, Peterborough NH 03458-0876 USA
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Phone: 603-924-9464 • Fax: 603-924-9467

E-mail: custserv@audioXpress.com

Transcending our Impasse

Stimulus packages are abundant in the news these days of economic downturn. Fresh ways of turning the economy around are being offered from all directions, looking for new ideas and new opportunities. If you think about how new directions in technology come about it is almost always a matter of putting things together that have never before been paired.

One of the strangest characteristics of discoveries is that they are often stumbled upon outside the field of expertise of the discoverer. One illustration among many took place when James Watson and Francis Crick discovered the shape of the human genome in 1953. Their insights that made the difference in modeling the double helix were not in their own fields but in each others'.

Education is usually learning what the common view of the facts happen to be when we are in school. We learn the *status quo*. How old the content is depends on what sort of teacher you are assigned. If s/he is voracious about what is going on in the course field, your facts will be fairly current. If not, you may be saddled with out-of-date views. Orthodoxies die slowly.

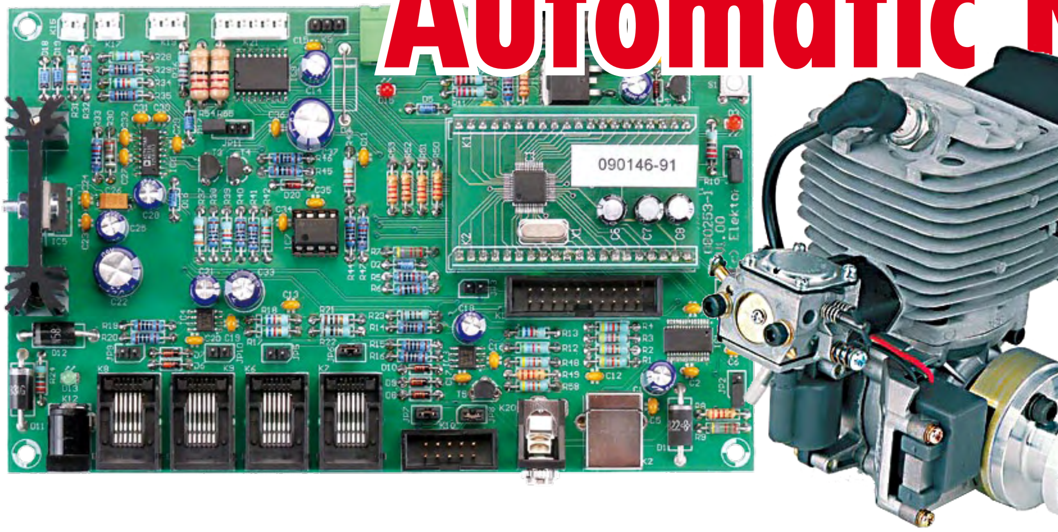
Innovation requires fresh input, and the imagination to pair unlikely elements. Adventuresomeness and even silliness is sometimes a vital ingredient. Who realized that a government communication grid would become the basis for the Internet? Who would make a worldwide powerhouse business out of a search algorithm?

Over the many years I have been enjoying this magazine, one of its most interesting and salient functions has been its wealth of ideas, its fearless presentation of the basis of new inventions. Human heads accumulate an amazingly wide assortment of information. Sharing that uniqueness through a common medium is the foundation for the growth and advancement, and sometimes destruction, of our futures. Thus I have always been a firm believer in the authentic quality and variety of *Elektor*. Your participation as subscriber, critic, response agent, and author all contribute to the brilliant work the publishers bring to us month after month, year after year.

Ed Dell
Editor/Publisher, Audio Xpress magazine

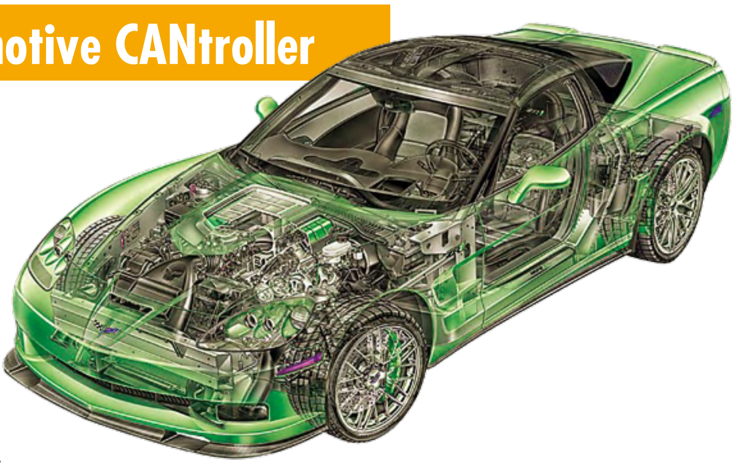
elektor
electronics worldwide

Automatic F

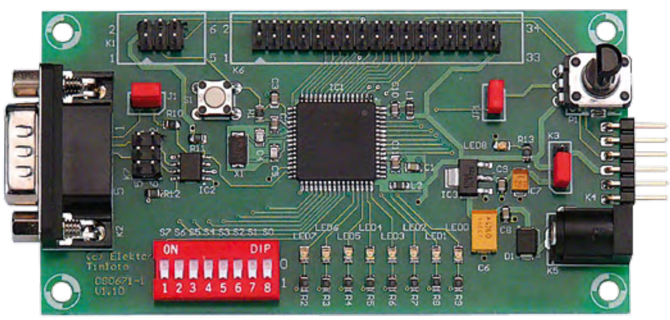


Come see us at
Embedded Systems Conference Silicon Valley, San Jose USA, March 30—April 3, 2009.

34 Automotive CANtroller



This universal microcontroller board was designed, in the first instance, for use by students studying automotive technologies, but it can also be used for other applications, of course. The heart of this board is an Atmel AT90CAN32 with a fast RISC core.



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April 2009
no. 4

Running-in Bench

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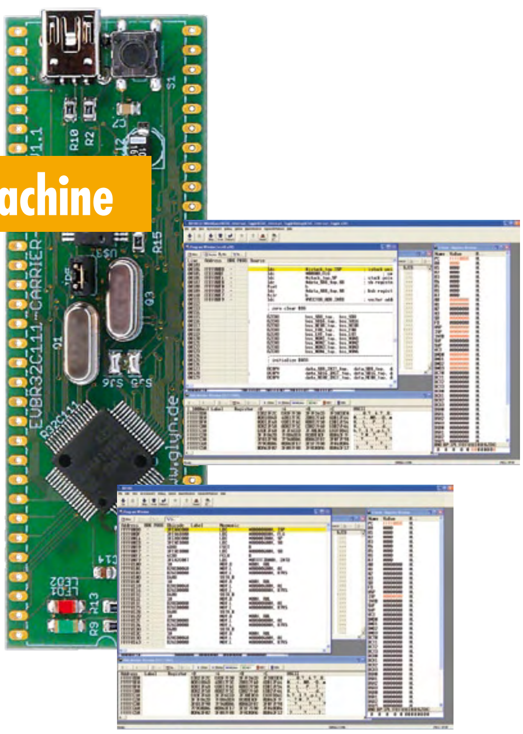
While an electric motor can be used at full power immediately it is brought into service, an internal combustion motor needs a period of running in before it is capable of delivering its maximum power. The idea of the project described here is to automate this important operation.

Maybe soon, owning a supercomputer at home will no longer be just a dream. Indeed, inventive solutions enabling a wider public to have access to enormous computing powers do already exist…

40 A Supercomputer on your Desk



46 The 32-bit Machine

These pages will familiarize you with the tools required for programming and debugging the R32/C111 'beast'. Those of you already familiar with the R8C/13 from Renesas will recognize plenty of similarity in the way all this is handled.

projects

technology

info & market

infotainment

elektor international media

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

APRIL 2009 ISSN 1757-0875

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

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

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

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

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A boxful of Dekatrons and the hunt for 'Trochotron'

In response to the publication of our article 'The Dekatron decimal counter valve" in Elektor March 2008, Mr Roger Ellis of London, UK, kindly offered to send some of these rare counter tubes to the author of the article, Mr Jean Herman in Belgium.

The shipment was arranged to go by way of Elektor and your Editor took the liberty of photographing the contents of the box for all readers to admire. Thanks are due to both correspondents for allowing us to publish about these rare components dating back to the dawn of digital electronics.

Apart from ZM1020 tubes and a dozen unused sockets (originally intended for the Belgian national railway Authority SNCB), the box also contained an interesting leaflet from a French component distributor. It lists Decatron types Z303C, Z502S, the E1T (also covered in Retronics) and a device called Trochotron ET51 which immediately aroused our curiosity. Can anyone help with further information, aiming of course, at a short article for the Retronics section in Elektor? Does anyone have real life specimens of Trochotrons lurking in a drawer or a lab cabinet?

Replacement type for BB112 500-pF varicap diode

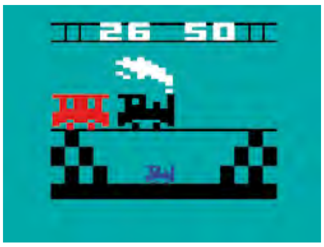
Dear Editor — an alternative to the BB112, which is no longer readily available, is the 1SV149, which is compatible and has similar specifications. The BB112 has a capacitance range of 20 to 500 pF and is mainly used in tuned circuits for the low and medium short-wave bands, such as the automatically tuned preselector for the DRM receiver described in the November 2004 issue of Elektor Electronics. The 1SV149 is available from www.ak-modul-bus.de. The direct link is: www.ak-modul-bus.de/stat/kapazitaetsdiode_1sv149.html.

Burkhard Kainka (Germany)

Games Computer in Retronics

Dear Jan — I would like to comment on the Retronics installment on the Games Computer in the October 2008 issue of the magazine. I found it especially interesting because it was one of my main jobs during the period when I worked as a designer and member of the editorial staff of Elektor (April 1976 to July 1979).

To the best of my knowledge, the picture of the little train at the top of page 76 is one of my creations. It was a nice design – ahead of its time actually – but I think it was a bit on the expensive side for the hobbyists of that time, especially the younger ones.



I maintained many contacts with the technical specialists at Philips at that time, and there may be someone on your editorial team who can still remember this. During those days I attended a course on the 2650 microprocessor at Philips, along with one of my co-workers, Karel Walraven. We used a 2650 development kit in the course, the 'Instructor 50'. I still have the marketing brochure for this kit, which has a picture of a class with several students including Karel and myself.

However, the Games Computer was not the first article involving microprocessors to appear in Elektor. It was preceded by a series of articles on the SC/MP computer – 30 years ago now – to which I also made a major contribution. I don't know whether you have already mentioned it under this topic, since I don't see every issue of Elektor.

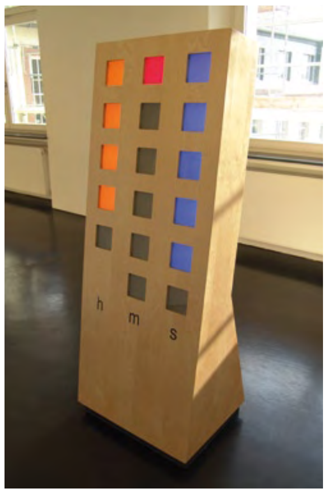
If not, I hope it will appear sometime. I still have a pristine example of the SC/MP, the first Elektor computer, which is available for taking photos if desired. I also have one of the blue 'gramophone records' for the SC/MP. It wasn't especially reliable, but it did work!

André Pauptit (France)

It's nice to hear from a former colleague, and it's especially rewarding to be able to publish this in our Mailbox. As regards the SC/MP, I already described it Retronics, April 2005; otherwise I would be pleased to accept your offer.

US clock speaks German

Dear Editor — I am a new subscriber to Elektor USA and I would like to find someone to help with a project. I was particularity interested in the articles on the Tri-state Time and the Model Railway Car Lighting Decoder in the 2/2009 issue of Elektor.



Back in the early 80s I worked for Diehl Research Center in Stamford. I am now a retired electronic engineer. This company was part of Diehl GmbH based in Nürnberg, Germany. The director and I went to the German Language School in Westport to learn German.

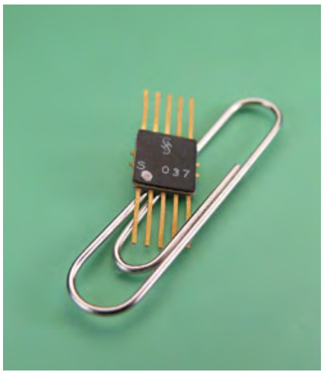
I can understand more than speaking as my parents were German.
We used a book called *Deutsch 2000* and on page 156 they have "Die Uhrzeit" (the Time of Day). At the time I was working for a clock company and said why not put this into digital format. I did make a prototype which is still working to this day. This prototype is done the old fashioned way by wiring the hardware counters, CD4029s since they can count up and down.

I would to make a new version using a microprocessor and perhaps a VF display. I would like to find someone who would like to do a program and help make this a joint project for Elektor. I could give hardware support and the other person could write the write a program and together we could build a sample.
My prototype has two digits for the minute, two digits for the hours and four indicators lights for the words "nach, vor, viertel, and halb", but this new version could be a 16-digit VF display.

There could be a lot of potential for this. As a learning tool we could combine it with an analog clock so the 'viertel vor', 'viertel nach', 'vor halb', and 'nach halb' fit in. I have mine next to an analog clock. Perhaps in a German class it would be useful.
I have my prototype with LED digits and HP light bars for the words. A 16-digit vacuum fluorescent display might be nice, as the digits and words are all in line.

I hope you can put me in touch with a programmer who would like this project. Maybe we can get a company to produce it.
George Fischer (USA)

A cordial welcome to the Elektor experience, George and hope you continue to enjoy Elektor's new USA edition.
Anyone willing and able to help George, please contact the Editor.



When SMD was young

Dear Editor — I have been an enthusiastic reader of Elektor for about 30 years and I eagerly await the new edition every month. I have built a fair number of your projects. I particularly like the mix of unorthodox ways to tackle problems, circuit development and the odd page of nostalgia.
Prompted by your articles on the SMD Oven in the October 2008 issue I'd like to add a little something to the above theme: a photocopy of an article from *Siemens Component Information,* edition 1968, and an original SMD integrated circuit from the early 1970s.
I wish your team every success.
Fritz Lackner (Germany)

Many thanks for responding Fritz and for the rare example of an antediluvian SMD chip from Siemens. It proves that the concept of SMD is older than some readers complaining about the technology being used in DIY projects.

LED Spinning Top

Dear Editor — I was very pleased to see the 'Messaging spin Top' article in the 2008 December issue of Elektor (pp 16-21).
However, when I read the article I was very disappointed to find out that the original inventors of this 'striking gadget' were not mentioned.
Please note that iTop was invented and patented in 2003 by Dr. Gyora Benedek, Avi Olti, Shai Seger and Robert Fuhrer. (US Pat. no. 7037169). Itop was and still is sold worldwide with a new model coming soon. The design presented in the article looks like a perfect copy of our product except for the double row of LEDs.
Our group together and separately invented and developed several hit games such as Lights Out (video game), Hidato (www.hidato.com), KenKen (www.kenken.com).
I hope you will find a way to correctly attribute this toy and mention us in your next issue.
Dr Gyora Benedek (Israel)
www.doo-bee-toys.com

Dr. Benedek's email was copied to the German author and editors responsible for the 'Messaging Spin Top' project.

In reply, they would certainly have mentioned Dr. Gyora Benedek, Avi Olti, Shai Seger, Robert Fuhrer and the relevant patent(s) if such information had been available to them. When publishing contributions about developments in electronics, a trade journal like Elektor has no legal obligation to identify patent(s) or other protection describing similar approaches (see also the Copyright Notice on page 7). In practice, it is impossible for the Elektor team to do extensive patent research work for every circuit or article proposal received. The author of the Spinning Top project was not aware of the inventor or his patent(s).
The US patent mentioned by Dr Benedek was awarded in 2006 and has a very broad content. We were unable to find details of practical circuit implementations or indeed control software, which, from our experience, is the crux of the development. The patent does however describe the operating principle of a spinning top with a rotating LED bar, as well as synchronization by detection of a magnetic field (as an example, the earth's magnetic field is mentioned) using "rotation data measuring means including an induction coil."

MailBox Terms

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- When replying to Mailbox correspondence, please quote Issue number.
- Please send your MailBox correspondence to:

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Elektor, The Editor,
1000 Great West Road,
Brentford TW8 9HH, England.

Start-Up launches new, competitive video platform

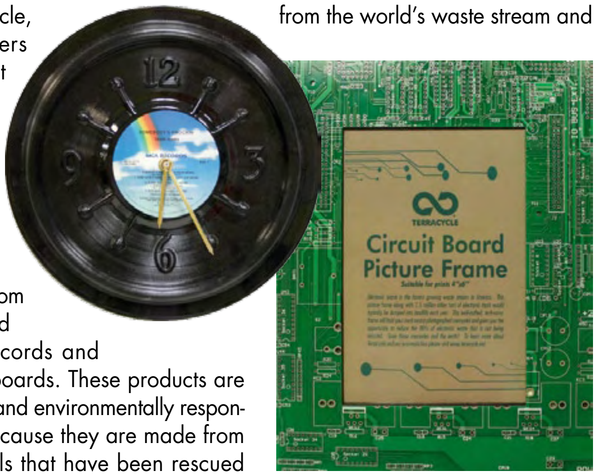
A new player in online video platform technology, voped, has developed and launched the first of its new embeddable video applications, the voped Embeddable Video Platform (EVP). The voped Embeddable Video Platform brings enhanced functionality to news, corporate, nonprofit, and other web publishers and facilitates easy uploading and organization of video content such as user-generated video, citizen reporting, newsroom videos, customer videos, etc.
voped's Embeddable Video Platform (EVP) technology aims to provide voped customers affordability for all sizes of online publishers, a high degree of functionality that raises the profile of video on websites, and customer options to help monetize video content.

The voped EVP can be used with any website at an affordable cost and can be customized to produce a platform that suits specific online needs. voped also plans to roll out additional features and services in the near future and will continue to build on valued partnerships with premier online publishers and websites.
In addition to voped's new product and services launch, voped announced a major online agreement with a leader in the digital marketing industry, SimpleSeason, which hosts micro-sites for celebrity powerhouses like The Doors, Mike Tyson, Janis Joplin, and many others. SimpleSeason and voped recently re-launched the official Mike Tyson website.

hwww.voped.com/videoplatform.htm

(090173-I)

TerraCycle delivers unique recycling products



TerraCycle, Inc. offers the first nationally distributed product line made from upcycled vinyl records and circuit boards. These products are unique and environmentally responsible because they are made from materials that have been rescued from the world's waste stream and would have ended up in already overflowing landfills.
Technology progresses at an astounding rate, and a trail of trash is close in tow. Every time consumers upgrade their PC, TV, stereo, or other electronics, they add to the colossal stream of e-waste. TerraCycle counters this trend by reusing circuit boards to create new products.
With the advent of CDs, followed by the current prevalence of digital media and portable music players, vinyl records have become obsolete. While serious collectors hang on to their vintage discs, most people are disposing of their records that have been collecting dust in the attic. TerraCycle Vinyl Record products are perfect for anyone with a sense of nostalgia, and for music fans who want to enjoy the roots of their passion every day at home or in the office.
TerraCycle uses the circuit boards and vinyl records to make three unique product lines in varying sizes: clocks, coasters, and picture frames.

www.terracycle.net/press/circuit_vinyl_release.html

(090173-II)

PCI Express SDR boards boast direct FPGA connectivity

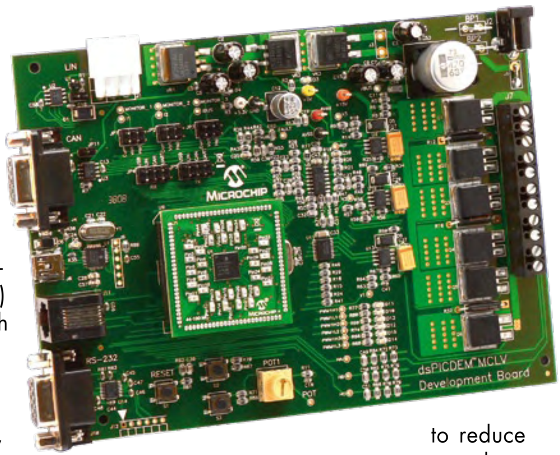
The latest family of Pentek software-defined radio products, the 7700 series, features a PCI Express (PCIe) form factor with advanced connectivity options. The new family comprises five models: the 7741, 7742, 7750, 7751 and 7752. Each model offers a unique set of software radio features in a full-length PCIe board with the latest Gen 2 PCIex16 interface. This emerging standard for high-end PCs, blade servers and enterprise computers delivers fast interconnect links for economical, high-performance system solutions.

The full-length PCIe board of the 7700 series enables them to host up to two PMC/XMC modules in a single PCIe envelope. This doubles the channel count of earlier models and delivers a lot of performance in a very small space. Customers can utilize the PCIe interface for motherboard connections and the XMC interfaces for gigabit links between the modules and other boards. This flexibility allows users to build high-speed multi-board PC systems at relatively low cost.
The Model 7741 offers up to four 125-MHz, 14-bit A/Ds and four 500-MHz, 16-bit D/As. It features one or two TI/Graychip GC4016 quad digital down converters with output bandwidths up to 10 MHz, and one or two digital up converters that accept baseband real or complex data streams with signal bandwidths up to 40 MHz. One or two Xilinx XC2VP50 Virtex-II Pro FPGAs serve as control and status engines with data and programming interfaces to all of the on-board resources, including the A/D converters, digital down converters, digital up converters, and D/A converters. The other models offer even more performance and features.

www.pentek.com/

(090173-III)

Motor control board supports BLDC and PMSM



Microchip has announced expanded support for motor control applications based on the dsPIC® digital signal controller (DSC). The dsPICDEM™ MCLV Development Board (part #DM330021) is a new development platform for low-voltage brushless DC motor control (BLDC) applications. It supports the dsPIC33F family of motor control DSCs and provides a cost-effective platform for evaluating and developing sensored or sensorless BLDCs and permanent-magnet synchronous motor (PMSM) controls.
The board includes a three-phase inverter bridge circuit that can drive a BLDC or PMSM motor using different control techniques without requiring any additional hardware. The dsPICDEM MCLV board can control motors rated up to 48 V and 15 A and provides several communication channels, including USB, CAN, LIN, and RS-232. It employs a processor-differentiated plug-in module (PIM) strategy to support a variety of dsPIC33F motor-control DSCs with different memory and pin configurations. The dsPICDEM MCLV Development Board also includes a dsPIC33FJ32MC204 PIM (32 KB flash).
Microchip has also released two new motor-control software solutions. Application Note AN1208 describes how to combine power factor correction (PFC) algorithms with sensorless motor-control algorithms on a single chip, while Application Note AN1206 discusses operating an AC induction motor (ACIM) faster than its rated speed for a class of applications in order to reduce cost, save space, or reduce weight.

www.microchip.com/motor

(090173-IV)

Tiny blue laser announced for micro-projectors; red and green coming soon

An optimized TO38 package makes the new blue laser diode from OSRAM Opto Semiconductors the smallest in its class, the company says, bringing the world one step closer to the vision of tiny projectors that can be integrated into mobile devices such as cell phones and digital cameras.
Lasers are the ideal choice as light sources for micro-projectors, which convert mobile devices into high-performance multifunctional devices that can not only record images but also present them in razor-sharp detail. Mobile devices currently available on the market can produce and download high-quality photos and video clips. Integrated laser projectors will enable them to project this content in high quality on almost any surface.
Laser projection is the next milestone in the development of mobile devices and has a promising future in terms of integrated projection modules. End users will appreciate the extremely low power requirements and compact dimensions offered by laser-based projection units. Lasers also offer exceptionally vibrant colors and high contrast, and they always produce sharp images regardless of the projection distance.
OSRAM's new blue laser diode has a wavelength of 450 nm, an output power of 50 mW, and an operating voltage of 5.5 V. It has all the important attributes required for micro-projectors, such as small size (3.2 mm height), high efficiency (0.9 W/A), and excellent blue light visibility. As a ridge laser, it has outstanding beam quality and needs only relatively simple, small beam-shaping optics.
OSRAM Opto Semiconductors is also developing red and green lasers for laser projection. The red laser, like the blue laser, will be designed as a direct semiconductor laser, while the green laser will be implemented using a frequency-doubling technique.

http://www.osram.com/

(090173-V)

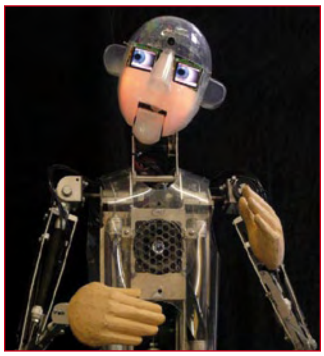
Interactive robot features 31 proportionally-controlled axes and lifelike movement

Engineered Arts Ltd, a UK-based company that specializes in hi-tech multimedia, has created an interactive robot named RoboThespian capable of lifelike movement using Festo fluidic muscles. Initially developed to provide entertaining theatrical performances, the life-sized robot's capabilities have recently been expanded to enable higher levels of audience interaction.
The robot's siblings are now much in demand at science and technology centers as animated public orators, tireless front-of-house presenters, and generally all-round benevolent funsters.

The first generation of RoboThespian robots was developed in January 2005, and the first interactive RoboThespian was exhibited in Los Angeles in November 2007.

This robot's repertoire included a series of song and dance routines, and for the first time, it could respond to its audience vocally and by reactive physical movement. This wowed the audience – but of course, after a while people wanted even more, such as shaking hands with the RoboThespian or having the robot perform their own routines.

The robot has now been upgraded to include articulated hands, an additional axis in each arm, and feedback sensors on all movement axes, with a total of 31 powered axes, each featuring full proportional control. The robot contains six dc motors, but all its major movements are controlled by Festo DMSP fluidic muscles. These pneumatic actuators boast a very high power-to-weight ratio and essentially consist of a flexible tube with a mesh of reinforcing fibers. They contract when they filled with compressed air and elongate when the air is released.



www.robothespian.com/

(090173-VI)

Intel researchers demo RF energy harvester

Researchers at Intel Research Seattle lab have reported on an ambient RF energy-harvesting scheme that can scavenge 60 microwatts, or enough energy to drive a thermometer/hygrometer and its associated LCD, from a TV tower at a distance of 2.5 miles. The demonstration project, called Wireless Ambient Radio Power (WARP) by the researchers, broadens the range of potential ambient energy sources, which already includes vibration, solar and heat. It was presented as another application of the Wireless Identification and Sensing Platform (WISP), a sensing and computation platform that is powered and read by a commercial off-the-shelf UHF RFID reader. Each WISP consumes between 2 microwatts and 2 milliwatts and can be operated at a distance of up to several yards from the reader.

A WISP comprises an antenna, impedance-matching components, an RF power harvester, a demodulator to extract reader-to-WISP data, a backscatter modulator for WISP-to-reader data, a voltage regulator, a programmable microcontroller (the MSP430), and optional external sensors. The harvester itself is a four-stage charge pump.

To date, the WISP has been used for a variety of sensing and other applications, including accelerometers, temperature, strain gage, capacitance, and a custom neural amplifier. This project marked its first use for energy harvesting.

From a balcony of the Intel Research Seattle lab, the researchers harvested RF power from the KING TV tower 2.5 miles away, which broadcasts 960 kW ERP on channel 48 at 674–680 MHz. Energy was collected using a manually oriented broadband log periodic antenna (5 dBi) designed for TV applications and a four-stage power harvesting circuit of the same design as WISP, but with a front end tuned to the desired channel.

To stimulate the development of other applications, Intel Research has launched the 'WISP Challenge' program and will send a full WISP kit to potential collaborators in the academic world on receipt of a suitable proposal.

www.seattle.intel-research.net/wisp/

(090173-VII)

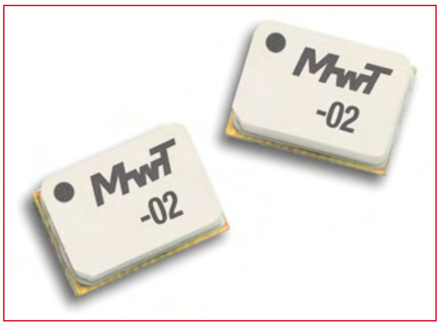
High-performance GaN RF power amplifiers target wireless applications

MWT, a division of IXYS Corporation's Microwave Technology, Inc., has introduced a family of three high-linearity, high-efficiency RF power amplifiers with output power up to 10 W, based on advanced high-quality GaN device technology.

The power amplifiers are the MGA-242740-02, MGA-495922-02, and MGA-4959-02. They are targeted at 802.16d/e WiMax applications and 802.11 WLAN related applications in three different frequencies bands: 2.4 to 2.7 GHz, 3.3 to 3.8 GHz, and 4.9 to 5.9 GHz. All three devices have an output power of 10 watts (40 dBm) measured at the 3-dB gain compression point and a linear power gain of 12 to 15 dB.

The GaN-based RF power amplifiers have achieved 23 percent power-added efficiency at 2 W (33 dBm) linear power (burst power) with 2.5 percent error vector magnitude (EVM) using the 64 QAM 802.16 WiMax digital signal modulation scheme.

MWT claims that the linear power efficiency of the GaN-based power amplifiers is more than twice as high as comparable amplifiers based on GaAs or silicon LDMOS.



The GaN-based power amplifiers operate at a 28-V drain voltage with a quiescent current of 80 to 300 mA. They are available in various packages, including low-cost surface-mount 02 packages. The MTBF of the GaN based microwave/RF power amplifiers is more than 100 years at 85 ºC ambient temperature. Evaluation boards for power amplifiers in 02 packages are available now.

www.mwtinc.com/

(090173-VIII)

Secure supervisor supports FIPS 140-2 levels 3 and 4

Maxim Integrated Products has introduced what it describes as the industry's most secure supervisor for servers, cryptographic coprocessors, POS terminals, and secure communication applications.

The newest member of Maxim's secure supervisor family, the DS3645, integrates a real-time clock (RTC), automatic battery switch, and I²C interface. The DS3645 provides active tamper detection with rapid erasure of key memory and is packaged in a leadless CSBGA for enhanced

security. Eight uncommitted external inputs allow design engineers to implement additional levels of security. Designed for applications requiring the highest level of security, this device supports FIPS 140-2 levels 3 and 4, as well as the most stringent requirements of Common Criteria.

The most innovative feature of the DS3645 is the 4 KB of proprietary on-chip nonvolatile SRAM it uses to store encryption keys. The memory architecture constantly complements the SRAM cells to eliminate the possibility of memory imprinting due to oxide stress, thereby preventing the passive detection of data remnants in stressed memory cells. Additionally, the DS3645 employs a high-speed hardwired clearing function to erase the entire 4-KB array in less than 100 ns after a tamper alarm has been generated by the device.

The DS3645 provides tamper-detection inputs and low-power continuous monitoring of system voltages, resistive meshes, external sensors, and digital interlocks. The RTC crystal oscillator is also monitored and invokes a tamper response if the frequency falls outside a specified window. An internal digital temperature sensor with a programmable rate-of-change detector protects the DS3645's internal encryption-key memory from thermal attacks. The DS3645 constantly monitors primary power, and in the event of failure, an external battery power source is automatically switched in to keep the SRAM, RTC, and tamper-detection circuitry alive.

The DS3645 is specified over the -55 degrees Celsius to +95 degrees Celsius temperature range.

www.maxim-ic.com/DS3645

(090173-IX)

COM Express module boasts high graphics performance

congatec AG has introduced the company's fourth embedded computer module based on the Intel Atom processor family. With a maximum design dissipation of less than 10 W, it is targeted at mobile and fanless applications that require high graphics performance.

The conga-BA945 is a COM Express module with type-2 pinout and conforms to the basic COM Express format of 95 x 125 mm.

The Intel Atom N270 processor has a clock rate of 1.6 GHz, 512 KB cache, and a 533 MHz frontside bus. Despite its high performance, the processor can manage with a maximum power dissipation of 2.5 W. With the sophisticated power management provided by the congatec embedded BIOS, the actual value in use remains well below this level.

The congatec conga-BA945 supports Intel Hyper Threading Technology, which means that with suitable software it can run two operating systems in parallel, fully independent of each another.

The conga-BA945 uses the Intel 945GME chipset, which facilitates parallel use of two memory modules to allow the memory to be expanded to a maximum of 4 GB and supports dual-channel memory access. This yields gains of more than 50 percent in raw graphics performance.

The Intel Graphics Media Accelerator 950 graphics controller integrated in the chipset can access up to 224 MB of video memory at 10.6 GB/s. The two independent graphics channels can output imagery via two 24-bit LVDS ports, SDVO, TV out, or analog VGA. The conga-BA945 uses the EPI graphics standard and the VESA Display ID definition for automatic recognition and configuration of flat-panel displays.

Five PCI Express lanes, a PCI Express graphics slot (PEG 1×16), eight USB 2.0 ports, two serial ATA port, and signals for two Express cards are provided to enable easy expansion. The functionality also includes a fan controller, an LPC bus for slow extensions, and an HDA interface for high-performance digital audio.

www.congatec.com/

(090173-X)

Organic RFID progress reported

A pair of papers presented at the IEEE International Solid State Circuits Conference described progress in the field of organic electronics for RFID applications. German printed electronics specialist PolyIC GmbH reported that it had created the first working 4-bit organic CMOS transponder for a carrier frequency of 13.56 MHz. The prototype transponder was built as a proof of concept and has yet to be optimized in any way, according to one of the paper's authors.

He said that although a number of groups have demonstrated prototypes of p-type organic tags operating at 13.56 MHz, the PolyIC prototype was believed to be the first working model of an RFID transponder.

Organic CMOS devices made from carbon-based materials are regarded as a promising technology because they can be printed on large, thin and flexible films. However, organic electronics have technical limitations compared with silicon-based devices, including speed and accuracy issues. Organic CMOS devices are regarded as particularly promising for RFID applications because they are flexible and could be printed on product packaging, eventually replacing the ubiquitous barcodes but carrying much more information.

Organic circuits typically degrade over time in storage, but the PolyIC prototype continued to work at 13.56 MHz even after 15 months in storage, which is considered adequate shelf life for organic electronics without encapsulation.

The PolyIC prototype devices are fabricated on a flexible polyester substrate roughly 250 microns thick. Aside from the electrodes, all layers of the device consist of soluble organic molecules deposited on the substrate by spin coating. The device has a clock frequency of 196 Hz with a 20-V supply voltage.

www.polyid.de/en/

(090173-XI)

Shock absorbers harvests energy

By harvesting the energy wasted by ordinary shock absorbers, a prototype device called 'GenShock' aims to take over much of the work now performed by alternators. In hybrid vehicles, GenShocks also could boost mileage by 10 percent. The GenShock design has been patented by Massachusetts Institute of Technology (MIT) students who formed a startup, Levant Power Corp., that is targeting heavy vehicles like Humvees and AM General's proposed Joint Light Tactical Vehicle.

In a marriage of electrical and mechanical engineering, GenShock units compress hydraulic fluid as they damp the vertical motion of the shock absorber, generating up to 1 kilowatt per shock. An active suspension system with a centralized generator converts the combined hydraulic pressure from all the shock absorbers into electricity.

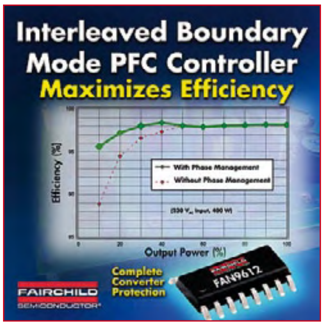
Ordinary shock absorbers damp vertical motion with friction that converts mechanical energy into heat, but the GenShock converts the damped vertical motion into hydraulic pressure that exactly matches the counter EMF of a hydraulically-driven electric generator. If the active suspension system fails or is turned off, the GenShock acts like an ordinary shock absorber.

AM General is currently supplying Levant Power with a Hummer vehicle that is being used for prototyping the GenShock active suspension system. One possible use could be on the U.S. military's planned Joint Light Tactical Vehicle. The military is also interested in using GenShocks to provide auxiliary power to supplement hybrid power generators currently used for refrigeration.

www.levantpower.com/

(090173-XII)

PFC controller extends BCM to 1000-W designs



Fairchild has announced the FAN9612 power factor correction (PFC) controller IC, which can deliver better than 96% efficiency in AC to DC power supplies. It achieves an efficiency advantage by using variable-frequency boundary conduction mode (BCM) operation, which has typically been limited to relatively low-power supplies rated at 300 W or less. The FAN9612 supports designs ranging from 100 W to 1000 W, conventionally the domain of less-efficient fixed-frequency, continuous conduction mode (CCM) operation.

Fairchild combined a boost-topology converter, BCM operation, and a two-phase interleaved architecture to attain the efficiency benefits of the new IC. The two-phase design provides the advantage of higher switching frequency, which allows the use of smaller components, without the drawback of EMI filter problems. The two converters inherent in the design operate in parallel with a 180-degree phase shift. The summed signals is relatively free of ripple current as a result of cancellation by precise matching of the phase difference.

BCM provides high efficiency by minimizing switching losses. It would be impractical at high power levels with a single-phase design due to the ripple current, but the dual-phase architecture extends BCM operation to the kilowatt range.

Other features include dual-output overvoltage protection with latching and non-latching options. The design implements overcurrent and power-limit protection for each channel. The IC also features programmable closed-loop soft-start operation to minimize overshoot at startup.

Finally, the FAN9612 implements automatic phase control, which is increasingly in demand in digital power controllers. Phase shedding provides a relatively flat efficiency curve across a broad load range. The converters are designer for maximum efficiency at relatively high load levels. When the load drops, the converter can shed or shut down one phase and keep the remaining phase operating in the sweet spot of the load efficiency curve.

www.fairchildsemi.com/

(090173-XIII)

A New 'Intelligent' 2.4 GHz Transceiver

The new low-cost 2.4 GHz transceiver type CYRF7936 from Cypress Semiconductor Corp. is specially designed for home automation, health-care applications, remote controls and wireless sensor networks.

With its voltage range from 1.8 V to 3.6 V the device is ideally suited for battery powered systems. A special feature protocol was developed based on the PSoC® microcontroller. It has a memory requirement of only 5 kBytes for a node and 8 kBytes for a hub. The highly effective CYFi Star Network Protocol recognizes the optimal data transfer rate and output power. In case of interruptions, it switches automatically from the highest data transfer rate of 1 Mbps in Gaussian Frequency Shift Keying to the safe Direct Spread Spectrum transmission method at 250 kbps.

Output performance is increased to the maximum +4 dBm as soon as the connection is interrupted.

When operating with two AA battery cells, the typical lifetime is 4 years due to the power saving protocol and technical parameters of the transceiver.

The associated demo kit no. CY3271 is from available from Cypress online or authorized distributors.

www.cypress.com

(091069-V)

OK. Now you need an ... MP3 player

By Milan Rajic
MikroElektronika - Software Department

SmartMP3 module connected to *EasyPIC5* Development System

The adoption of the MP3 format caused a revolution in digital sound compression technology by enabling audio files to become much smaller. If you want audio messages or music to be part of your project then you can easily make it happen. You just need any standard MMC or SD memory card, a few chips and a little time...

Before we start, it is necessary to format the MMC card and save the sound1.mp3 file on it (the card should be formatted in FAT16, i.e. FAT format).
The quality of sound coded in MP3 format depends on sampling rate and bitrate. Similar to an audio CD, most MP3 files are sampled 44.1 kHz. The MP3 file's bitrate indicates the quality of the compressed audio compared to the original uncompressed one, i.e. its fidelity. A bitrate of 64 kbit/s is sufficient for speech reproduction, while it has to be 128 kbit/s or more for music reproduction. In this example a music file with a bitrate of 128 kbit/s is used.

Hardware

The sound contained in this file is coded in the MP3 format so that an MP3 decoder is needed for its decoding. In our example, the VS1011E chip is used for this purpose. This chip decodes MP3 records and performs digital-to-analog conversion of the signal in order to produce a signal that can be fed to audio speakers over a small audio amplifier.
Considering that MMC/SD cards use sections of 512 bytes in size, a microcontroller with 512 byte RAM or more is needed for the purpose of controlling MP3 decoding process. We have chosen the PIC18F4520 with 1536 byte RAM.

Software

The program controlling the operation of this device consists of five steps:

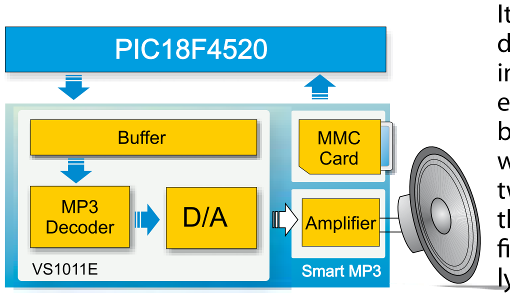
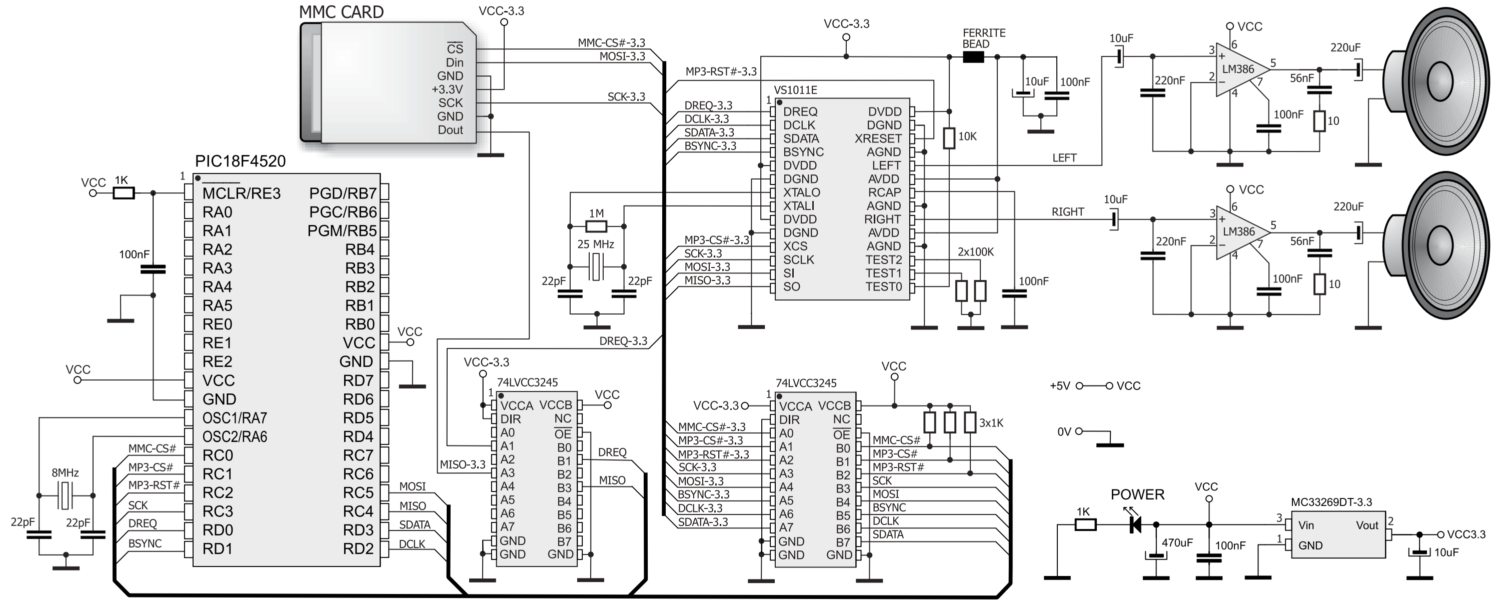


Figure 1. Block diagram of *Smart MP3* module connected to a PIC 18F4520

Step 1: Initialization of the SPI module of the microcontroller.
Step 2: Initialization of the compiler's Mmc_FAT16 library, which enables MP3 files to be read from MMC or SD cards.
Step 3: Reading a part of the file.
Step 4: Sending data to the MP3 decoder buffer.
Step 5: If the end of the file is not reached, jump to step 3.

Testing

It is recommended to start testing the device operation with low bitrate and increase it gradually. The MP3 decoder buffer has a size of 2048 bytes. If the buffer is loaded with a part of MP3 file with 128 kbit/s bitrate, it will contain twice the number of sound samples than when it is loaded with a part of file with 256 kbit/s bitrate. Accordingly, if the bitrate of the file is lower it will take twice as long to encode the buffer content. If we overdo the bitrate of the file it may happen that buffer con-



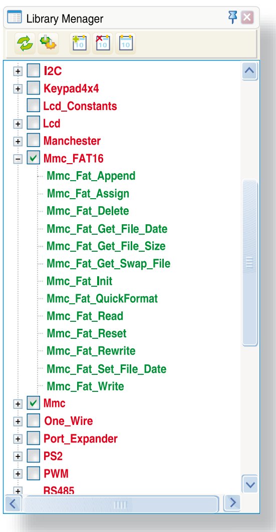
Schematic 1. Connecting the *Smart MP3* module to a PIC18F4520

tent is encoded before the microcontroller can manage to read the next part of the file from the card and write it in the buffer, which will cause the sound to be discontinuous. If this happens, we can reduce the MP3 file's bitrate or use a quartz-crystal 8MHz or more. Refer to Schematic 1. Anyway, you don't have to worry about this as our program has been tested on several microcontroller families with different crystal values and it is capable of decoding MP3 files of average and high quality. On the other hand, a low bitrate means that buffer decoder is filled with sound of longer duration. It may happen that the decoder doesn't decode the buffer content before we try to reload it. In order to avoid this, it is necessary to make sure that the decoder is ready to receive a new data before it has been sent. In other words, it is necessary to wait until decoder's data request signal (DREQ) is set to logic one (1).

Enhancements

This example may also be extended after being tested. The DREQ signal can be periodically tested. A routine for volume control or built-in Bass/Treble enhancer control etc. may be incorporated in the program as well. The MMC library enables you to select a file with a different name. In this way it is possible to create a set of MP3 messages, sounds or songs to be used in other applications and send appropriate MP3 files to the decoder depending on the needs.

Below is a list of ready to use functions contained in the *Mmc_FAT16 Library*. This library is integrated in *mikroC PRO for PIC* compiler.



Mmc_Fat_Append()	Write at the end of the file
Mmc_Fat_Assign()*	Assign file for FAT operations
Mmc_Fat_Delete()	Delete file
Mmc_Fat_Get_File_Date()	Get file date and time
Mmc_Fat_Get_File_Size()	Get file size
Mmc_Fat_Get_Swap_File()	Create a swap file
Mmc_Fat_Init()*	Init card for FAT operations
Mmc_Fat_QuickFormat()	
Mmc_Fat_Read()*	Read data from file
Mmc_Fat_Reset()*	Open file for reading
Mmc_Fat_Rewrite()	Open file for writing
Mmc_Fat_Set_File_Date()	Set file date and time
Mmc_Fat_Write()	Write data to file

* Mmc_FAT16 functions used in program

Other *mikroC for PIC* functions used in program:

Spi_Init_Advanced()	Initialize microcontroller SPI module

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

Example 1: Program to demonstrate operation of *Smart MP3* module

```
char          filename[14] = "sound1.mp3";             // Set File name
unsigned long  i, file_size;
const         BUFFER_SIZE = 512;
char          data_buffer_32[32], BufferLarge[BUFFER_SIZE];
sbit          Mmc_Chip_Select at RC0_bit;
sbit          Mmc_Chip_Select_Direction at TRISC0_bit;
// Writes one byte to MP3 SDI
void SW_SPI_Write(unsigned data_) {
  RD1_bit = 1;                                         // Set BSYNC before sending the first bit
  RD2_bit = 0;  RD3_bit = data_;  RD2_bit = 1;  data_ >>= 1;   // Send data_ LSB, data_.0
  RD2_bit = 0;  RD3_bit = data_;  RD2_bit = 1;  data_ >>= 1;   // Send data_.1
  RD1_bit = 0;                                         // Clear BSYNC after sending the second bit
  RD2_bit = 0;  RD3_bit = data_;  RD2_bit = 1;  data_ >>= 1;   // Send data_.2
  RD2_bit = 0;  RD3_bit = data_;  RD2_bit = 1;  data_ >>= 1;   // Send data_.3
  RD2_bit = 0;  RD3_bit = data_;  RD2_bit = 1;  data_ >>= 1;   // Send data_.4
  RD2_bit = 0;  RD3_bit = data_;  RD2_bit = 1;  data_ >>= 1;   // Send data_.5
  RD2_bit = 0;  RD3_bit = data_;  RD2_bit = 1;  data_ >>= 1;   // Send data_.6
  RD2_bit = 0;  RD3_bit = data_;  RD2_bit = 1;  data_ >>= 1;   // Send data_.7
  RD2_bit = 0;
}
// Writes one word to MP3 SCI
void MP3_SCI_Write(char address, unsigned int data_in) {
  RC1_bit = 0;                        // select MP3 SCI
  SPI1_Write(0x02);                   // send WRITE command
  SPI1_Write(address);
  SPI1_Write(data_in >> 8);           // Send High byte
  SPI1_Write(data_in);                // Send Low byte
  RC1_bit = 1;                        // deselect MP3 SCI
  Delay_us(5);                        // Required, see VS1001k datasheet chapter 5.4.1
}
// Reads words_count words from MP3 SCI
void MP3_SCI_Read(char start_address, char words_count, unsigned int *data_buffer) {
  unsigned int temp;
  RC1_bit = 0;                                  // select MP3 SCI
  SPI1_Write(0x03);                             // send READ command
  SPI1_Write(start_address);
  while (words_count--) {                       // read words_count words byte per byte
  temp = SPI1_Read(0);
  temp <<= 8;
  temp += SPI1_Read(0);
  *(data_buffer++) = temp;
  }
  RC1_bit = 1;                                  // deselect MP3 SCI
  Delay_us(5);                                  // Required, see VS1001k datasheet chapter 5.4.1
}
// Write one byte to MP3 SDI
void MP3_SDI_Write(char data_) {
  while (RD0_bit == 0) ;                        // wait until DREQ becomes 1
  SW_SPI_Write(data_);
}
// Write 32 bytes to MP3 SDI
void MP3_SDI_Write_32(char *data_) {
  char i;
  while (RD0_bit == 0) ;                        // wait until DREQ becomes 1
  for (i=0; i<32; i++) SW_SPI_Write(data_[i]);
}
// Set clock
void Set_Clock(unsigned int clock_khz, char doubler) {
  clock_khz /= 2;                               // calculate value
  if (doubler) clock_khz |= 0x8000;
  MP3_SCI_Write(0x03, clock_khz);               // Write value to CLOCKF register
}
void Init() {
  ADCON1 |= 0x0F;                               // set all AN pins to digital
  RD2_bit = 0;   RD3_bit = 0;                   // Clear SW SPI SCK and SDO
  TRISD2_bit = 0; TRISD3_bit = 0;               // Set SW SPI pin directions
  RC1_bit = 1;                                  // Deselect MP3_CS
  TRISC1_bit = 0;                               // Configure MP3_CS as output
  RC2_bit = 1;                                  // Set MP3_RST pin
  TRISC2_bit = 0;                               // Configure MP3_RST as output
  TRISD0_bit = 1;                               // Configure DREQ as input
  RD1_bit = 0;                                  // Clear BSYNC
  TRISD1_bit = 0;                               // Configure BSYNC as output
}
// Software Reset
void Soft_Reset() {
  MP3_SCI_Write(0x00,0x0204);     // Write to MODE register: set SM_RESET bit and SM_BITORD bit
  Delay_us(2);                                  // Required, see VS1001k datasheet chapter 7.4
  while (RD0_bit == 0) ;                        // wait until DREQ becomes 1
  for (i=0; i<2048; i++) MP3_SDI_Write(0);      // feed 2048 zeros to the MP3 SDI bus:
}
void main() {                                   // main function
  Init();
  SPI1_Init_Advanced(MASTER_OSC_DIV64, DATA_SAMPLE_MIDDLE, CLK_IDLE_LOW, LOW_2_HIGH);
  Spi_Rd_Ptr = SPI1_Read;
  Set_Clock(25000,0);                           // Set clock to 25MHz, do not use clock doubler
  Soft_Reset();                                 // SW Reset
  if (Mmc_Fat_Init() == 0) {
    if (Mmc_Fat_Assign(&filename, 0) ) {        // Assign file "sound1.mp3"
      Mmc_Fat_Reset(&file_size);                // Call Reset before file reading
      while (file_size > BUFFER_SIZE) {         // Send file blocks to MP3 SDI
        for (i=0; i<BUFFER_SIZE; i++)           // Read file block
           Mmc_Fat_Read(BufferLarge + i);
      for (i=0; i<BUFFER_SIZE/32; i++)          // Send file block to mp3 decoder
      MP3_SDI_Write_32(BufferLarge + i*32);
      file_size -= BUFFER_SIZE;                 // Decrease file size
    }
    for (i=0; i<file_size; i++)                 // Send the rest of the file
     Mmc_Fat_Read(BufferLarge + i);
    for (i=0; i<file_size; i++)
     MP3_SDI_Write(BufferLarge[i]);
   }
  }
}
```

Written in compiler mikroC PRO for PIC

OKISEC: MULTIPLAYER ONLINE ROBOHOCKEY

Micael S. Couceiro, Carlos M. Figueiredo, J. Miguel Luz, N. M. Fonseca Ferreira (Portugal)

Here we report briefly on a project for real-time robot hockey played over the Internet, developed at ISEC, the Higher Institute for Engineering of Coimbra.

Each robot player has a height of about 30 cm (10 inch) (including antenna) and a maximum width of 20 cm (7.8 inch). **Figure 1** shows the team players being charged up for the game. The model was designed using AutoCAD (**Figure 2**). The overall weight of the structure is a primary concern to ensure a long battery life. The power source for all electronics and actuators is carried on-board and to comply with competition rules, no external power may be used. The entire robot weighs 1.12 kg (2.5 lbs).

The hockey playing robot has two wheels, each one connected with the help of two gears and a drive belt to a separate servo motor acting as an electric DC motor.

For manoeuvring around on the hockey field, the speed and direction of the motor on each wheel is controlled individually. This setup gives an easy control of the robot's movements and, at the same time, is efficient and easy to implement. The robot has a small turning radius and its top speed is only dependent on the maximum drive power of the motors.

As opposed to other robots built with a static hockey stick, each OKISEC robot has a (remote) controlled stick to allow it to drive the ball in front of it. Actuation is by means of a servo motor so the player can shoot easily.

The hockey field (**Figure 3**) is made of a resistant canvas that can be shaped to an extent thanks to its texture. The field dimensions are 2.40 × 1.38 m (8 × 4.6 ft) with 3 cm (1.2 inch) high sides.

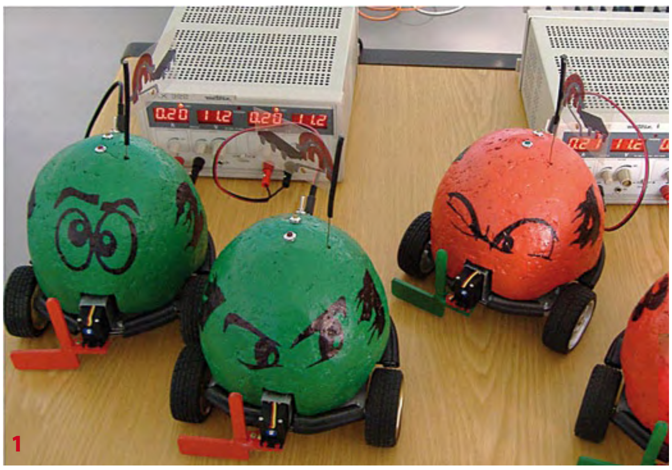
Each robot has three servo motors, one actuating the stick; the other two for motion. The two drive motors have been modified without too much trouble to act as common DC motors.

A clear advantage of the use of a microcontroller is to be able to detect malfunctions easily. Also, allowing for their characteristics, sensors or other actuators are easy to connect up without much work because all the in/out pins of the PIC18F2580 microcontroller are enabled.

The communication circuit receives information from the OKISEC games server through 433 MHz (ISM band) radio control or RS-232 (serial) by flipping a local switch. The control information received 'over the air' does not require any kind of hardware conversion or adaption, the receiver module being directly connected to the PIC.

For the battery, the designers went for a Graupner 9.6 V, 1.5 Ah type; for servos the HS-311 from HITEC was used.

The user interface for online hockey playing was written in Delphi®. The PIC firmware for the robot was coded in C. The user interface is divided



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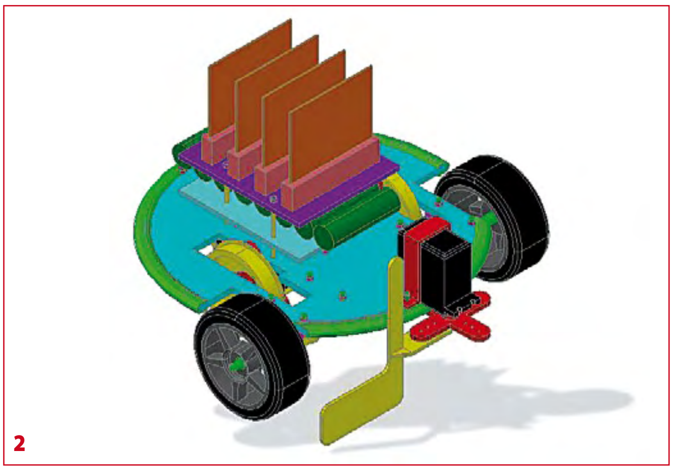


2

3

in client and server software. The client part comprises separate timers for various functions like keyboard or gamepad reading, refreshing of the video frame acquired by the server and sending information over TCP about the robot's movement. The server software comprises an interrupt structure to receive each client's data through TCP, an algorithm to adapt data from all clients, and a timer to send information over radio to all robots.

Two types of video transmission are incorporated. The first was created for the internal LAN to get video frames using HTTP commands, mainly to provide independency of video and data communications. This functionality requires an HTTP server that can be made with Apache®. The other one is optimized for Web communications and based on an ActiveX controller for video transmission. The disadvantage of the latter is that it requires additional software to enable fast video acquisition to be performed by an ActiveX controller.

The additional software used was Active® Webcam that provides utilities and functions for video transmission over Internet for ActiveX controllers, applets and others. The web software can also be used in the internal LAN but the need to have ActiveX plug-ins installed on the central server is reason enough to have one piece of software implemented just for LAN connected players and another for web connected players. The frame rate of the video stream will depend on the remote player's ISP connection and other conditions but can reach up to six frames per second. The webpage was made in HTML, JavaScript and CSS (Cascade Style Sheets).

(080995-I)

Internet Links

Robotic application for multiplayer online game:
www2.isec.pt/~nunomig/internationalconference_files/AEC_nunomig_2008_paper2.pdf

Youtube movie:
www.youtube.com/watch?v=n3ufmoKu36o&feature=channel_page

Authors' websites:
www2.isec.pt/~nunomig/

http://micaelcouceiro.07x.net/

http://carlosfigueiredo.07x.net/

Fully Automated

Process control with PLCs

R.A. Hulsebos (The Netherlands)

Mass production is an important part of our modern society. Every production process involves actions that are repeated innumerable times, and these actions are often controlled by PLCs. What exactly are PLCs, and how are they used?

Programmable logic controllers (PLCs) are the workhorses of industrial automation. Originally developed as software simulations of relay control circuits, PLCs have developed into a platform that forms the basis for control applications generated using structured programming languages (IEC 61131), including high-speed motion, machine vision, networking, and integration with databases and logistics systems.

From an electronics perspective, a PLC is simply a processor with memory, I/O channels (digital, analogue, and/or serial), some counters and logic circuitry, and a network interface. What transforms this into a PLC is the PLC operating system (OS). Using a programming package running on a PC, programmers generate PLC application software to control machines and production lines.

The electronic configuration of a PLC varies from one supplier to the next. A wide variety of processor types can be used for the processing function, such as ARM, X86, NIOS, and so on. Although PLCs are industrial equipment instead of consumer products, there is considerable price pressure, so suppliers devote a lot of attention to cost-efficient development.
Some suppliers take a different approach. They start with a PC, install a PLC OS, add some I/O, and the result is a PLC. This is called a 'software PLC'. The difference between this and a 'real' PLC is that it also has all the capabilities of a normal PC. However, from a hardware perspective a PC is not entirely the same as a 'real' PLC. Some of the specific features are discussed below.

Fast up and running

A PLC must operate all the time, 24/7. If a PLC fails, the result is usually dramatic: production grinds to a halt. In most companies, the maintenance department has only one priority when this happens: getting production up and running again. If power cycling (off/on) doesn't help, the PLC is replaced by a spare unit. It must be possible to install and

connect this unit quickly.
Software installation is often a tricky problem in this situation. It is increasingly common practice for controllers to fetch their software from a central server. However, central servers are not always available, so some suppliers use memory sticks instead. Memory sticks resemble USB sticks, but they are different. An example of a memory stick is the C-Plug (**Figure 1**) for the Siemens S7 family of PLCs. A memory sticks holds all the required software and configuration data, and it can simply be unplugged from the old PLC and plugged into the new one. This technique is also being used more and more often with peripheral equipment.
A problem with Ethernet is that the new controller has a new MAC address, since the Ethernet standard requires every device in the world to have a unique MAC address. This creates difficulties in an industrial environment, because the Ethernet network address depends on the MAC address. In a network environment, this means that the new controller is invisible until the other network devices have been configured to use the new MAC address. Naturally, this is very inconvenient in an industrial environment. For this reason, many suppliers allow customers to configure the controllers with their own MAC addresses. This increases flexibility, but it also creates responsibility: since every MAC address must remain unique worldwide, the old controller must never again be used with its original MAC address.

Figure 1.
A Siemens C-Plug with a capacity of 32 MB. Source: Siemens

No more battery backup

PLCs rarely have hard-disk drives. In the first place, hard disk drives are far too expensive, and the vast majority of their storage capacity would remain unused. The moving parts of hard disk drives also make them too vulnerable, and they are very sensitive to hard shocks and strong vibrations. As a result of rapid technological evolution, hard disks are quickly replaced by newer models with even more capacity.

Most PLCs need only a few megabytes of memory, and until a few years ago many of them used static RAM (SRAM) for this. However, static RAM requires a battery, and batteries have a limited operating life. The situation changed with the advent of flash memory, which is now more or less standard for program code storage. However, it is not always practical for data storage because it does not support write transactions for individual bytes. Ferromagnetic RAM (FRAM) is much more suitable for this purpose.

Watchdog

It's always possible for an application program to hang or the underlying core routines to stop working. In order to prevent the entire system or machine from coming to a halt when this happens, a watchdog is always present. A watchdog is nothing more than a simple timer that resets the processor if it times out, which causes the controller to execute a restart. The watchdog is reset periodically by the application code or a core routine, so it never times out under normal conditions.

Dual processors are used in applications where controller failure is intolerable. One of the processors is the active or 'hot' processor, while the other one is the standby processor. Both processors execute the same code and receive the same input data, but only the hot processor drives the outputs. If the hot processor fails, the standby processor can seamlessly take over control.
Naturally, dual processors cannot eliminate the risk of problems due to software errors. If a controller fails due to a bug in its application software, there's little point in switching to another one, since the other processor has the same software with the same bug. There is only one way to avoid this problem, which is to develop all software redundantly using teams that are not allowed to communicate with each other. The idea here is that the two versions of the software will have completely different designs, so it is unlikely that the same conceptual error, and thus the same bug in the same routine, will be present both versions. This approach is used in the control systems of Airbus aircraft, among other examples.

Windows

The enormous popularity of Windows makes it a natural candidate for use as the internal operating system of controllers. This is entirely hidden from users because the PLC's control application completely conceals the OS. Microsoft provides two products for this purpose: Windows CE6 and Windows XP Embedded (XPe). Windows CE is primarily intended for embedded applications, such as small PLCs. It has a very low licence fee (a few pounds) and can run on all sorts of processors. XP Embedded is more suitable for rel-

Figure 2.
A DiskOnChip flash disk with wear leveling, which can be plugged directly into an IDE connector. Source: Coresolid Storage

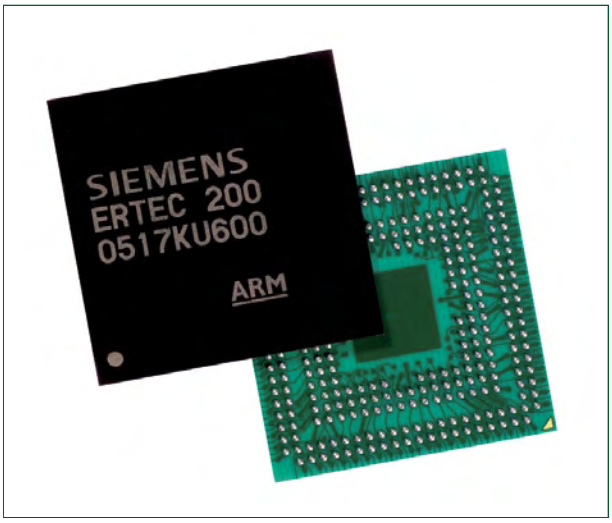


Figure 3. A Siemens ERTEC 200 processor with a built-in ARM processor and two Ethernet interfaces. Source: Siemens

atively large PLCs with networking capability, video, image processing and data handling capability, but it requires a more powerful processor (500 MHz minimum) and more memory (at least 256 MB of RAM), and it is much more expensive (around £100 / $145 per licence). On the other hand, with XPe you can do everything you can do with a normal PC, because XPe is essentially the same as XP Professional. The only difference is that you can choose which parts to leave out, which yields major savings in storage space: an XPe installation can fit into 100 MB. Up until a few years ago, this was ideal for working with flash disks, although their capacity has increased enormously in recent years to the point that a few megabytes more or less are no longer a major issue.

However, flash memory suffers from the limitation of a finite number of write cycles per sector. For example, many flash chips can only be written 1 million times. This is too little for Windows XP, especially in areas of the file system that are written very often, such as folders and the Registry. The NTFS file system is also very active source of write transactions. For this reason, Microsoft has an option for XPe called 'Embedded Write Filter' (EWF), which stores disk transactions in RAM. The disk appears entirely normal to the application software, but all changes are lost when XPe restarts. For many applications, this does not pose a serious problem. In fact, it can be an advantage to always start with a clean slate.

For applications where EWF is too restrictive, flash disks that spread write transactions over the entire disk must be used. This is called 'wear leveling', and it is available from a variety of suppliers. One example is DiskOnModule from Coresolid Storage, which can be fitted directly to an IDE connector (**Figure 2**). Even if an application constantly writes data to a disk of this sort, wear leveling provides an acceptable service life. Windows sees a DiskOnModule as a normal hard disk, and no special driver is necessary.
If you wish, you can experiment with XP Embedded free of charge. All of the software can be downloaded from the Microsoft website, and applications will run for 90 days without a licence.

Copy exactly

Some industries demand 'copy exactly' from their suppliers. This means that a controller that they buy today must be exactly the same as one they bought several years ago. In this way, customers are not repeatedly confronted with new controllers that require the installation of different software or make it necessary to revise drawings, modify connecting cables, rewrite documentation, and so on. There are also companies that put together a production line in one country and then want to copy it in other countries, so that the same product can be made everywhere in the world in the same way.
Naturally, 'copy exactly' places heavy demands on logistics chains. It prevents the use of components with short market lives, which is a frequent phenomenon in the PC world. Industrial PCs also suffer from this phenomenon. If you want to avoid it, you must explicitly look for a PC supplier that can guarantee long-term deliverability. As this is requested relatively often by industrial customers, there are

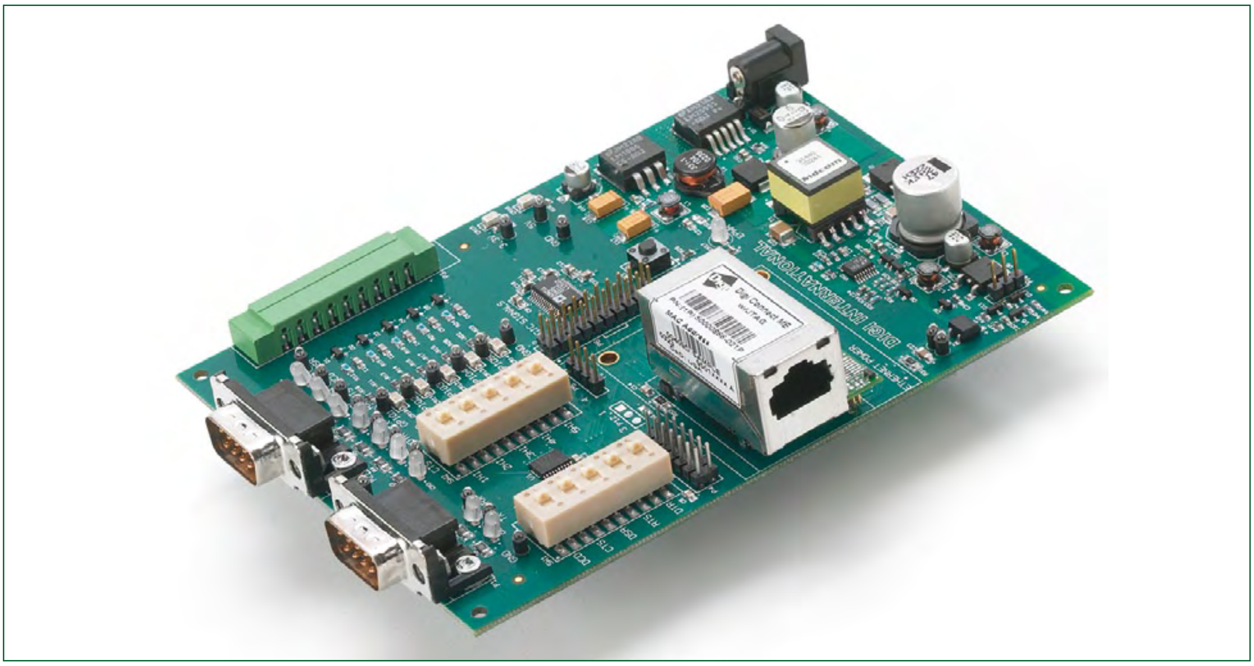


Figure 4. Developer's kit for the Digi/ME controller. The controller is fitted in the middle of the PCB. Source: Digi

in fact suppliers (such as Advantech) that can do so. Intel can also provide long-term delivery guarantees for some processors, including Celeron.
If you want long-term deliverability, you're looking in the wrong place if you constantly focus on the leading edge of industrial PCs. Instead, you should be thinking in terms of a 500-MHz Intel Celeron processor. Although this may sound rather archaic, it isn't. Many industrial applications do not require especially high processing power, and 500 MHz is already more than enough for such applications. Another helpful factor is that industrial IT programmers are often used to working with controllers that have limited resources. This is quite different from the situation in business IT, where nobody thinks twice about another gigahertz or an extra gigabyte.

Networks

A modern PLC is equipped with suitable interfaces, including network interfaces. This naturally includes Ethernet, which makes it very easy to use a PC to download program code and correct bugs in the software. Ethernet can also be used for quick, inexpensive linking to a supervisory control and data acquisition (SCADA) system. Operators can use a SCADA system to run the machine or system, check the current status, enter production orders, collect statistical data, and analyse error messages.

Many PLCs also have an RS232 interface, although this interface is being used less and less often. RS422 and RS485 are also quite common because they can be used over much longer distances (up to 1200 metres). In top-end units, these interfaces always have galvanic isolation with short-circuit protection. This is often missing in inexpensive controllers, or they may only be able to withstand a one-second short circuit. As it is very easy to cause a short circuit, especially with 9-way D-Sub connectors, inexpensive controllers often turn out to be a costly choice. On top of this, you will be faced with a failed controller, and thus possibly a production shutdown. if the short circuit causes the transceiver to fail.

In addition to the RSxxx interfaces, there are all sorts of fieldbus interfaces available. The fieldbus market is highly fragmented, with more than 500 different bus systems. A few of them are very well known, such as Profibus, CANbus and AS Interface, but there are also many systems with only a small market share. As each system has not only its own cabling and connectors but also its own range of products, including I/O modules, motor controllers, dampers, valves, serial interfaces, repeaters (amplifiers) and so on, the market can be regarded as highly fragmented. Consequently, before you buy a PLC you must carefully consider which fieldbus you want to use and whether all of the necessary functionality is actually available for it.

Ethernet

A trend toward using only Ethernet instead of the hundreds of different fieldbus systems has developed in recent years. As certain adjustments are made to make this interface suitable for control applications, it is also referred to as 'industrial Ethernet'.
Two different philosophies can be seen here. Some companies use the TCP/IP protocol as much as possible with standard Ethernet, while other companies want to use Ethernet in high-speed motion control systems to drive as many motors (servos) as possible and run them as fast as possible.
This requires special Ethernet interfaces. The idea here is to execute the entire Ethernet protocol in hardware so that it is very fast and real-time (deterministic).
Siemens supplies an ARM-based ERTEC-400 controller (**Figure 3**) for its ProfiNet protocol, and Beckhoff supplies special ASICs for its Ethernet protocol. This makes it possible to drive Ethernet I/O directly without processor involvement. The author managed to do this at a frequency of 30 kHz using a standard desktop PC. There is ongoing development activity in the Ethernet world, and gigabit industrial Ethernet is expected to be available fairly soon.

USB

Due to the popularity of USB on PCs, this interface is also being used more and more in industrial applications. Much longer distances than the usual 5 metres can be bridged by using USB extenders. This means that keyboards and mice can be located much further away than usual, which makes it considerably easier to install a PC (or an industrial PC) in a system. USB is hardly used for I/O. With its short cable lengths and star topology, it is not a good fit with typical industrial applications. However, it is used in instrumentation systems, such as with Matlab or Labview.

Figure 5.
A Lantronix XPort/AR controller, which is scarcely larger than an RJ45 plug. Source: Lantronix.

No PLC

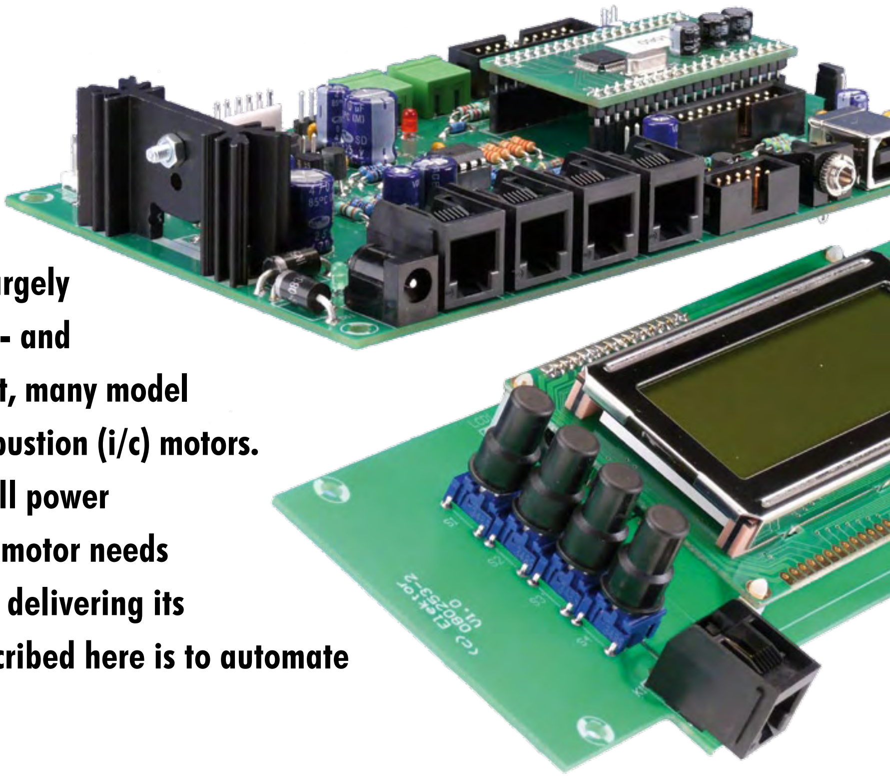
Despite the popularity of PLCs, there are a fair number of automation specialists that prefer not to not use them. Limited memory capacity, the low-level programming languages specified by IEC 61131 (which among other things do not support object-oriented programming), and strict encapsulation in typical application architectures make them unsuitable for use as high-end machine controllers. Instead of PLCs, such applications employ several small embedded controllers linked to an industrial PC by a network. In this arrangement, the non-real-time portions of the application are executed on the PC. Two examples of small embedded controllers are the XPort from Lantronix and the Digi/ME from Digi (**Figures 4** and **5**). Actually, these devices are small only with respect to their dimensions (the size of an RJ45 connector) and their prices (a few dozen pounds); they both have a powerful processor, lots of memory, ample I/O, and networking capabilities. They also come with a (hard) real-time kernel. Program code can be downloaded via the Ethernet interface or the JTAG port.

Automatic Running-in

for internal combustion model motors

Part 1: the hardware

Michel Kuenemann (France)



Even though brushless electric motors have largely replaced internal combustion motors in small- and medium-sized radio-controlled model aircraft, many model enthusiasts are still attached to internal combustion (i/c) motors. But while an electric motor can be used at full power immediately it is brought into service, an i/c motor needs a period of running in before it is capable of delivering its maximum power. The idea of the project described here is to automate this important operation.

Technical specifications

- 32-bit ARM7 processor running at 59 MHz, 128 KB flash memory and 64 KB RAM.
- Throttle control by standard model servo. Configurable travel and direction of movement.
- Microcontroller-driven glow plug heating.
- Motor speed measurement from 0 to over 30,000 rpm.
- Motor temperature measurement from 0–160 °C.
- Ambient temperature measurement
- Mixture adjustment managed by the on-board software.
- Mobile pocket terminal with 4-line / 20 character alphanumeric LCD display, push buttons and encoder knob.
- USB link
- Direct Servo Control (DSC) interface
- Emergency stop push button
- Power supply: 7–15 Vdc.

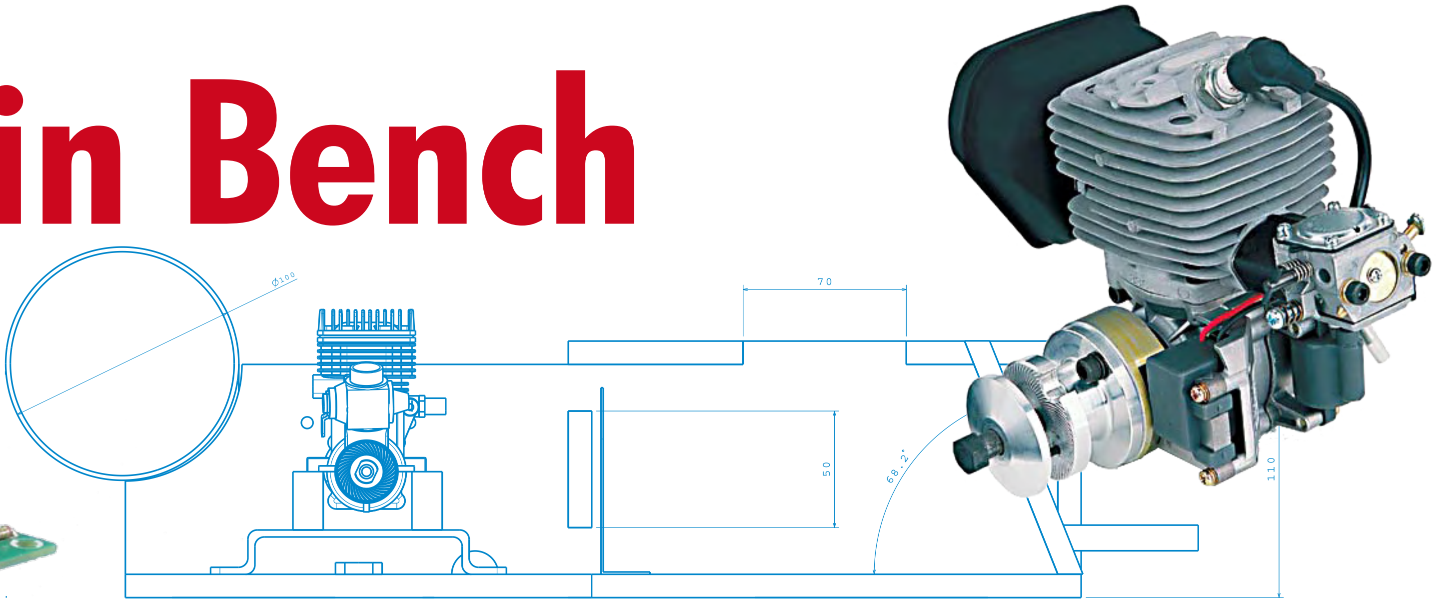
A miniature i/c motor can be run in either in the model it is destined for, or on a test bench dedicated to this purpose.
Running-in consists of running the motor, loaded with a propeller of suitable pitch and diameter, and putting it through controlled cycles of acceleration and deceleration. These alternating high and low speeds cause controlled 'wear' (particularly of the piston and cylinder wall) that enables an accurate fit to be achieved between these components. The way these cycles are achieved depends on the motor specifications, the manufacturer's recommendations, and individual habits. The key parameters to be managed are:

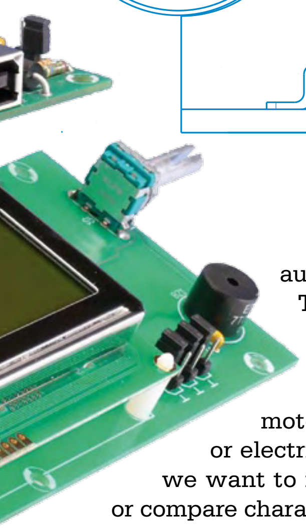
- Motor speed
- Motor temperature
- Richness of the air/fuel mixture

Traditionally, the speed is controlled by using the throttle, often operated by hand when running-in on a test bench. The motor speed is monitored using a hand-held rev counter, or just by ear. The motor temperature is often monitored by 'feel' and the richness of the mixture adjusted by hand. Under these conditions, the running-in operation is performed 100% manually with little objective feedback about how the process is progressing.
The idea of the board described here is to offer automation and repeatability in this phase, by managing the main parameters of the running-in

Figure 1. Running-in bench block diagram.

-in Bench





automatically.

The board also offers extended possibilities for testing and adjusting i/c motors (already run in) or electric motors for which we want to measure, estimate, or compare characteristics like static thrust, the power supplied, fuel curves, or torque and power curves. The board can also be helpful for adjusting the needle-valve level (acceleration).

The software and the functions of this project will be described in detail in Part 2 of our article to be published next month.

Block diagram

The block diagram of the running-in bench is given in **Figure 1.** At the heart of the system is a 32-bit microcontroller board which manages the motor and gathers the 'motor' parameters required for the running-in.

The throttle is operated by way of

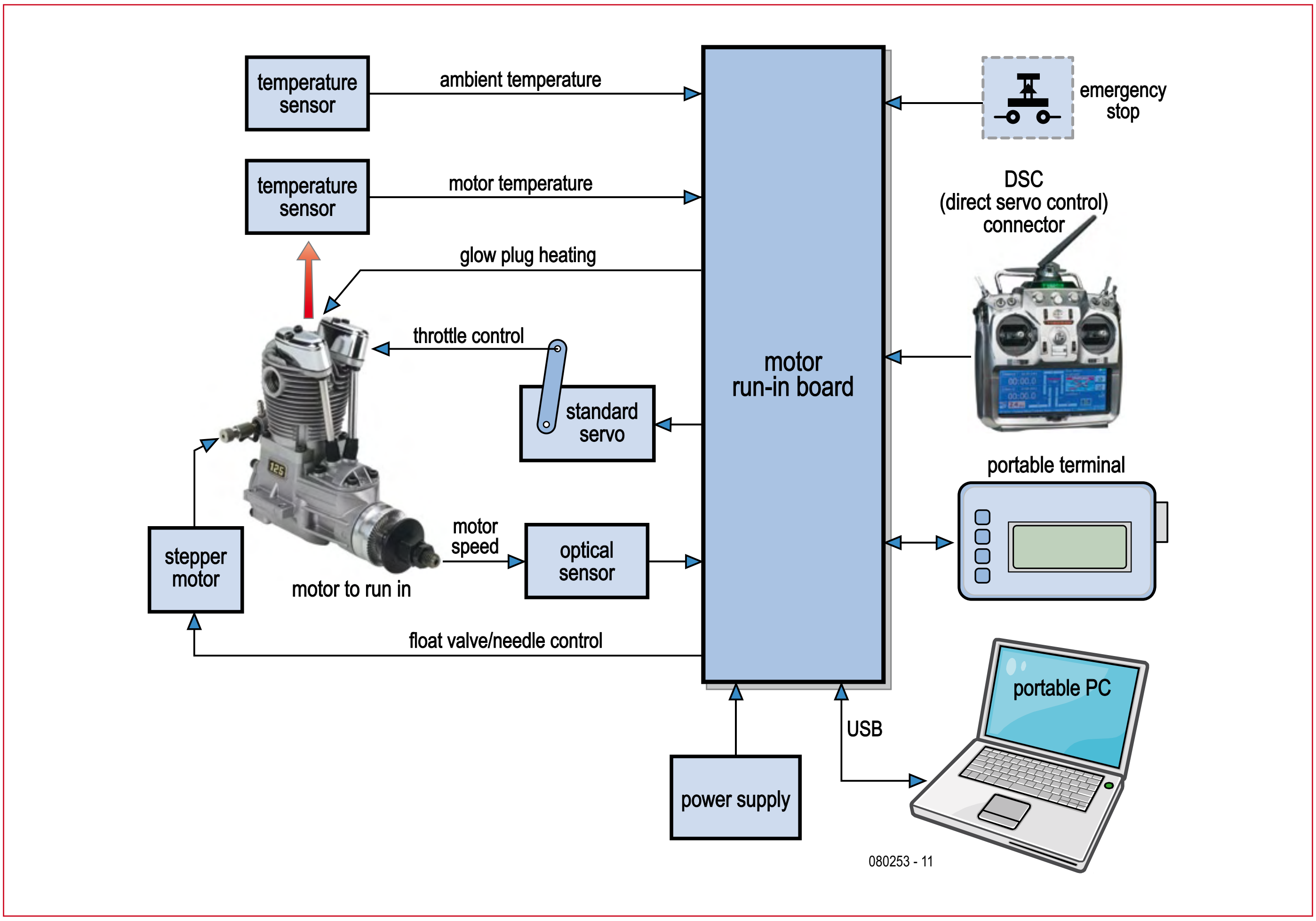


Table 1.
Microcontroller specifications and resources used for the application.

Resource	Specification	Notes
Central unit	ARM7-TDMI, 32-bit central unit.	RISC-type central unit, one instruction per clock pulse.
Clock	60 MHz	Clock frequency used in the application: 58.9824 MHz
RAM	64 kB	
Flash memory	128 kB	
UART0	16C551 compatible	Used for programming and communication with a PC
UART1	16C551 compatible	Available on expansion connector Multiplexed, with PWM generation
SPI		Available on expansion connector
I²C #2	Up to 400 kbps	Available on expansion connector
'bit bang' I²C	Up to 400 kbps	Used for the pocket terminal and temperature detector. Expandable. 3 connectors available.
I/O port		3 ports available on expansion connector

a standard servo. The motor speed reached is measured using an optical detector. The board also manages the heating of the glow-plug and adjusts the mixture needle via a stepper motor. To complete the task, the board monitors the motor and ambient temperatures.

A pocket terminal comprising an LCD display, a coding button, a few pushbuttons and a sounder, to let you control the running-in bench without needing a computer.

The USB link (full speed @ 12 Mbps), obligatory these days, lets you program the board, control it, and read off the recorded data.

The bench has a DSC (Direct Servo Control) interface, which lets you connect a remote-control transmitter and control the servo by means of the throttle control. This is also how you access the functions associated with optimising the fuel curve.

Provision has been made for an 'emergency stop' button in order to stop the motor quickly in the event of an critical problem.

With these facilities; the board lets you control the running-in of all types of 2- or 4-stroke, single- or multi-cylinder i/c motors, running on methanol or petrol, with glow or spark (electronic) ignition.

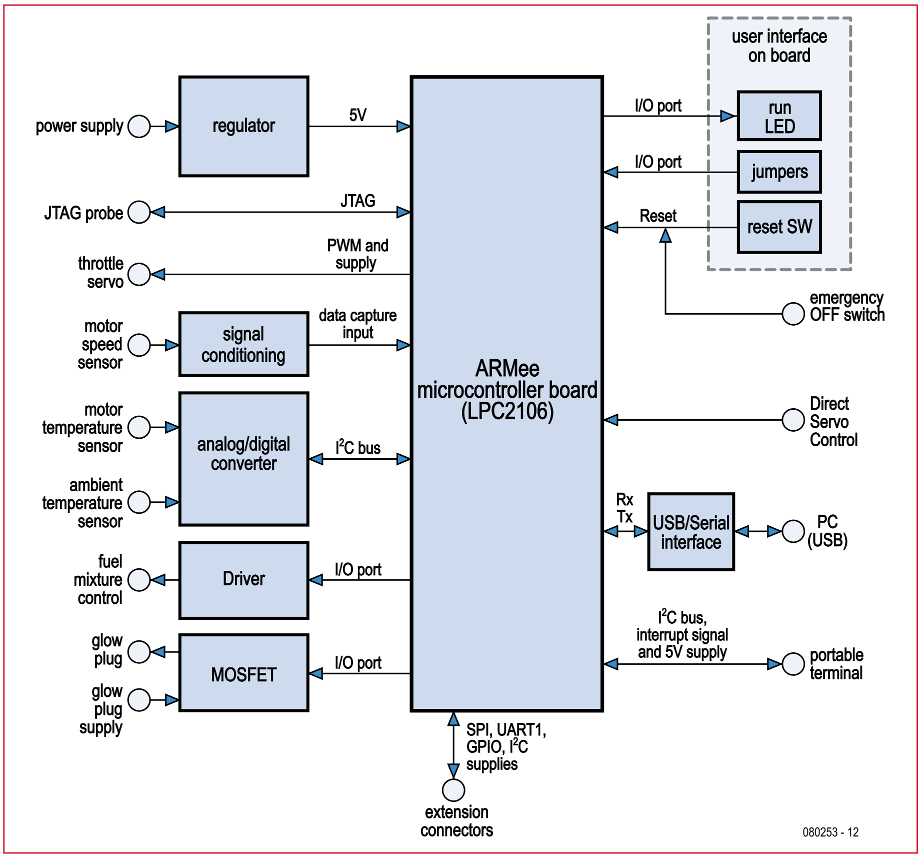


Figure 2. Running-in bench driver board block diagram.

Block diagram of main board

The board, the block diagram for which is given in **Figure 2**, is designed around a microcontroller that may already be familiar to Elektor readers, the LPC2106 from NXP. This 32-bit processor using RISC ARM7 architecture has ideal characteristics for this project (see **Table 1**). Since the LPC2106 is only available in a 0.5 mm (0.02") pitch SMD package, we thought it advisable to use a module that readers will be able to buy 'ready-made', in this case, the *ARMee* board described in our April and May 2005 issues [1][2].

On the left of **Figure 2** we find the 'system' interfaces and the interfaces with the motor to be run in.

The board works correctly with a power supply from 7–15 V. So the board can be powered from a mains adaptor, a car cigar lighter, or a 7-cell NiCd, NiMH or even 2S or 3S lithium polymer battery, which modeling enthusiasts will be familiar with.

The throttle servo is controlled quite conventionally by way of a PWM signal. Naturally, the board supplies the power for the servo, and the connector used is the same type as is found on all radio-control receivers. Hence the throttle control can use any 'standard' off-the-shelf model servo.

The motor speed detector comprises a phototransistor and an LED. The signal from the phototransistor is processed before being fed to one of the microcontroller's data capture inputs.

As the microcontroller doesn't have any analog inputs, it was necessary to make provision for an external analog/digital convertor for inputting the temperature data. A type with an I^{2}C interface was chosen.

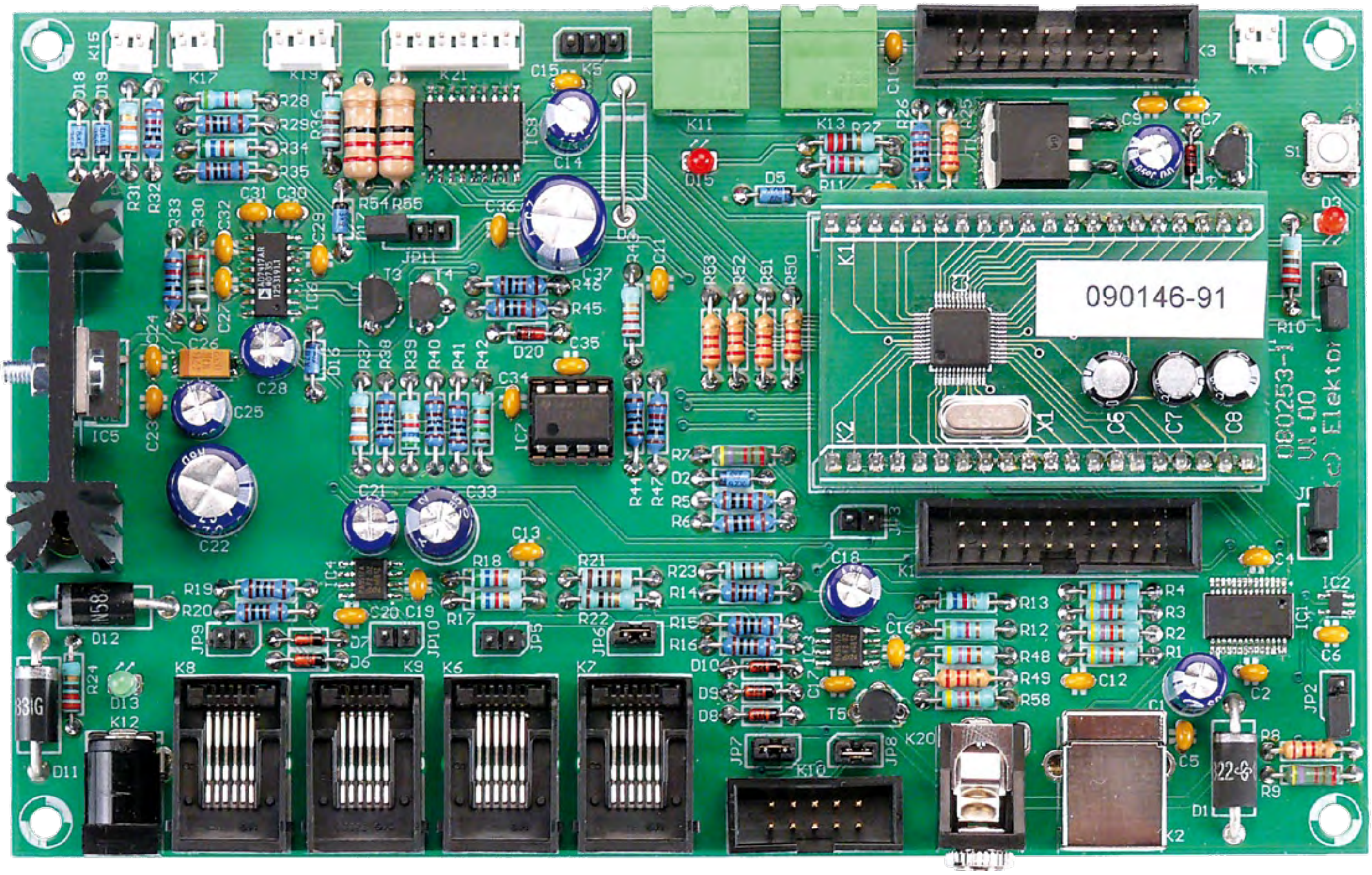
The single-pole stepper motor plus gearbox for adjusting the mixture is governed by an open-collector driver, controlled in turn by four of the microcontroller's I/O port lines.

Circuit diagram of main board

It's only a small step from the block diagram to the 'real' circuit diagram of the controller board (**Figure 3**). The large number of connectors and protection components make the circuit pretty impressive, but it's still relatively easy to pick out the elements of the block diagram. Pride of place right in the middle of the circuit goes to the ARMee module fitted with an LPC2106/01 microcontroller and a 14.7456 MHz crystal. Do note that these components are different from the ones on the board described in 2005 [1][2]. If you want to use the 2005 board, all you have to do is change the original crystal. The ARMee module is powered from 5 V only, as the 1.8 V and 3.3 V rails required by the core and the inputs/outputs respectively are generated on the ARMee board itself. The 3.3 V supplied by the ARMee board is used (sparingly) by certain components on the main board.

A 20-pin expansion connector (K3), unused for the moment, carries all the board's supply voltages (except the 1.8 V for the microcontroller core), all the microcontroller's unused I/O pins (including an SPI bus, a UART, a PWM generation port and two I/O ports) and the #1 I^{2}C bus with interrupt.

The #1 I^{2}C bus is a 'bit bang' type, i.e. the pulse trains required by the I^{2}C protocol are generated in software by the driver. This has the advantage of being able to convert any pair of the microcontroller's ports into an I^{2}C bus.



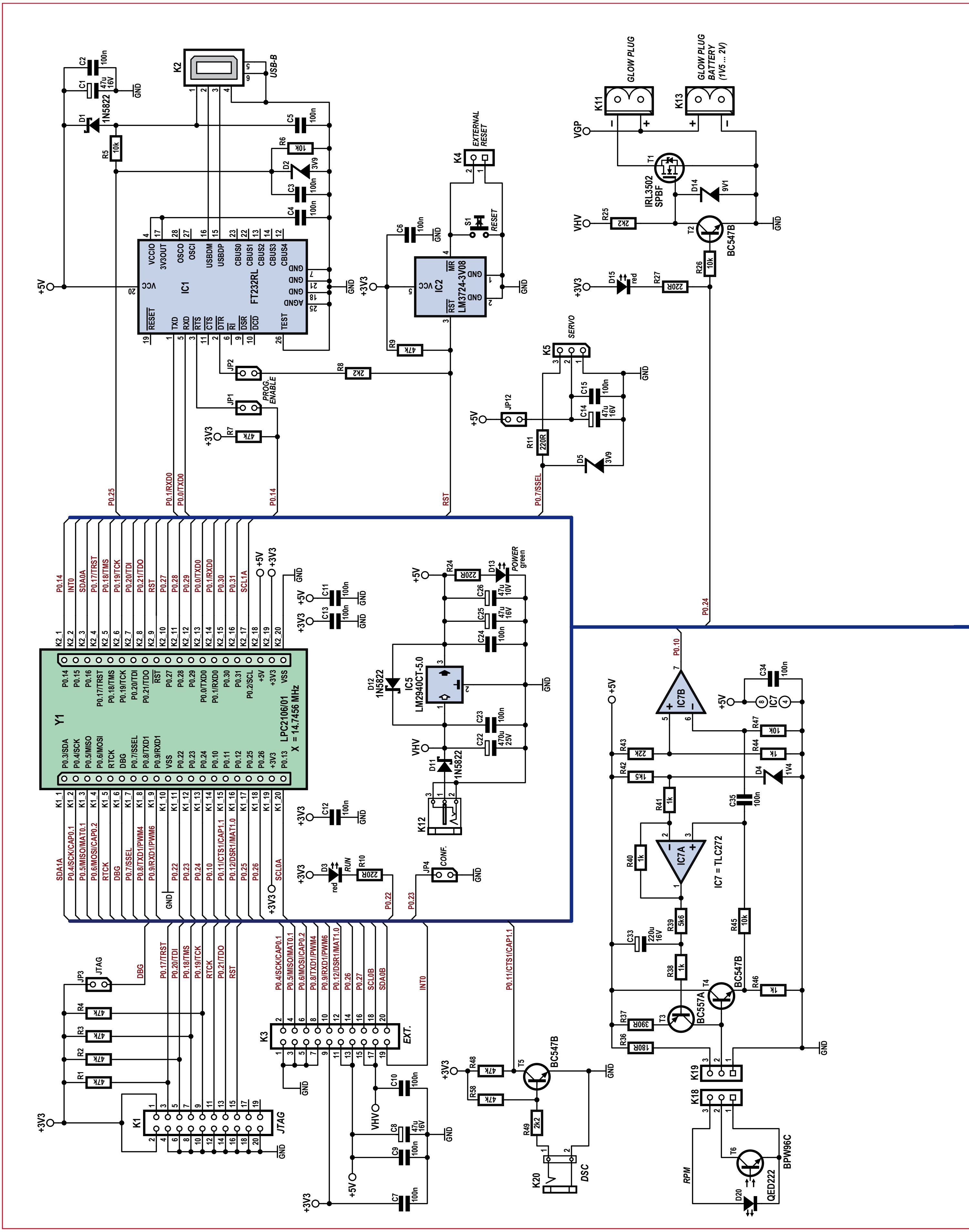
Glow-plug heating is taken care of by a power MOSFET, driven again from one of the microcontroller's I/O port lines.

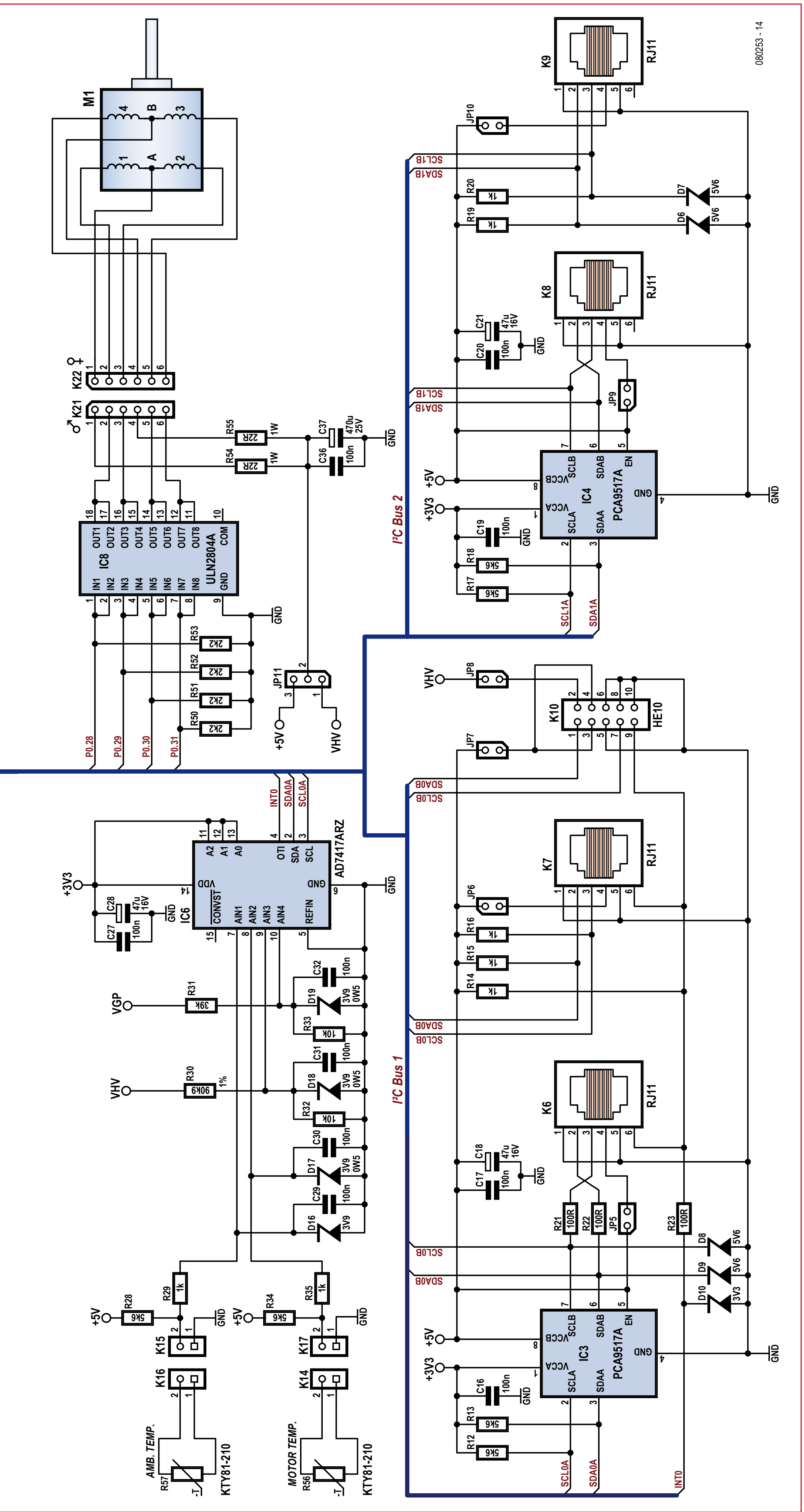
On the right of the board block diagram we find a few LEDs that tell you the status of the board, a few jumpers, a reset button, the USB port and the DSC interface.

A pocket terminal…
…for controlling the board is connected to the main board via a 6-way cable with RJ11 connectors. This cable carries a 400 kbps I^{2}C bus, an interrupt signal, and the power for the terminal (5 V).

However, this type of bus represents a not inconsiderable load on the microcontroller if the bus is used intensively, and even more so if we want to use the bus in slave mode.
To get round these drawbacks, we operate the #1 I^{2}C port in master mode only, and we've added an interrupt signal (INT0) to this bus so as to avoid scanning the push buttons and coder in the pocket terminal. This reduces the transactions on the I^{2}C bus to the strict minimum.

To finish, it may be noted that this interface includes one active device (IC3), a PCA9517A . This device serves three functions:


IC1
FT232RL
IC2
LM3724-3V08
IC5
LM2940CT-5.0
IC7 = TLC272
Y1
LPC2106/01
X = 14.7456 MHz
USB-B
GLOW PLUG
GLOW PLUG BATTERY (1V5 ... 2V)
EXTERNAL RESET
SERVO
PROG ENABLE
JTAG
EXT.
DSC
RPM
IRL3502 SPBF
BC547B
BC557A
BPW96C
QED222
1N5822



- adapting the voltage swing of the microcontroller (3.3 V) to the levels of the external bus (5 V);
- offering a protective barrier against 'onslaughts' from the outside world;
- buffering the signals from the microcontroller, thereby making it possible to get round the 400 pF limit specified for the I²C bus.

A number of 100 Ω series resistors, in association with 5.6 V zener diodes, round off the protection for this bus. The jumpers (JP5–JP8) let you power — or not — the peripherals connected to the three connector K6, K7, and K10.
The pocket terminal can be connected to either K6 or K7, it doesn't matter which.
K10 makes it possible to connect an expansion board using HE-10 connectors, far more practical than RJ11 connectors when the board is hand-wired on 2.54 mm (0.1") 'breadboard'. This connector supplies a 5 V rail, along with the unregulated board supply (via JP8).

The #2 I²C bus is connected to the microcontroller's 'official' I²C peripheral, with master and slave modes, and is capable of a maximum speed of 400 kbps. From a hardware point of view, it is just like the #1 I²C bus, except without the interrupt signal and HE-10 connector. Given the possibilities, this bus offers for expanding the system, we've opted to keep it free and make do with just the #1 I²C bus. Readers may leave out IC4 and its associated components.

The 12 Mbps full-speed USB interface is achieved using a device that may already be familiar to Elektor readers, the FT232RL from FTDI, connected directly to the microcontroller's UART0 interface. Diode D1 allows the board's power to be derived from the USB bus. This is particularly useful during programming or when recovering the data stored on the board when no other power source is available. In 'normal' operation, powering the board from the USB bus is not recommended, as this power source is not powerful enough. Port P0.25 makes it possible to

Figure 3. Circuit diagram of main board.

detect if the USB bus is connected and active. Jumpers JP1 and JP2 work in tandem: if they are fitted, the 'programming' mode is active. In this mode, it is possible to easily and quickly load new software into the microcontroller through the intermediary of the (free) flashing by NXP [3] (see box). Without these jumpers, the USB link operates as a simplified conventional serial link, but with a markedly higher transmission speed (3 Mbps maximum).

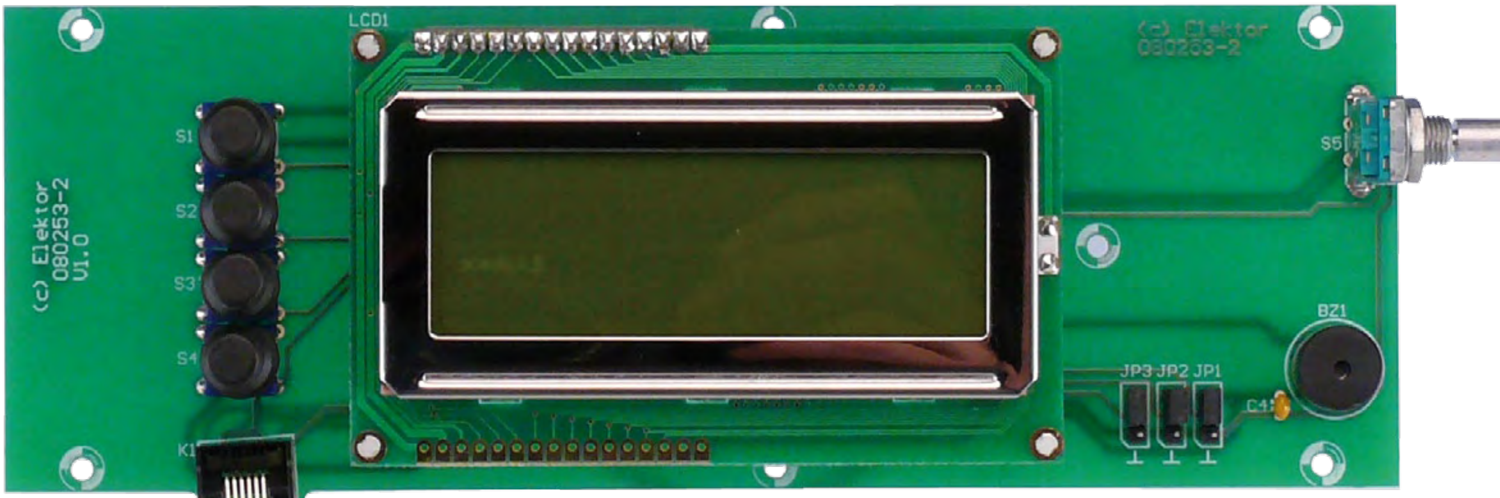
Management of the microcontroller's reset is entrusted to a specialized device, the LM3724 from National Semiconductor. This ensures correct start-up when the board is powered up and allows additional reset push-buttons to be added; a feature that we have made use of, since the board has two reset buttons (one on the board, the other external one connected via K4).

The throttle servo is controlled by the microcontroller's P0.7/SSEL/PWM2 output. R11 and D5 protect this pin in the event of an external voltage being injected onto the control line. The servo is powered from the board's 5 V rail or via a jumper (JP12). This jumper lets you choose not to power the servo socket, so as to avoid an external voltage being injected. This can occur if the user connects an electric motor speed controller with a BEC (Battery Eliminator Circuit) function to this output. In this way, either a servo or a speed controller with BEC can be connected to this output.
Powering of the board is entrusted to a 'low voltage drop' linear regulator. Thus the board works correctly from as little as 7 V, which means the board can be powered from a battery of dual-element lithium polymer accumulators, delivering a nominal voltage of 7.4 V. Diode D11 protects the circuit against possible reverse polarity. The VHV voltage is tapped off at the regulator input and used to power the stepper motor (see below).

The 'motor' and 'external ambient' temperature measurements are made using KTY81-210 linear two-terminal detectors in TO-92 packages. These detectors, whose active element is made of silicon, have the advantage of exhibiting a virtually linear variation in their resistance. Biasing resistors R28 and R34 linearise their values over a huge temperature range. Since the microcontroller doesn't have any analog inputs, it was necessary to resort to an external convertor. The convertor chosen for this task is an AD7417 from Analog Devices (IC6). This convertor, with four 10-bit inputs, and connected to the #1 I²C bus, has an internal 2.5 V reference. The device has an internal temperature detector that provides the device temperature — which is also the prevailing ambient temperature around the board. This convertor is kind enough to return this temperature directly in degrees Celsius, without needing any scaling or calibration. The interrupt line to which the convertor is connected makes it possible to warn of any possible overheating. The remaining two inputs are used to monitor the supply voltages to the board (VHV) and the glow plug (VGP).

The motor speed detector is one of the key elements of the circuit. The signal processing circuit for this detector was designed by Paul Goossens and was the subject of the project 'Rev counter for models' [4]. The optical detector, a phototransistor, works by reflection and should be positioned a few inches from the propeller. The LED built into the detector provides a little local light source. Depending on the ambient lighting, the conduction of this device varies considerably, and it is impossible to detect the movement of the propeller unless the processing stage allows for these variations. To do this, operational amplifier IC7A holds the voltage at the emitter of T4 at an average value of 1.4 V, which sets the phototransistor's operating point and compensates for the variations in ambient lighting. If the voltage at the emitter of T4 falls, the conduction of T3 increases, which causes the voltage on the detector terminals to increase, and hence likewise on the emitter of T4, as it is connected as a follower. The low-pass filter formed by R39 and C33 slows down this control loop to avoid the short pulses associated with the movement of the propeller in front of the detector moving the operating point. These pulses, present at the emitter of T4, are picked off by a high-pass filter C35/R47 which eliminates the 1.4 V DC component and any slow voltage variations. IC7B, wired as a comparator, looks after shaping these analog pulses to make them 'microcontroller-compatible'.

A logic-controlled power MOS transistor has the job of controlling the heating of the glow plug. The transistor gate is biased with the board input voltage in order to take advantage of its 'high' value. However, zener diode D14 prevents this voltage reaching 10 V, the maximum gate voltage. When heating of the glow plug is activated,



a red LED lights to warn the user. The power source for the glow plug can be either a NiMH cell (1.2 V), a lead-acid cell (2 V), or the glow plug heating output of a model 'power panel'.

The Direct Servo Control (DSC) input is particularly simple, as a single NPN transistor is all it takes to interface with the microcontroller. The resistor values in the circuit have been tested using a Graupner MX16s transmitter. If your transmitter is a different type, you may need to adjust some values.

The stepper motor driver output allows you to drive a stepper motor with gearbox with a rated voltage of 5 V or 12 V. The values of resistors R54 and R55 may need adjusting, depending on the motor you're using. If you're not planning to use a stepper motor in your application, these four open-collector outputs can be put to other uses, such as driving lamps, LEDs, DC motors, or relays.

Pocket terminal

The electrical circuit of the pocket terminal (**Figure 4**) is very simple, thanks to the high level of integration in the devices used. The heart of this board is an MCP23017 port expander with I²C bus from Microchip, which provides no fewer than 16 I/Os, ideal for producing a handy user interface.
The 6-way RJ11 input connector provides the MCP23017 with power, the I²C bus, and an interrupt signal. The IC is protected from electrostatic discharge and over-voltage by three zener diodes (D1–D3).

The MCP23017's three address select lines have been connected to the same number of jumpers, which means you can select the terminal's bus address. The alphanumeric display is interfaced in 4-bit mode and it takes up the whole of the MCP23017's port B.

Incremental encoder S5 gives the user the impression of an analog control, arguably much more ergonomic than a pair of +/− buttons when you're driving a servo. The MCP23017 has an 'interrupt-on-change' mode, which means that a change of state on any of its 16 pins generates an interrupt. Hence the incremental coder doesn't have to be scanned: the software will only launch a read cycle on the I²C bus after receiving such an interrupt, which reduces the load on the bus to a strict minimum.

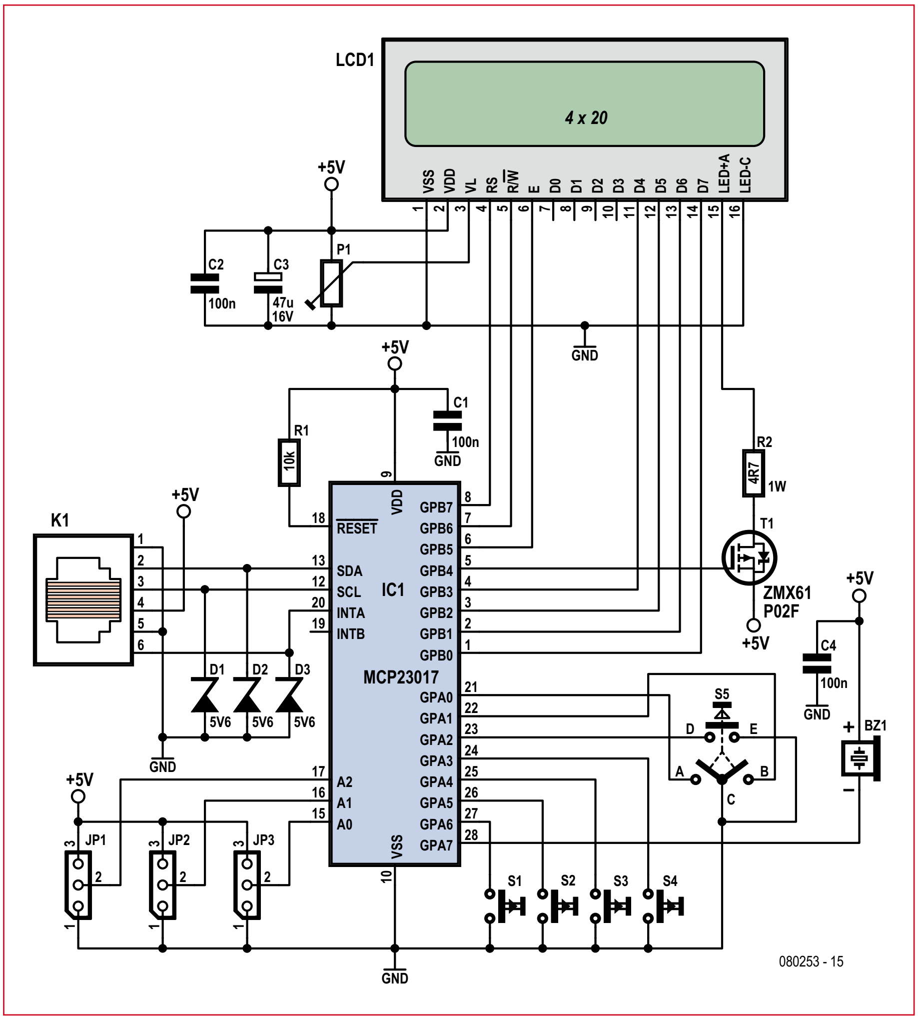


Figure 4. Circuit diagram of pocket terminal.

Pushbuttons S1–S4, along with the pushbutton on S5, employ the same type of event-driven processing. No pull-up resistors are needed, as they are built into the MCP23017.
And lastly, the terminal's sounder is controlled by a P-channel MOS transistor.

Construction

To make building the boards easier, we've chosen traditional through-hole components wherever possible. Start by soldering the SMD devices IC1–IC6, IC8, and T1. Take care not to overheat them, and to remove any shorts between pins using desoldering braid once soldering is finished. Then fit the through-hole components and end with the connectors. Check the orientation carefully for all the polarised components like the ICs, electrolytic and tantalum capacitors, and diodes. The ARMee module is fitted with the help of the board's component overlay.

Building the pocket terminal board is quick and easy and doesn't call for any special remarks. Depending on the type of display you've chosen, it may be necessary to adjust the value of R2 to suit the backlight current for it. At the end of building, fit the three jumpers JP1–JP3 in the '5 check' position.

Testing the boards

Testing takes place in four steps:

- Power up for the first time to check supply rails;
- Fit the ARMee module and flash-in the test firmware;
- Operating test of the main controller board ('CBRM');
- Operating test of the pocket terminal ('GMMI')

Powering up for the first time

Do not connect any peripherals to the board connectors, remove all the jumpers and the ARMee module, then

Firmware flashing procedure

First install the free LPC2000 Flash Utility from NXP [3] on your computer.

Power up the controller board and connect it to the PC via a USB cable. Check that the operating system has correctly recognised the new USB serial port. If the number assigned to the port is higher than COM5, change it.

Start LPC2000 Flash Utility In 'Connected To Port', select the COM port to be used and select a speed of 115,200 baud. Check the 'Use DTR/RTS for Reset and Boot Loader Selection' box.

In the box 'Device:', select the LPC2106 and enter the value 14745 in the 'XTAL Freq. [kHz]:' box.

On the controller board, fit jumpers JP1 and JP2 and remove jumper JP3.

Click the 'Read Device ID' button. The 'Part ID' and 'Boot Loader ID' should get filled in. If not, go back through the procedure step by step – it is vital to get through this stage successfully, otherwise it won't be possible to program the controller.

Use the button alongside the 'Filename' box to select the .hex file to load into the controller. Click the 'Upload to Flash' button and wait for the operation to finish.

Exit the tool to free up the serial port and remove jumpers JP1 and JP2.

All this seems very long-winded, but as the software saves the selected options, flashing is very quick after the first time.

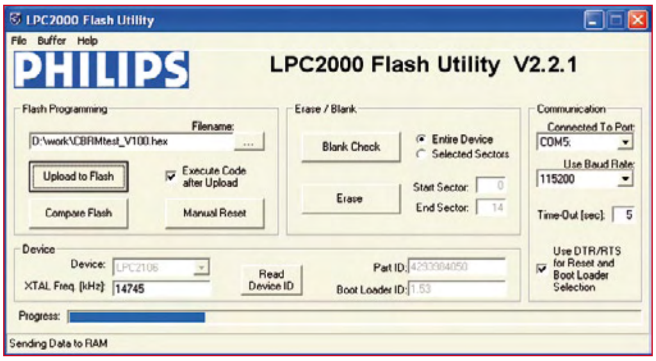


Figure 5. How to configure the LPC2000 Flash Utility programming utility.

JTAG

If you have a JTAG probe, you'll be able to program the microcontroller after connecting your probe to K1 (Keil Ulink compatible connector) and fitting JP3. Don't forget to remove JP3 afterwards. If JP3 is fitted while the JTAG probe is disconnected, the program will work, but ports P0.22 and P0.31 will remain in Embedded Trace Macrocell (ETM) mode and so won't be accessible to the program.

This will mean that the RUN LED, the 'user' jumper, the glow plug drive, USB status reading, and the stepper motor driver won't work.

power the board up from a bench supply set to 8 V / 200 mA. The current consumption should not exceed 70 mA. The green power LED should light, and you should check with a multimeter the value of the 5 V supply to pin 3 of IC5, which must be between 4.9 V and 5.1 V. If all is well at this stage, move on to the next; if not, check once again for solder bridges or reversed components.

Now let's add the ARMee board

The next step is going to consist of powering down the board and fitting the ARMee module, taking care not to get it the wrong way round. Check that it is correctly fitted with a 14.7456 MHz crystal. If not, it is vital to change it before proceeding. Power the board up again and check the presence of the 3.3 V rail on pin 1 of IC3. The current consumption should remain under 70 mA if the microcontroller has never been programmed or while the reset button is pressed. That's the hardest part over!

Now we need to test that all the stages on the board are working correctly and check that the microcontroller is able to communicate with the outside world. To do this, the microcontroller needs to be 'flashed' with the *CBRMtest.hex* software, available by download. Refer to the box for this operation. Once the board has been programmed, unplug the USB cable and check that there are no jumpers fitted. Power the board up again. The current consumption should now settle at around 100 mA. Pressing the reset button causes the current to drop to around 60 mA. The red 'RUN' LED should be flashing regularly. Now disconnect the power.

Testing the main CRBM board

If not already there, install the TeraTerm Pro [5] freeware on your PC. Connect the board to one of the USB ports on your PC. The green power LED should light and the red 'RUN' LED should flash. Run TeraTerm and in the Setup -> Serial port menu, configure the port to which the board is connected as follows:

Opening screen for CBRMtst_v200.hex.

Baud rate: 115200
Data: 8 bits
Parity : none
Stop: 1 bit
Flow control: none

Close the configuration window and press the Escape key on the PC keyboard in order to get the screen in **Figure 6**.

Select the parts to be tested in turn by pressing the corresponding letter on the PC keyboard. The software is self-documented and explains what should be happening with the hardware as each element is tested. An oscilloscope and multimeter are required.

For the time being, don't activate the tests for the GMMI board (pocket terminal).

Testing the pocket terminal (GMMI)

Unplug the USB cable and power the CBRM board up again using the bench supply set to 8 V / 500 mA. Fit jumper JP8 and connect a ribbon cable fitted with 6/6 RJ11 connectors to K7 and the GMMI board. The current consumption should not increase significantly. Adjust the contrast pot P1 until little dark rectangles appear on lines 1 and 3 of the display. Check that the three jumpers JP1–JP3 are in the '5 V' position. Connect the board to the PC again under TeraTerm and now run the tests devoted to the GMMI board and follow the instructions. It will probably be necessary to adjust the contrast and possibly R2 which sets the backlight current.

The rest

You now have a powerful 32-bit ARM7 microcontroller board and a handy data entry terminal. In Part 2 of this article, we'll be looking in detail at how to connect the board to its detector and actuators, together with the application software for this project. In the meantime, good luck with the construction!

(080253-I)

A few words about the author

A graduate from the National Institute of Applied Sciences at Lyon, France, Michel Kuenemann has been an independent electronics consultant for about 20 years. Michel currently works on electrical supply systems for a large transport aircraft and enjoys building much smaller ones in his spare time.

References and Internet Links

[1] LPC210x 'ARMee' Development Board (1), Elektor Electronics March 2005. Online: www.elektor.com/080444-1.

[2] LPC210x 'ARMee' Development Board (2), Elektor Electronics April 2005. Online: www.elektor.com/080444-2.

[3] LPC2000 Flash Utility: www.nxp.com/products/microcontrollers/support/software_download/lpc2000/

[4] Rev counter for R/C Models, Elektor Electronics November 2003. Online: www.elektor.com/024111.

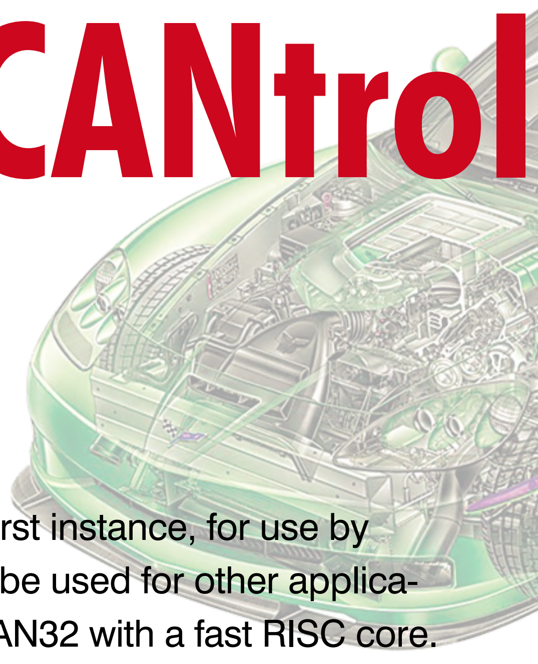
[5] TeraTerm: ttssh2.sourceforge.jp/

[6] www.elektor-usa.com/080253

Note: in view of the length of the components list, this is being offered as a free download from the website for this article [6]. That way, you can download it at the same time as the software you'll need to make the board work.

Automotive CANtrol

Auto electronics exposed



Chris Vossen (Elektor Labs) and Ep Gernaat (Timloto, The Netherlands)

This universal microcontroller board was designed, in the first instance, for use by students studying automotive technologies, but it can also be used for other applications, of course. The heart of this board is an Atmel AT90CAN32 with a fast RISC core.

Technical Specifications

- **Microcontroller: Atmel AT90CAN32**
- **Fast RISC architecture with 133 instructions**
- **Clock speed: 12 MHz**
- **32 KB flash, 2 KB RAM and 1 KB EEPROM available**
- **53 programmable I/O lines**
- **Integrated CAN2.0 controller**
- **8-channel 10-bit A/D converter**
- **SPI interface**
- **JTAG interface**
- **2 USARTs**
- **Two-Wire interface**
- **8 DIP switches and 8 LEDs available for experimental applications**
- **Power supply: 5 V**

Since motor vehicles contain an ever increasing amount of electronics, students learning about motor vehicle technology also need to know more about electronics and microcontrollers. In collaboration with the Timloto o.s. Foundation in the Netherlands, Elektor designed a special controller PCB, which will be used in schools in several countries for teaching students about automotive technologies. Particular attention was paid to issues such as universal design, cost, connection options, expandability and the availability of free development software for various platforms.

Cars and electronics

About 20 years ago, teachers of the subject of motor vehicle technology introduced the topic of microcontrollers into the curriculum of automotive technicians. In those days they used a teaching kit that was based on the Z80, which was appropriately named the Microprofessor.

This kit has been used intensively for at least 10 years, at the higher grades of technician training and teachers united in the TIM working group (TIM = Technical Informatics Motor Vehicles) have made many automotive applications over the years.

However, at some stage a 'real' automotive microcontroller was selected, the Motorola 68HC11, which at that time was frequently used in various automotive computers. The educational programs which were originally developed for the Z80 were ported across and expanded. An engineering consultant developed a 68HC11 controller board based on the specifications from the TIM group. One of the prerequisites was that the already developed Z80 hardware applications could be used again. A textbook was written and the teachers were given further training. Even now the 68HC11 is still used successfully as an educational controller within the context of motor vehicle technology.

The TIM working group evolved into the Timloto o.s. foundation, a working group of teachers which sets itself the purpose of closely monitoring the technical developments in cars and make these available as teaching resources to other teachers and students as soon as possible and at no cost. New times, new opportunities: the Timloto website with open-source licence became a fact. See www.timloto.org.

In the meantime the CAN bus became common and car computers started receiving Flash memory upgrades while the cars were being serviced. Again there was a call for a new(er) controller and this time the editors at Elektor were approached for advice. The choice for the Atmel AT90CAN32 was quite quickly made because of its reasonable purchase price, the many features and the programmability under Windows and Linux (Ubuntu). Thanks to the ingenuity of the Elektor designers all the requirements from the Timloto specifications could be met. The demands were considerable. Because Timloto works together with another automotive teachers initiative (the 'GoforAfrica' foundation) it also had to be possible to use the controller in technical schools in Senegal and Gambia. The computers there run the Ubuntu operating system so that a Linux development environment was an absolute requirement.

Costs also play an important role. The approach was to keep the cost of the controller board as low as possible so that it could be added to

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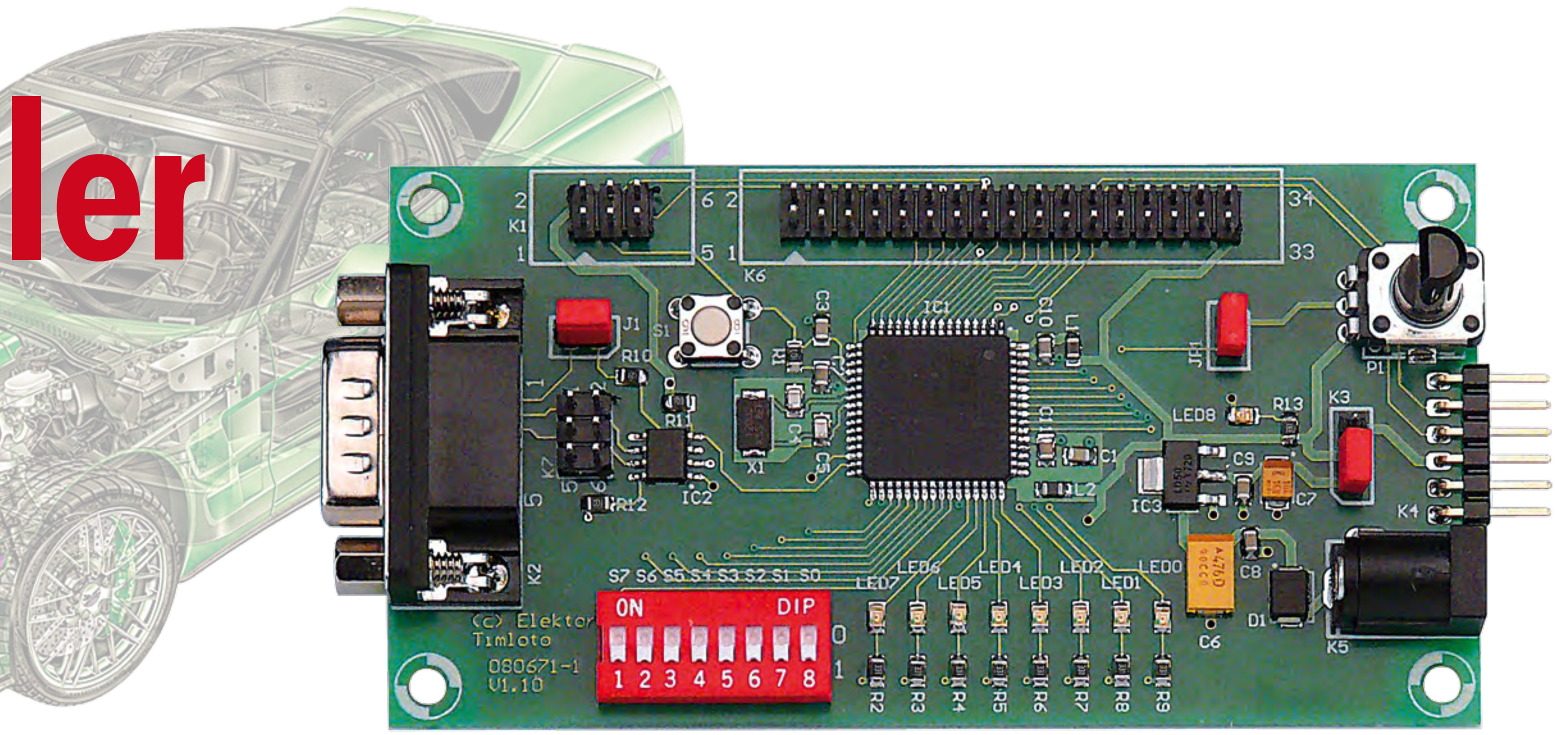


A significant amount of teaching material is already available, which is freely available to anyone via the Timloto website. You can therefore also use this project at home. But the design of this circuit is so universal that it will also be excellent for all kinds of other home, or should we say, garage, projects.

Choice of microcontroller

When searching for a suitable microcontroller we soon arrived at the AT90CAN32 made by Atmel. This controller is packed with many features. It has 32 KB of Flash memory and 2 KB of RAM. An EEPROM of size 1 KB is also available. In addition to a 10-bit A/D-converter with eight channels, the controller also has multiple timers, an SPI interface and two USARTS (one of which is used as the programming interface).

There is also a TWI interface and a CAN2.0 controller. The latter makes this controller eminently suitable for applications in an automotive environment. The core of this controller has a RISC architecture with an instruction set consisting of 133 instructions.

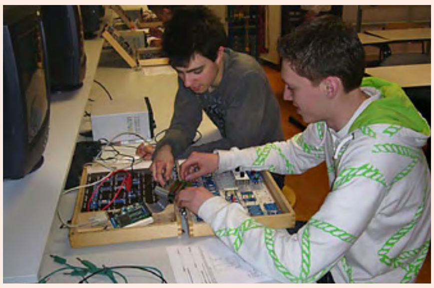
The AT90CAN32 is available in both 64-pin TQFP and QFN packages. For this design we chose the TQFP version. This package type has all the pins accessible around the outside edge of the package, which makes it much easier to solder by hand.

Finally we would like to mention that this controller is completely compatible with its bigger siblings the AT90CAN64 and AT90CAN128. For a detailed description of all its features (such as the TWI) we refer you to the datasheet [1].

the book list of the automotive science students and in this way each student also has the opportunity to practice in his or her own time. The switches in particular were a hurdle initially. Eight toggle switches would increase the price of the design considerably. A clever Elektor solution was found by using a separate expansion board for use in class, which contains the switches. The module is plugged into the expansion board. In this way, during classes at school the robust switches on the expansion board are available.

Using the first Elektor prototypes, members of the Timloto working group could translate the first (educational) 68HC11 programs into AT90CAN32 assembly language. For this purpose, use was made of AVR Studio 4 and gcc-avr, avrdude and kontrollerlab for Linux.

The lesson materials are now organised in a matrix and can be found at www.timloto.org/nl/matrix/matrix_atmel.html



In the Spring and Fall Timloto will organize training courses for automotive technology teachers in Gambia, Senegal and the Netherlands to show them the educational use of the AT90CAN32. Timloto aspires to international cooperation between all (automotive) technical education and would like to see as many people as possible supporting this Elektor-Timloto project. Help is required to translate programs (comments and questions) into English and French. Program ideas and new applications are also very welcome. Consideration can also be made to use the C programming language instead of assembly language.

We would like to appeal to teachers, electronics and information technology experts to cooperate and develop things further, all in the spirit of open-source.

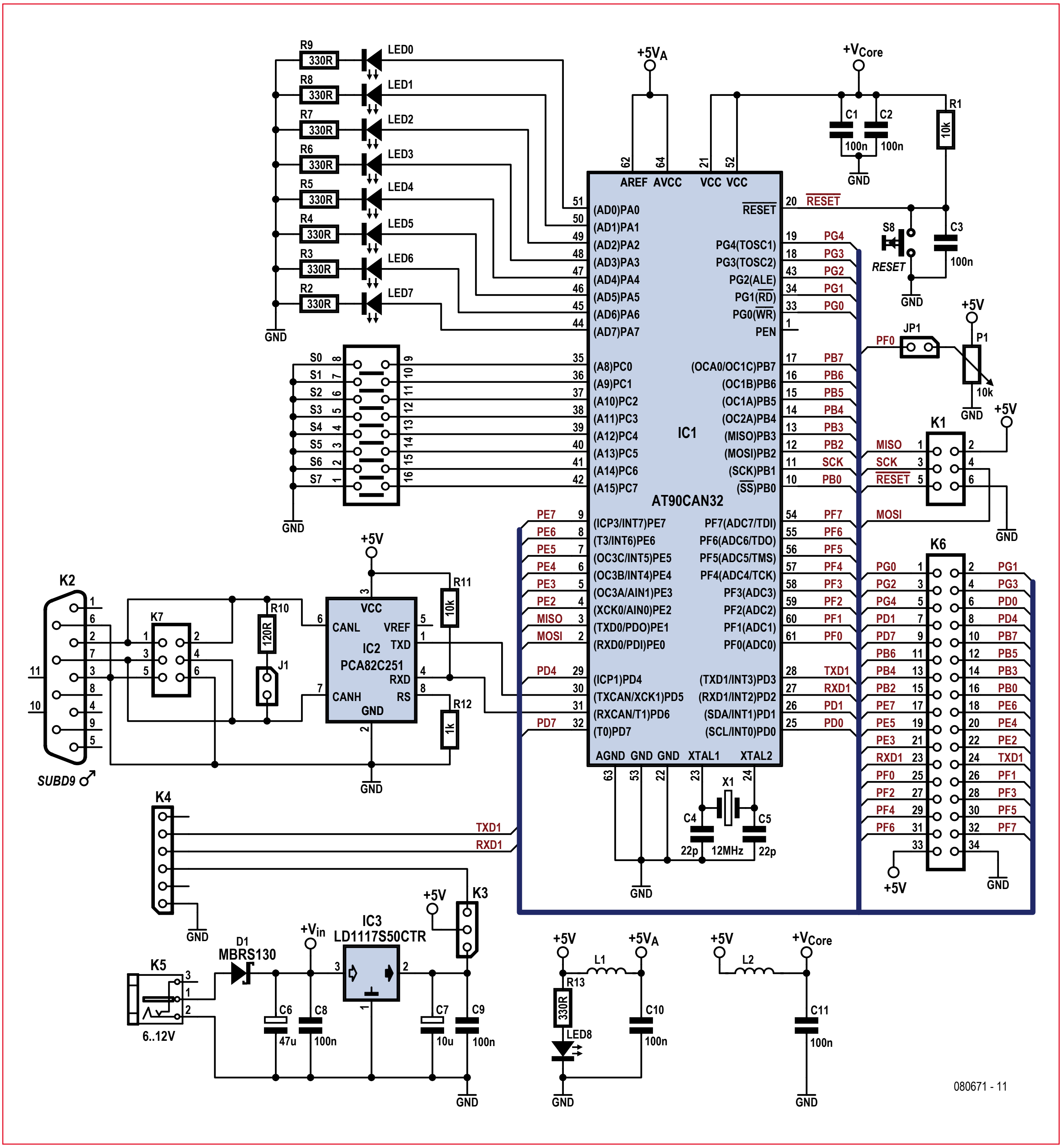


Figure 1. The schematic for automotive CANtroller module.

Schematic

The schematic for this module is a relatively simple design (**Figure 1**). The heart of the circuit is formed by the AT90CAN32 (IC1). The Reset pin is connected to an RC network (R1/C3) which provides a reset when the power supply voltage is turned on. S8 provides the option of manually resetting the circuit. A crystal of 12 MHz is used for generating the clock frequency. To use this crystal the configuration fuses of the microcontroller have to be programmed with the correct settings. Using AVR Studio, the SUT_CKSEL bits can be configured for an external crystal with 8 MHz minimum frequency.

To enable the CAN controller to communicate with a real CAN bus a CAN transceiver is required. This can be found on the schematic in the form of a PCA82C251 (IC2). This IC is quite well known by now and conforms to the ISO11898-24V standard. This transceiver can therefore be used with both

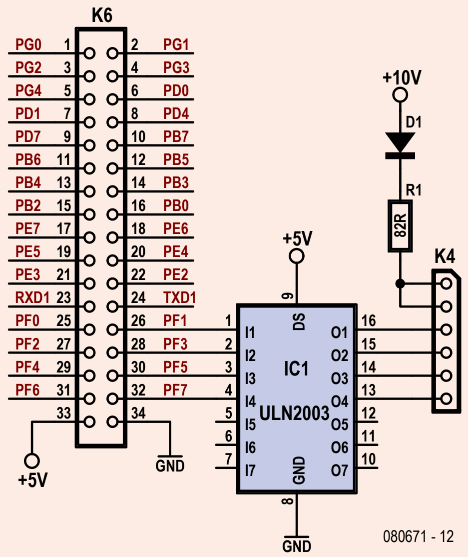
Stepper motor control

The example below shows how a bipolar stepper motor can be connected to the control module. Bipolar stepper motors contain a number of windings which need to be driven according to a certain pattern. In our example this is the following continuously repeating pattern : 0101 1001 1010 0110.

In the initialization routine of this example, Ports A and F are configured as outputs. The stack pointer is initialized before any subroutines are used. Port C is entirely configured as inputs, because this is where the switches are connected. The switches are not used in this example, however.

In the main program the four steps, one at a time, are continuously written to Port F, with a small pause between each one. The stepper motor will rotate as a result. When step 4 is completed the software will begin again with step 1. The controller will repeat this pattern over and over again.

The stepper motor is connected to the microcontroller using the familiar ULN2003A (see schematic). This IC contains a number of Darlington transistors which can deliver sufficient current to get a small stepper motor to turn.



The example program is available as a free download from the Elektor website filed under number 080671-11.zip.

```
/*Program name: TESTPORTF.ASM
Program for de AT90CAN32 Elektor-Timloto board
Port F output
Port A output and drives LEDs
This program uses AVR Studio 4
The program runs from flash memory
*/
```

```
.DEVICE AT90CAN32
.INCLUDE "can32def.inc";definition of ports
                        are in a separate file

   RJMP RESET  ;jump to starting address

/*INITIALISATION*/

RESET:  LDI R16,$FF     ;set all pins of Ports A and
                         F to outputs
   OUT DDRF,R16
   OUT DDRA,R16

   LDI R16,high(RAMEND)
   OUT SPH,R16
   LDI R16,low(RAMEND)
   OUT SPL,R16 ;stack pointer initialization is
                necessary for subroutine

               ;is not yet used here

   LDI R16,$FF         ;activate the pull-up
                        resistors
   OUT PORTC,R16       ;by writing ones the the
                        output port
   LDI R17,$00         ;set all pins of Port C to
                        inputs
   OUT DDRC,R17        ;not really necessary
                        (default value)
   NOP


/* MAIN PROGRAM*/


BEGIN:  LDI R17,0b00100010     ;0101 step 1
   OUT PORTF,R17
   OUT PORTA,R17
   RCALL WAIT1

   LDI R17,0b10000010          ;1001 step 2
   OUT PORTF,R17
   OUT PORTA,R17
   RCALL WAIT1

   LDI R17,0b10001000          ;1010 step 3
   OUT PORTF,R17
   OUT PORTA,R17
   RCALL WAIT1

   LDI R17,0b00101000          ;0110 step 4
   OUT PORTF,R17
   OUT PORTA,R17
   RCALL WAIT1


   RJMP BEGIN

/*DELAY SUBROUTINE*/

WAIT1:  LDI R20,0x0F   ;0F   (01 for debugger)
WAIT:   LDI R18,0xFF   ;0x77  (01 for debugger)
AGAIN:  LDI R19,0xFF   ;0xFF  (01 for debugger)
LOOP:   SUBI R19,0x01
   BRNE LOOP
   SUBI R18,0x01
   BRNE AGAIN
   SUBI R20,0x01
   BRNE WAIT
   RET  ;return to main program
```

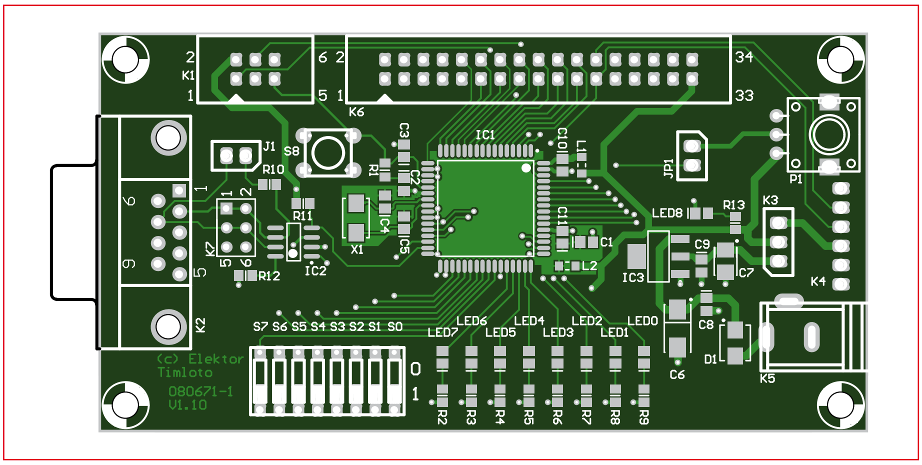
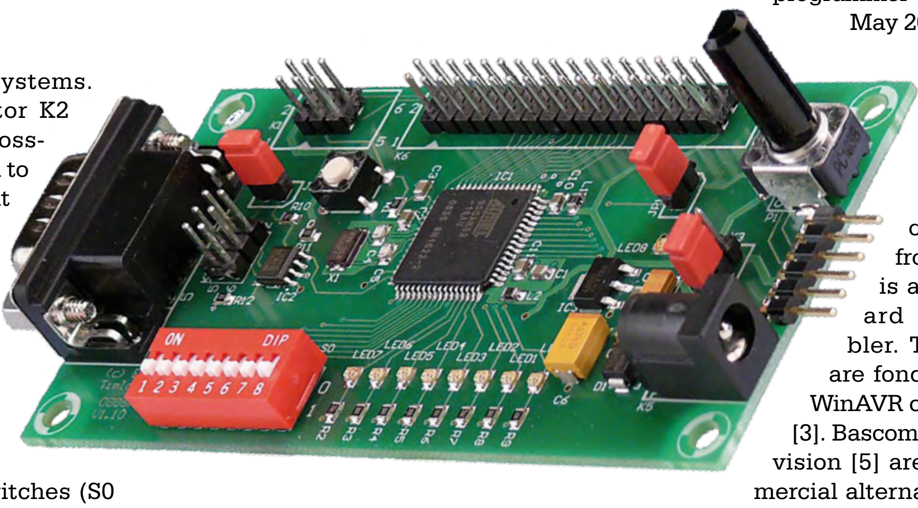


Figure 2. Component layout for the PCB that was designed for this circuit.



12-V as well as 24-V systems. Using sub-D9 connector K2 or pin header K7 it is possible to connect the board to the CAN-bus. The pinout of this connector corresponds with that of the USB-CAN adapter which was published in our October 2008 issue.

Considering the educational character of this project, the board is also provided with eight switches (S0 to S7) and eight LEDs (LED0 to LED7) which can be used when doing programming exercises. There is also a potentiometer (P1) on the board. You can, for example, let the microcontroller read the position of the potentiometer and depending on the measured value turn on a number of LEDs. You need to fit jumper JP1 to connect the potentiometer to the microcontroller.

K4 is the familiar header for the USB-TTL cable which we have used in several earlier Elektor projects (080213-71, see Elektor Shop).

The power supply for the circuit is built around a classic design using a LD1117S50. This is a linear low-drop 5-V regulator which requires very few external components. With K3 you can choose whether the circuit is powered from the USB-connection or from voltage regulator IC3.

The PCB layout for the circuit is shown in **Figure 2**. We won't discuss the details of assembling the PCB. Experienced electronics enthusiasts are certainly capable of assembling this board by hand, but most users would probably order the ready-made board from Elektor instead.

Programming

In order to program the microcontroller you need to have a programmer. You can do this by, for example, connecting the Elektor USB AVRprog to K1. This programmer was featured in the May 2008 issue. This programmer is still available from the Elektor Shop (no. 080083-71).

For the programming software you can use AVR Studio from Atmel [2]. This is available as standard with an assembler. Those of you who are fond of C can use the WinAVR open-source toolset [3]. Bascom AVR [4] and Codevision [5] are a couple of commercial alternatives. These have evaluation versions available that you can download.

The Automotive CANtroller module is available from the Elektor Shop and has the catalog number **080671-91**. All SMD parts are already fitted on the board. Only the through-hole parts and the connectors still need to be soldered.

Finally, a comment about the power supply for the module. As you will have noticed already, this can be powered from either the USB connection or from a mains adapter. Make sure you have the correct setting for the jumper on connector K3.

(080671-I)

COMPONENT LIST

Resistors
R10 = 120 Ω (SMD0805)
R2-R9,R13 = 330 Ω (SMD0805)
R12 = 1kΩ (SMD0805)
R1,R11 = 10kΩ (SMD0805)
P1 = 10kΩ potentiometer (RK09K11310KB)

Capacitors
C1,C2,C3,C8-C11 = 100nF (SMD0805)
C4,C5 = 22pF (SMD0805)
C6 = 47µF 20V (CASE D)
C7 = 10µF 16V (CASE B)

Semiconductors
D1 = MBRS130 (SMB)
IC1 = AT90CAN32-16AU (TQFP-64)
IC2 = PCA82C251/N4 (SO8)
IC3 = LD1117S50CTR (SOT223)
LED1-LED9 = SMD LED (SMD0805)
X1 = 12MHz quartz crystal

Miscellaneous
JP1,JP2 = 2-way SIL pinheader + jumper
K1,K7 = 6-way DIL pinheader
K3 = 3-way SIL pinheader + jumper
K6 = 34-way DIL pinheader
K4 = right angled 6-way SIL pinheader
K5 = DC adapter connector
K2 = right angled 9-way sub-D plug (male), PCB mount
S0-S7= one 8-way DIP switch
S8 = pushbutton
Kit of parts, contains SMD-prestuffed board and all through-hole components. Elektor Shop # **080671-91**.

Internet Links

[1] www.atmel.com/dyn/resources/prod_documents/doc7682.pdf

[2] www.atmel.com/dyn/Products/tools_card.asp?tool_id=2725

[3] http://winavr.sourceforge.net/

[4] www.mcselec.com

[5] www.hpinfotech.ro/html/cvavr.htm

A Supercomputer Dream or Reality?

Franck Bigrat (France)

1105 Teraflops! Behind this strange term there hides a record, one that's been held by Roadrunner, the world's fastest computer, since June 2008. Built by IBM for the US Department of Energy at the National Laboratory in Los Alamos, it beats the previous record of 839 Teraflops held by the NEC SX9 since late 2007. Maybe soon, owning a supercomputer at home will no longer be just a dream. Indeed, inventive solutions enabling a wider public to have access to enormous computing powers do already exist…

Flops! Tera! What on earth…?

FLOPS is the acronym for Floating Point Operation Per Second. Perhaps we'd better just explain that floating-point numbers are used in computing to represent values that are not whole numbers. And Tera is a multiplier corresponding to 10^{12}, i.e. a trillion.
Armed with this information, we can say that Roadrunner [1] (**Figure 1**) is capable of performing a little over a thousand trillion floating-point operations in one second! So the legendary bar of the Petaflops has been crossed (Peta corresponds to 10^{15}).

To give a concrete idea of Roadrunner's speed, let's make a simple comparison: the IBM computer can perform, in one day, calculations that would take 6 billion people (i.e. the entire population of the world) working 24/7 on an ordinary scientific calculator 46 years to perform!

Why Supercomputers?

How can we define a supercomputer? It's a computer designed to achieve very high performance in terms of calculation speed and power. They are used in scientific and engineering applications that require enormous calculating powers.
Simulating the behavior of aircraft structures, determining the shapes and profiles for aircraft wings so as to obtain maximum lift, designing engine turbines, simulating deformations in car bodywork, meteorological forecasting, climate changes, predicting earthquakes, research in biology, particularly on the human genome, simulating nuclear explosions, research into nuclear fusion, or decoding secret codes…

The list of their uses is a long one. Here are two examples of applications in the field of scientific research:

A fierce competition

The current record is held by ***Roadrunner*** [1] with its 20,000 or so processors (12,960 IBM PowerXCell 8i + 6,480 AMD Opteron dual-core, running at 3.2 GHz and 1.8 GHz respectively), but let's just mention a few other recent technological feats that illustrate the competition between the major manufacturers of large-scale computer systems (IBM, Bull, NEC, etc.) to create the fastest supercomputer in the world.

- ***NEC SX9***: based on vector floating-point processors and a memory of 1 TB (Terabytes), it can reach a speed of 839 Teraflops.

- ***Blue Gene L***: held the record in 2005 with a speed of 367 Teraflops. Built by IBM, it comprises 131,072 'Power PC' ASIC processors, 16 TB of RAM and 400 TB of storage capacity.

- ***Tera 10***: Brought into service in 2006 by Bull for the French Commissariat à l'Energie Atomique (Atomic Energy Commission). It is made up of 602 Bull 'NovaScale' servers using 8 Intel Montecito dual-core processors. This represents a total of 8,704 cores enabling a speed of 64 Teraflops. The RAM capacity is 30 TB!

on your Desk –

1. The Blue Brain project, the ambition of which is to model the human brain by simulating the operation of the billions of neurons it comprises using IBM's BLUE GENE L.

2. The Horizon project which allows simulation of galaxy formation, thus making it possible to verify the validity of the models astronomers develop to describe the evolution of the universe.

One of the main motivations for developing these high-performance computers is simply the fact that developing a reliable computer simulation model and using a high-performance computer to run it cost infinitely less than carrying out incredible numbers of tests or scientific experiments in the laboratory.
But above all — and the Horizon and Blue Brain projects are good illustrations of this — they make it possible to simulate phenomena that are difficult, if not utterly impossible, to reproduce in the laboratory. This is often referred to as *'in silico'* testing, just as we speak of testing *in vivo* or *in vitro*.

A games console converted into a supercomputer!

Certain scientists, limited by their budgets and so unable to have access to a supercomputer (one simple simulation may cost several thousand euros), have found a solution that is radical to say the least: putting together their own supercomputer.
A team of researchers under Gaurav Khanna from the University of Massachusetts (USA) carrying out astrophysical research into gravitational waves and black holes have used eight Play Station 3 games consoles connected to a network in order to create a supercomputer at a reasonable cost [2].

Although perhaps an odd choice at first sight, this turns out to be entirely appropriate, since the PS3's CELL processor (**Figure 2**), designed by IBM and Toshiba, is identical to the one used in Roadrunner.

This eight-core processor is capable of amazing feats. Judge for yourself: 200 Gigaflops in single precision (32 bits) and 20 Gigaflops in double precision (64 bits). The computing power obtained by the 'cluster' (we'll explain this term later) of PS3s is equivalent to around 400 computers.
This example shows that it is possible — provided of course you possess the appropriate knowledge in electronics and computing — to put together a supercomputer for yourself; with modest performance, certainly, but adequate for certain applications.

Repurposing graphics processors

A different solution is offered by NVIDIA, well known for its graphics processors. It has announced the marketing of the Tesla (**Figure 3**), a product intended for scientists. Here, a new generation of graphics processors (GPUs), the G80 (better known under the name GeForce 8800 Ultra), made up of 128 cores working in parallel, is repurposed from its original function (generating images), via dedicated software, CUDA, to exploit all its computing power and convert workstations into personal supercomputers. In this way, it is the manufacturer's intention to rival the current supercomputers by offering powerful calculating solutions at 'affordable' cost.

NVIDIA will be offering its products in three forms:

1. The Tesla C870: a PCI Express format card with a GPU using 128 parallel processors, and 1,500 MB of memory, allowing a power of 500 Gigaflops.

- ***Mare Nostrum*** *(see photo)*: Built by IBM for the Barcelona Supercomputing Center. It reaches a speed of 94 Teraflops.
- ***Dawning 5000***: China has entered the field with this computer using 7,680 AMD Opteron quad-core processors running at 1.9 GHz This is the fastest computer running under Windows HPC 2008.

The official list of the 500 fastest computers in the world is maintained by the TOP500 project [9].

Figure 1.
Roadrunner, the fastest computer in the world.

Figure 2.
A CELL processor in a natural setting.

2. The Tesla D870: this external unit houses two C870 cards and is connected to a workstation by way of a PCI Express card. Power: 1,000 Gigaflops.

3. The Tesla S870: this is a server with either four GPUs (i.e. a power of 2,000 Gigaflops) or eight (4,000 Gigaflops), depending on version.
However, the prices — said to be between $1,300 and $12,000 — mean these products are still very much confined to large companies or research laboratories.

Figure 3.
Nvidia's racing model.

Lastly, let's just mention Cray [4] which is coming back onto the scene by marketing the CX1 at a price of $25,000. This is a workstation fitted with 16 Intel Xeon 4-core processors and running under the Windows HPC (High Performance Computing) Server 2008 operating system [5].

The secret of supercomputers' speed: their architecture

Modern supercomputers are based on a parallel architecture that can be regarded as several powerful computers working at the same time, each performing one small part of the final calculation and linked together in a group by a communication network. Network specialists use the term 'cluster' to describe this type of organization. At the end of the line, one computer centralizes the results (**Figure 4**).

This type of architecture has been made possible thanks to increased mastery of microprocessor manufacturing processes, performance improvements, and reducing costs due to massive production. The architecture found in the most recent dual- and four-core processors fitted to the latest generation of PCs is comparable, on a more modest scale.

The communication network needs to have characteristics that match the performance of the system in order to transfer the incredible quantity of data processed quickly and without loss. For example, the Blue Gene L network is made up of 1,024 1 GB/s Ethernet adaptors. In addition, the operating system for these machines obviously needs to be powerful and multi-tasking. This is why supercomputers usually operate with a UNIX operating system, or its general public version Linux [6]; but Windows too is beginning to make a place for itself [5].

Internal structure

The vast majority of supercomputers are based on the following principle (**see Figure 5**):
- Several processors are integrated onto the same chip;
- Several chips are fitted onto one board;
- Several boards are built into the same cabinet.

But the engineers designing these machines found themselves confronted with one problem that is simple enough to solve for an office computer, but takes on gigantic proportions in this type of machine: cooling. Let's look at one concrete example. The TERA 10 supercomputer consumes around 1.8 MW! Since consuming this much power inevitably involves very significant heating of the circuitry, so as not to affect system performance and to avoid malfunctions, the engineers have quite simply added a 2 MW refrigeration unit — so a total consumption of almost 4 MW for a single computer!

Calculation grids and distributed calculation

The growing number of computers being sold around the world, whether they are PC or Mac types, has given the engineers the idea for an original solution to the need to have access to substantial computing power: to get geographically-separated computers to work in tandem, linked together by a super communication network.
This virtual infrastructure is called a 'calculation grid' and

Building your own PS3 cluster

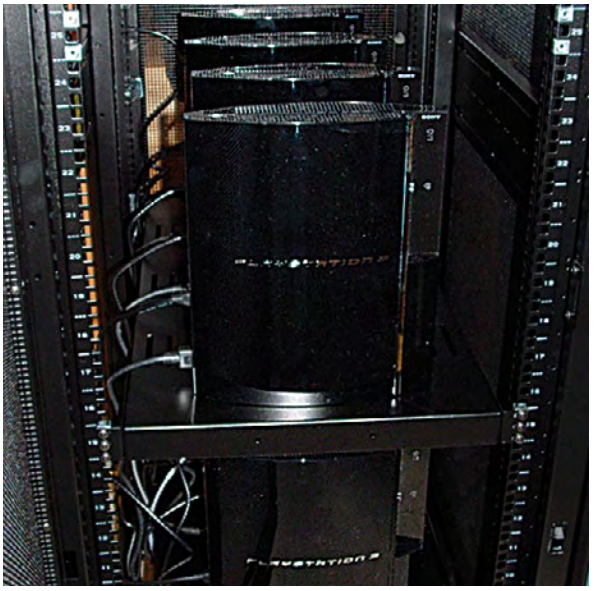
For highly-motivated DIY-ers who want to build their own machine, the ps3cluster website shows the various steps that will let you create a cluster based on the PS3 games console. The software needed is free, so all you have to do is get hold of a few PS3 consoles. Here's a summary of these steps:

1. Download, burn to DVD-ROM, and install the Linux-based 'Fedora' operating system.

2. Install the MPI (Message Passing Interface). This interface makes it possible to run remote computers running parallel programs in distributed-memory systems.

3. Install the CELL SDK (Software Development Kit) which provides the resources needed to develop and compile programs for the CELL processor operating under Linux.

www.ps3cluster.org



FlashMob Supercomputer

A 'flash mob' is the gathering of a group of people in a public place to perform actions agreed in advance, before quickly dispersing. In the case of a flash mob supercomputer, the action agreed upon is to set up a cluster using computers brought along by the participants and measure its speed. In this way, the first flash mob supercomputer was set up in San Francisco in the USA in April 2004. Within a few hours, 150 computers (out of the over 700 computers available) were networked to achieve a sustained speed of 77 Gigaflops. This is still a long way from the performance of real supercomputers, but it did demonstrate the validity of the principle.

The software used is available free from the website of the inventors of this 'game', all you have to do is burn it onto a CD-ROM (230 MB), boot up the computers using it, and connect them onto a network.

www.flashmobcomputing.org

The Beowulf cluster

A Beowulf cluster is a calculation grid made up of cheap PCs. The system was originally developed by Donald Becker at NASA, but is now regularly used around the world in applications requiring a large number of calculations.

The computers usually operate under Linux or other free operating systems. A Beowulf cluster does not involve the use of special software, only the system architecture is defined [source: Wikipedia].

So it is possible to use any hardware platform to create a Beowulf system. One good example of this is the Furbeowulf, a cluster built around Furbies. A Furby is a little moving furry toy, fitted with detectors that enable it to hear sound, feel when you touch it, and see light; what's more, they can communicate between themselves. The Furbeowulf runs under Linux Furby and doesn't really have particularly high performance. Another handicap of this system is the fact that you have to 'feed' the Furbies, regularly, otherwise they fall asleep…

www.trygve.com/furbeowulf.html

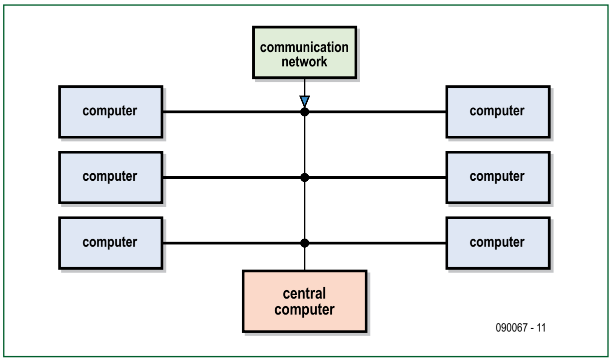


Figure 4. Block diagram of a cluster.

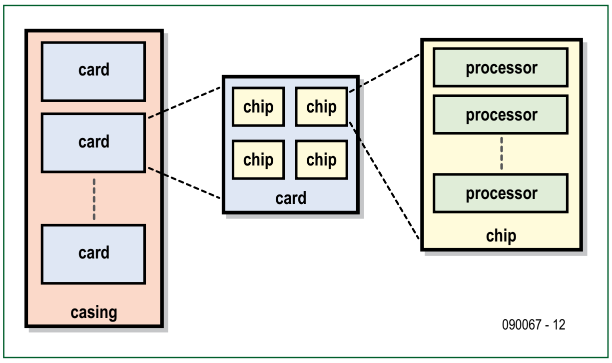


Figure 5. The principle of a supercomputer.

Figure 6. The Jaguar from Cray.

makes distributed calculation possible, where each computer performs one small part of a complex calculation. Via the Internet (the super network in question), 'inter-software' manages the exchanges between the various units, thus giving the appearance of a supercomputer at work. Some very serious scientific programmes are using this resource. Let's mention principally:

- SETI (Search For Extra-Terrestrial Intelligence) [7] which is trying to spot a possible message coming from an extra-terrestrial intelligence within the incredible quantities of radio signals (generated by the stars) coming from space.

- GIMPS (*Great Internet Mersenne Prime Search*) [8] which is researching Mersenne prime numbers: prime numbers equal to a power of 2 minus 1 ($2^x - 1$).

Conclusion

Quite apart from the technological feats that supercomputer represent, the competition between the big companies to design the most powerful computer reflects some important scientific stakes. Scientists around the world are counting a great deal on the capacities of these machines in order to advance their work. For the manufacturers, this competition is a fantastic showcase for their know-how and their skill in designing and producing powerful machines. Although the winner for the moment is IBM with its Roadrunner, a new claimant to the title has entered the race: is the Cray XT5 Jaguar (**Figure 6**, the name chosen by its designers speaks for itself…) going to be able to push the current limit still further?

We'll find out the answer when the new official list of the 500 fastest computers in the world is published in June 2009 [9].

(090067-I)

References, Notes, Internet Links

[1] Roadrunner is the common name of the Greater Roadrunner *(Geococcyx Californianus)*, a species of running bird that lives in the arid regions of North America (Texas, Nevada, Utah, etc.) It was made popular in the character of Beep-Beep, the hero of the cartoons produced by the Warner Bros studios.

[2] www.ps3cluster.org

[3] www.nvidia.fr/page/tesla_computing_solutions.html

[4] www.cray.com

[5] www.microsoft.com/uk/windowsserver2003/ccs/default.mspx

[6] www.linuxhpc.org

[7] setiathome.berkeley.edu

[8] www.mersenne.org

[9] www.top500.org

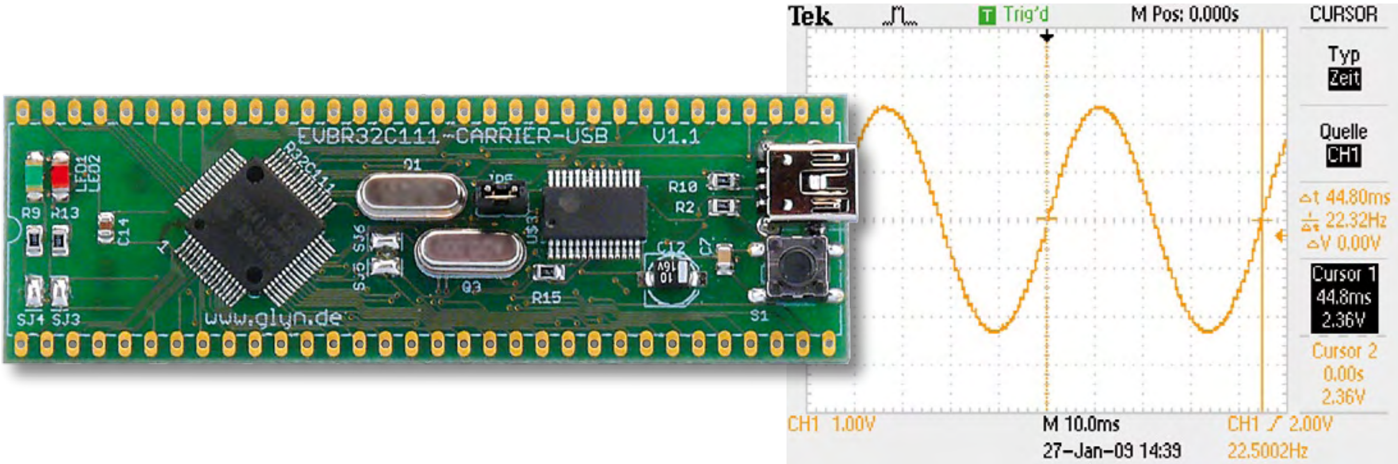
Anton

Instead of using standard hardware to solve a complex problem, it is also possible to adapt the hardware to the problem. This is exactly what's been done at the D.E. Shaw Research lab (New York, USA) in order to produce a specialized computer for molecular dynamics simulations. The system, based on a home-made 8×8×8 3D grid of ASICs christened 'Anton' in honour of the 17th-century scholar Anton van Leeuwenhoek, contains around 100 billion transistors and consumes a mere 100 kW. It seems that a prototype of Anton is operational, but has not yet achieved its maximum performance: it is intended to be up to 200 times faster than a supercomputer working on the same problem.

www.deshawresearch.com

The 32-bit Machine

Program development with the R32C starter kit



Marc Oliver Reinschmidt (Germany)

Having introduced the R32C/111 32-bit microcontroller in our previuous issue, it's time to roll up our sleeves for some practical experiments. A keenly priced starter kit is the basis for our work with this controller. These pages will familiarize you with the tools required for programming and debugging. Those of you already familiar with the R8C/13 from Renesas will recognise plenty of similarity in the way all this is handled.

The starter kit consists of an R32C carrier board (a microcontroller module equipped with the R32C/111 chip) and a software CD-ROM containing the necessary development tools. As with the earlier R8C/13 'Tom Thumb' project in *Elektor Electronics* (November 2005 through March 2006), the R32C carrier board is one of Glyn's in-house developments. Glyn Jones GmbH & Co as the company is officially called is an authorized distributor for Renesas in Germany. With the attractively priced starter kit (available through the Elektor Shop) you get everything you need for your first hands-on experiments with the new 32-bit controller. The power supply is drawn from your computer via the USB connection, which simplifies things rather nicely. **Figure 1** shows the circuit of the R32C carrier board, with the printed circuit board (PCB) in **Figure 2**. Placing the components on the PCB (upper photo) is pretty straightforward.

On the left side are two LEDs (LED1 and LED2 on the circuit diagram). LED1 (green) indicates that power supply is present. LED2 can be made to respond by software, being connected to the port P3_0. Being tied to V_{CC}, this LED can be made to light up when pin P3_0 is switched 'low'. The two LEDs can be uncoupled from these functions if you open the solder bridges SJ3 and SJ4. At the center of the PCB is the R32C/111 positioned by its 64 pins. All connections are taken out to the connector strips along the edges of the board. Once you have soldered in the pin-arrays provided the board can then plug into a standard 64-pin IC socket. The PCB is also equipped with two crystals. The 12 MHz crystal is needed for the USB serial transceiver module from Prolific. This IC (PL-2303X) enables the use of a virtual USB port on the PC for debugging or for simple

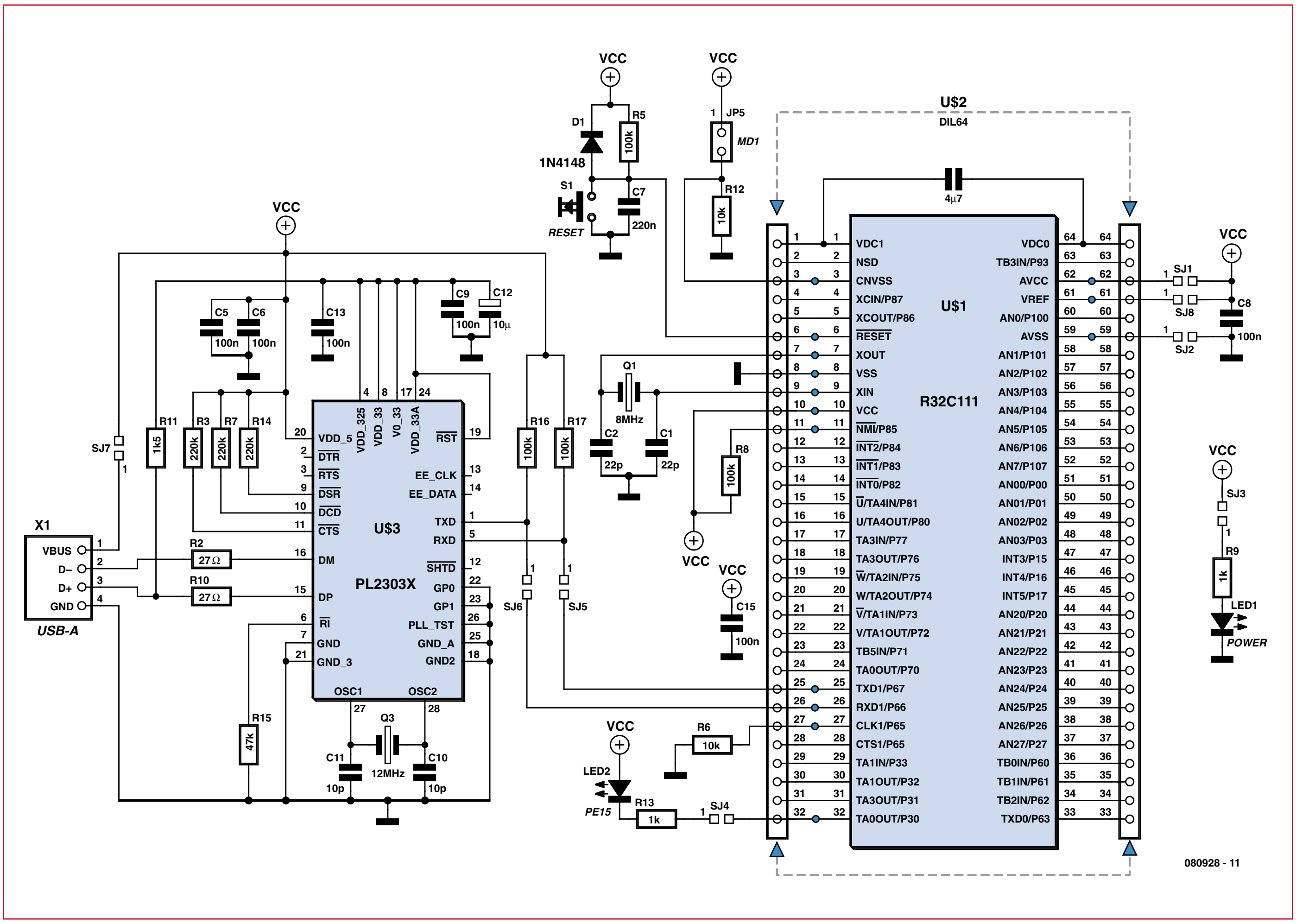


Figure 1. Circuit diagram of the R32C/111 carrier board.

inputs and outputs.

The second crystal is provided for the R32C. In fact an actual crystal is not crucially necessary, given that the R32C contains its own internal 50 MHz oscillator, but for best stability over wide temperature ranges a crystal is inevitably better, particularly for applications where time-critical accuracy is vital.

Right next to the crystals is Jumper JP5, which is used to switch between programming mode and run mode. Like all other Renesas microcontrollers, the R32C is equipped with an internal boot loader, which makes programming via the serial interface possible. This mode is always operational when this jumper is set, meaning that the CNV_{SS} pin is at V_{CC} level and a Reset has been called. When you remove the jumper, the CNV_{SS} pin is taken down to GND via a pull-down resistor. Following a Reset or Power-up the program that has been loaded is executed automatically.

To the right of the jumper is the Prolific IC mentioned, connected to the Mini-USB connector. The push-button directly next to the connector is the Reset switch (S1).

Monitor and debugger

As supplied, the R32C carrier board comes with a monitor program already loaded into flash memory. What does this mean in reality?

Let's take a look at the various methods of getting a project up and running. The more complicated and demanding a project is formed, the more necessary it is for the developer to be able to see what's actually going on inside the system. It's often interesting to see which values the variables have assumed or which registers have been set, which way the program is going following a polling request or branching — or simply where everything is hiding out.

If we were to burn our program straight into the chip, we would have very little access to these parameters, for which reason we use a so-called

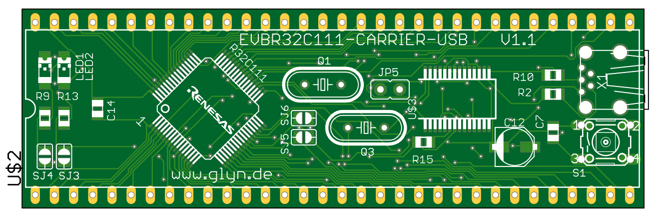


Figure 2. Component placement and track layout of the PCB.

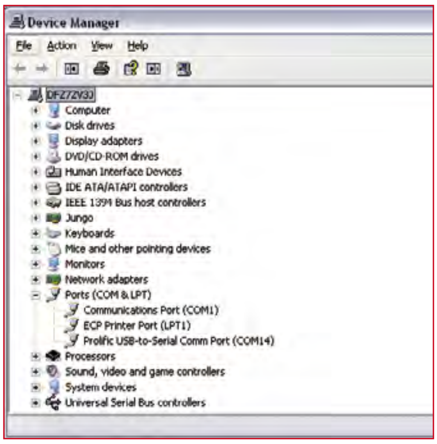


Figure 3. The Windows control panel reveals the number of the virtual COM port.

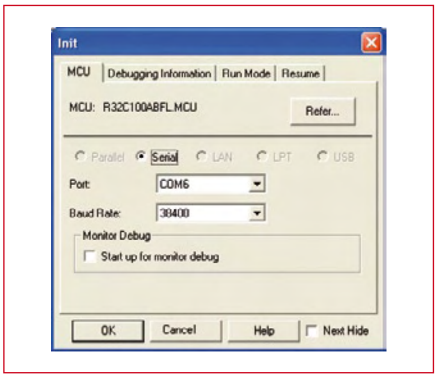


Figure 4. Setting the COM port and the baud rate in the KD100's initialisation window.

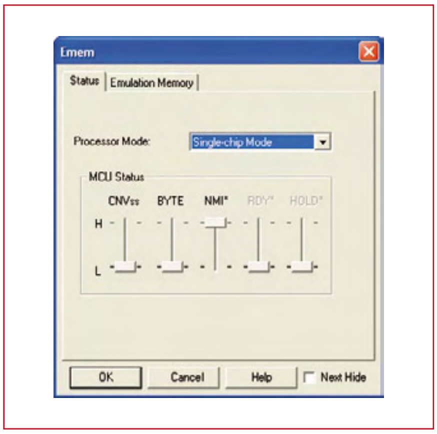


Figure 5. This window indicates that the debugger is linked to the carrier board.

debugger (debugging software). There are a number of approaches, according to the budget available. Here we shall look at the simplest solutions: the E8a Debugger, a low-cost hardware tool (see **inset**), and the software solution using a monitor program and KD100 software.

Since it is provided on the CD in the starter kit, the KD100 software debugger from Renesas is worth close inspection. Fans of the R8C13 should pay attention here. In its time the R8C13 used the old KD30 debugger, which bears a strong visual resemblance to the KD100. Skill sets built up with the KD30 can be re-used with the KD100. In contrast to hardware debuggers, the KD100 requires a monitor program to be loaded separately into the controller. This monitor program takes over the complete debug function and, as with the R8C/13, controls data exchange via the serial interface. The application itself then runs as a kind of sub-program of the monitor. At this point we should explain that we have resorted to using some 'special' programming techniques to deal with the vector tables.

The reason is this. Operating the KD100 means that two programs are running in parallel within the controller: the monitor and also our application program. Both programs operate with vector tables, which are necessary for executing the interrupts. As a rule these tables exist only once, but not in our situation. We therefore need to shift or displace the vector table of our application program so that after each interrupt, the microcontroller can access either the vector table of the monitor or that of the application program.

The debugger requires the interrupt of the UART1, to make debugging possible at all. As a result this interface is unfortunately unavailable for other uses. We shall put up with this sacrifice and turn our attention to the other UART interfaces. The only way we can make all of our UARTs available without restriction is if we flash our application program directly and do without any debugging.

The E8a debugger

The E8a is a hardware tool for all microcontrollers of the M16 family from Renesas (R8C, M16C, and R32C), with which you can both flash and debug microcontrollers. The E8a is hooked up to a PC using the USB link plus a 14-conductor flat cable connected to the application. The 14-way connector provides the interface to your hardware. Apart from a few resistors no other components are needed. For applications that do not require much current the E8a can supply up to 300 mA via the USB port. The voltage can be set at your choice of 5 V, 3.3 V or 1.8 V.

The E8a's debugging software is integrated in the Renesas development environment HEW, meaning that throughout production of a project only one development environment is used. This makes operation extremely simple and fast to learn.

Key characteristics:

- Usable across a broad voltage range from 1.8 to 5 V.
- Debugging with HEW.
- Ideal programming tool with the gratis Flash Development Toolkit.
- Hardware and software break points.
- Software tracing available.
- Compact, cost-effective and convenient.
- Usable also for on a production basis.

First signs of life

That's enough of theory for now. Let's hook up the board to the PC the simple way, using the USB connection. The Prolific transceiver announces its presence with the Windows message 'New Hardware Found' and once we have loaded the driver from the CD supplied, Windows provides a virtual COM port. At this stage it is important to note which number is assigned to the port. The simplest way of checking this is to look in Windows Control Panel under the heading Hardware (**Figure 3**). This done, we can now launch KD100 (assuming you have already installed this on the PC). In the initialization window (**Figure 4**) we select the COM port and the baud rate. Under MCU you can select the corresponding microcontroller family.

Now we should check once again whether jumper JP5 on the carrier

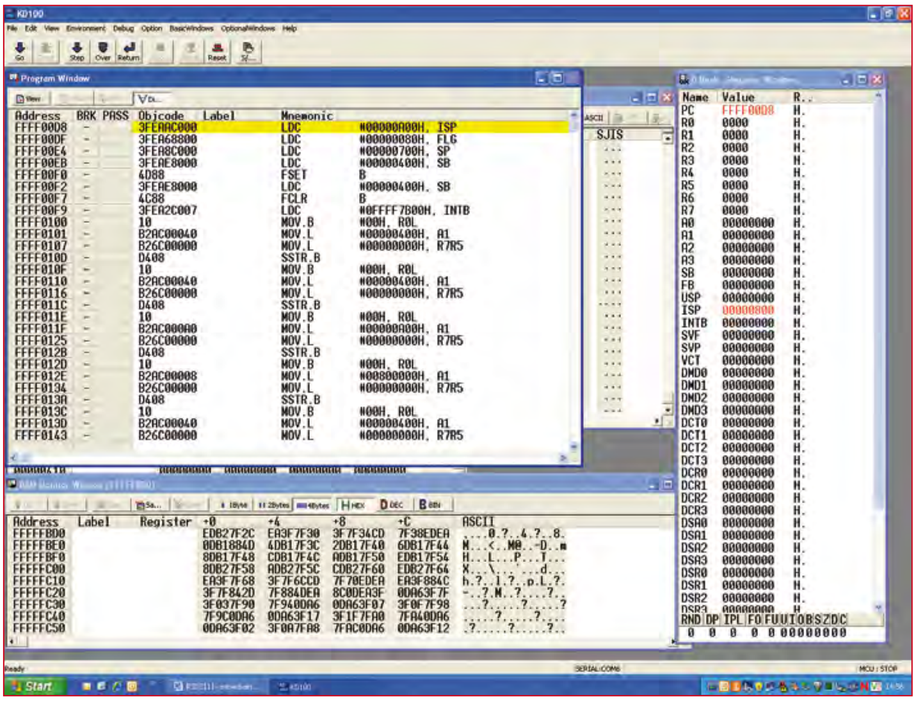


Figure 6. The KD100 on the screen. The monitor file is loaded and the controller is ready to respond.

board is open-circuit and press enthusiastically on the reset button. Following a click on 'OK', the debugger now links up to the carrier board. We can confirm this is happening in the following window (**Figure 5**), in which the debug parameters remain to be defined and the microcontroller unit status can be read.

After a further click on OK the KD100 signs on (**Figure 6**). This confirms that the controller is functioning properly and can be activated, also that the monitor file can now be loaded.

Only one further program needs to be loaded and tested for now. For speed and simplicity we will use a ready-made sample project for taking our first steps with KD100. We can experiment with a project of our own afterwards.

All necessary files are provided on the starter kit CD. For debugging we need to load a debug file into the controller. With the KD100 the protocol is File -> Download -> Load Module, at which stage we look for the file X30 in the Debug folder of the Workspace Project and load it using the KD100.

The tension mounts as the code is loading and when this is complete, the yellow cursor halts at the address FFFF00D8h (see **Figure 7**). And when you click on the control panel Go (upper left), the red LED on the board starts to flash — the program works!

SineWave

Now it's time to write a program of our own. Our mission is to use the R32C as a simple sine wave generator — which is why we have named our first application program 'SineWave'.

All necessary resources are integrated in the Renesas development environment known as the High-performance Embedded Workshop or HEW for short. The HEW is a top level element, a so-called front end combining project management, Editor, Compiler, Assembler and Debugger. The benefits are clear: there's only one top-level element to come to terms with — and this does not take very long really.

If you have installed HEW from the CD and launched it by hitting Start -> Program -> Renesas -> High-performance Embedded Workshop, you are offered the choice of opening an existing project or else creating a new one.

We'll opt for starting a new project. Using the 'Create new workspace' command we will shape this project for the R32C (**Figure 8**). A quiet word in your ear (sirrah): even in this era of modern operating systems it still makes sense to avoid the use of special symbols and long path names. These can confuse the compiler on occasion, making the hunt for errors afterwards extremely slow and tedious.

In the next step you need to select the precise type of microcontroller accurately. Here this is the R32C/100 and the Group is 118. This includes the R32C/111. The other parameters on the following pages can be re-used without alteration.

Now comes the programming of the simple sine wave generator, for which the D/A converter included with the R32C is extremely handy.

The D/A converter employs a simple 8-bit R-2R network (**Figure 9**), in which

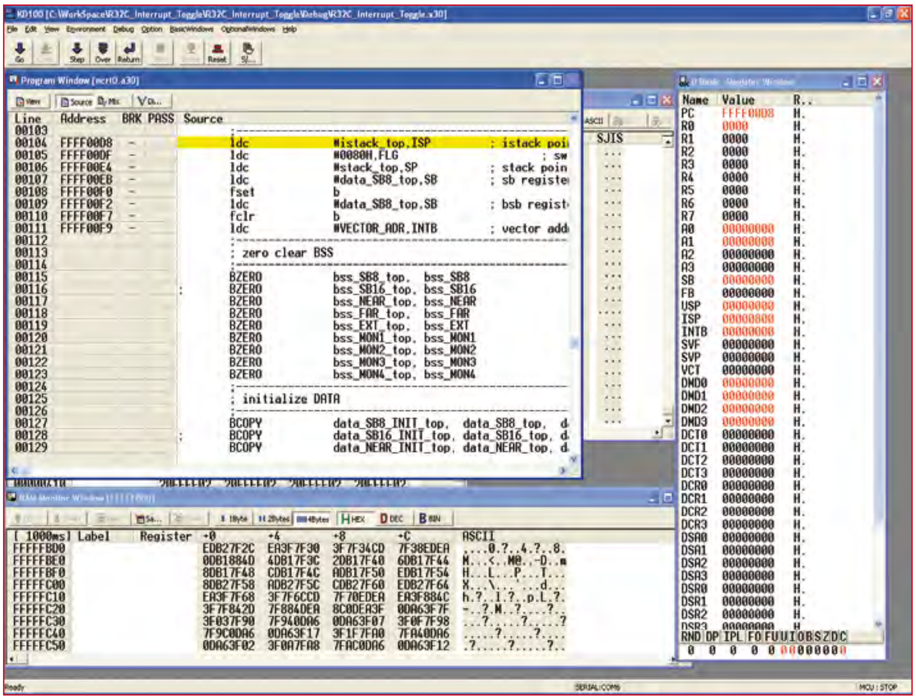


Figure 7. A click now on Go — and the red LED on the R32C board flashes!

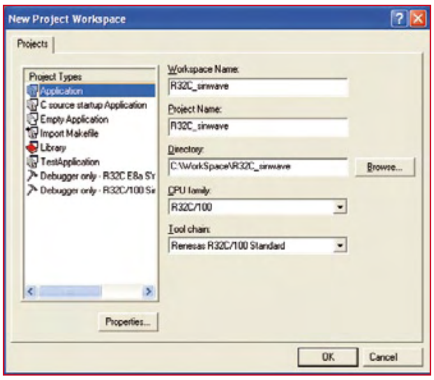


Figure 8. Workspace set-up for the sinewave generator project.

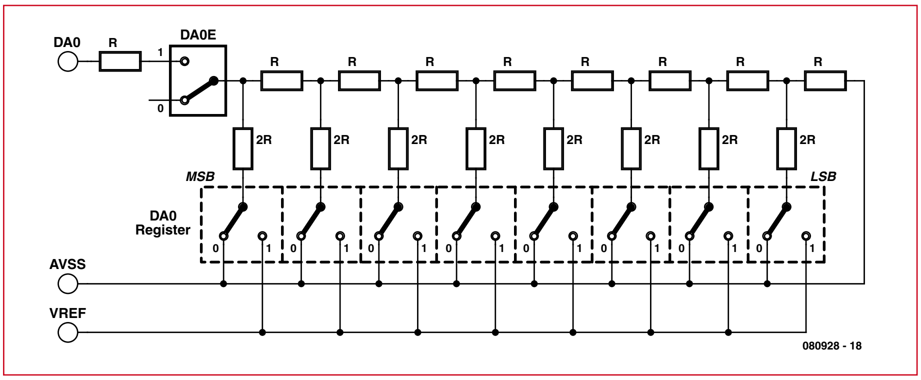


Figure 9. The integrated D/A converter uses a simple 8-bit R-2R network.

a digital value is transformed into an analog output voltage. The output voltage can lie within the range from AV_{SS} to V_{REF}. The AV_{SS} pin (pin 59) is linked via SJ2 to GND and the V_{REF} pin (pin 61) via SJ8 to VCC.

Depending on how the DA0 register is defined the output voltage on the DA0 pin varies according to the following formula:

$$V = \frac{VREF \times n}{256}$$

(n = 0 to 255)
VREF = reference voltage

Now for the programming. To make use of the D/A converter we first need to activate the output. We do this by setting the register bit 'da0e=1'. Now we can connect up the 'scope to the output pin, in this case being pin 63 on the carrier board. So that our output signal can represent a sine wave curve, it's necessary to integrate the <math.h> library (see **Listing 1**).

The file *sfr111.h* integrates the Special Function Register with the code written in C. The function *hwsetup.h* embraces all the functions that are necessary for configuring the clock-unit of the microcontroller. The actual program is set out in the annexe below.

To produce a variable frequency, the frequency output is executed within a Timer Interrupt Routine. The period duration is calculated using the short function *void set_frequency(unsigned int fre)* and passed to the timer for use as the timebase. Calculation of the sine values takes place in increments of 0.2. This is a compromise to achieve fine signal resolution without being forced to calculate an unreasonable number of values. With the floating point unit (FPU) enabled a frequency of up to 3 kHz can be produced, which is quite impressive for this number of sampling points. The default values run from 0

Listing 1

```
#include ”sfr111.h”
#include ”hwsetup.h”
#include <math.h>

// Interrupt declaration
#pragma INTERRUPT TimerA0_int

// functions
void Init_timer(void);
void set_frequency(unsigned int fre);

// globals
float y;
unsigned int speed;

// main function
void main(void)
{
 ConfigureOperatingFrequency(); //
   init oscillator and pll

 da0e=1; // enable DA0 converter
 set_frequency(2500); // set sine frequency (Hz)
 Init_timer(); // init timer for
   frequency calculation
 while(1); // endless while loop
}

// +++++++++++++++++++++++++++++++++++++++++++++++
// ++++++++++++++++ set_frequency ++++++++++++++++
// +++++++++++++++++++++++++++++++++++++++++++++++
void set_frequency(unsigned int fre)
{
      speed= 24000000/(fre*30.75); //
   timer base div output frequency
} // divided by DAC steps

// +++++++++++++++++++++++++++++++++++++++++++++++
// ++++++++++++++++++ Init_timer +++++++++++++++++
// +++++++++++++++++++++++++++++++++++++++++++++++
void Init_timer(void)
{
      ta0mr=0x00; // Timer mode, f8 @ 20MHz PClock
      ta0=speed; // Timer reload register
      asm (« FCLR I»); // Disable all interrupts
      ta0ic=0x03; // Set timer interrupt level to 3
      asm(«FSET I»); // Enable all interrupts
      ta0s=1; // start Timer A0
}

// +++++++++++++++++++++++++++++++++++++++++++++++
// ++++++++++++++++++ Interrupt ++++++++++++++++++
// +++++++++++++++++++++++++++++++++++++++++++++++
void TimerA0_int(void)
{
      y+=0.2; // sine signal steps
      if (y>=6.28) y=0; // set to 0 if 2pi reached
      da0=(128*sin(y))+128; // calculation
   of sine (offset by 128)
```

to 2π (0.628) and are then reset once more to zero. In this way a complete sine wave period is calculated.

All that needs be done now is to shift the sine wave upwards, as we don't want any negative values to be output by the D/A converter here. This offset is achieved by adding +128 to the resulting value.

After loading the program into the controller you can connect an oscilloscope to DA0 (pin 63) and if you do, the result is the sine wave signal shown in **Figure 11**.

(080928-I)

Internet Links

www.glyn.de/r32c

www.renesas.com

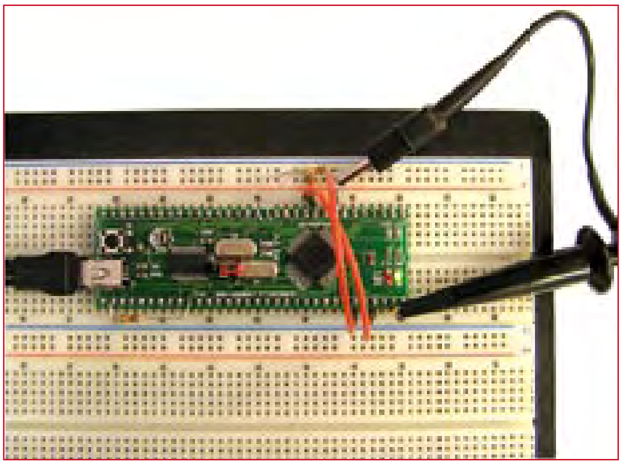


Figure 10. Test set-up with the carrier board. No additional parts are needed for this sine wave generator; just make the USB connection and hook up the probe to pin 63.

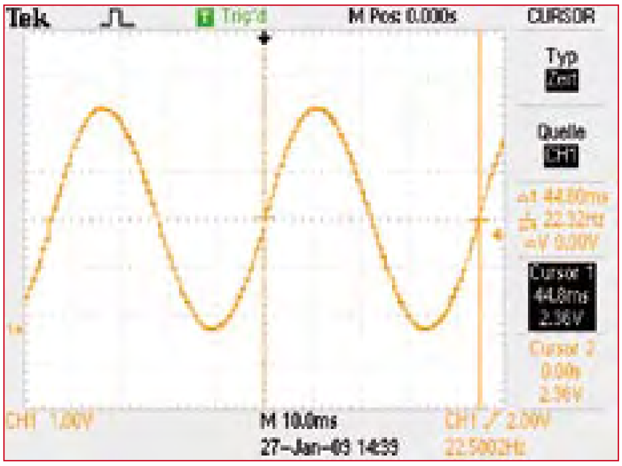
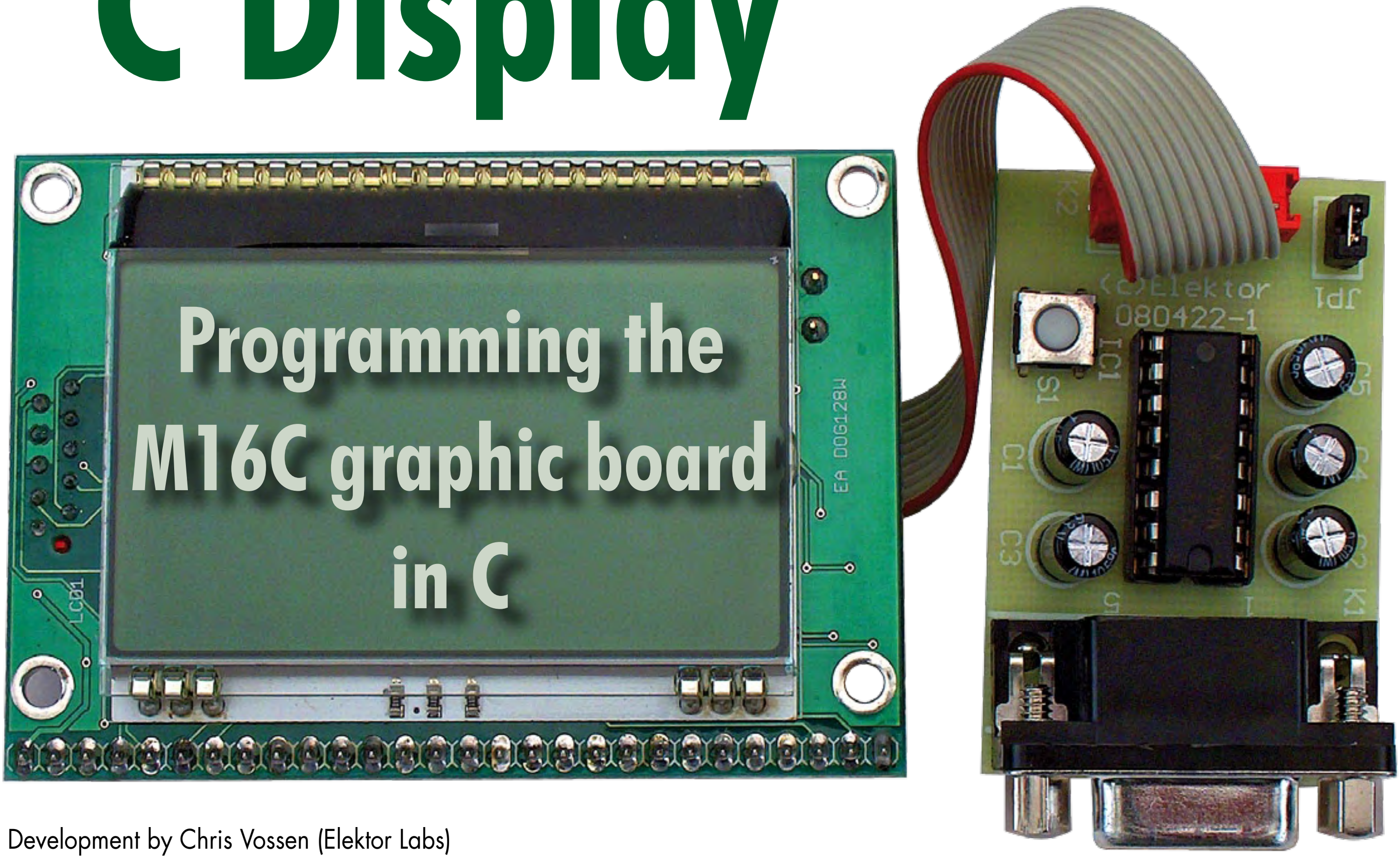


Figure 11. The sinewave signal produced on the scope.

C Display

Programming the M16C graphic board in C



Development by Chris Vossen (Elektor Labs)

Our May 2008 issue featured a very straightforward graphical control and measurement device using the compact M16C Display Board and its built-in BASIC interpreter. Readers who prefer programming in C can also use the design if they build this mini circuit and download some free software from the Web.

To begin: The M16C Display-Board [1] (**Figure 1**) from Elektor comes preloaded with a TinyBasic Interpreter [2]. Readers who are happy to carry on using TinyBasic — for educational and experimentation purposes or perhaps because they have already developed some handy programs for the board — need not read the rest of this article. That's because flashing the microcontroller with a compiled C program (as we shall do) overwrites the BASIC interpreter. No worries if you do this by accident, because we can reprogram the Interpreter as part of our after-sales service (for a modest charge).
Coming back on-topic, this article is aimed at the readers who do not need the TinyBasic-Interpreter and prefer to program in C. We have a shortcut for these readers as well!
Many of you are already familiar with the well-known R8C microcontroller and the M16C version [3] we're using for this project is really just a kind of big brother of the R8C. In fact the M16C is nothing more than a beefed-up version of the R8C, sharing the same core. In contrast to the R8C, however, the M16C uses a 16-bit wide Bus between core and peripherals, being also integrated with a DMA Controller.
Consequently the powerful advantages of the smaller 16-bit devices, which we have already discussed in the context of our major R8C project [4], apply equally to the M16C. Even better, there's a cost-free, yet

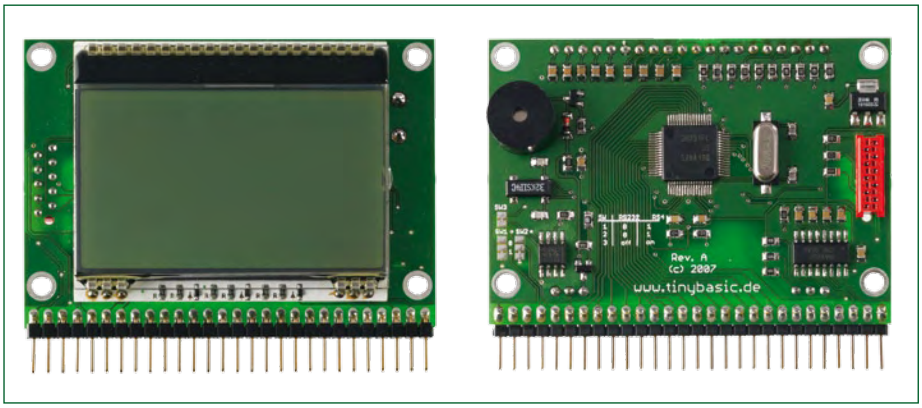


Figure 1. The M16C Display Board is an entry-level solution for monitoring, control and measurement with a graphic output.

extremely powerful C compiler. No extra programming device is necessary because it can be flashed very simply via the RS-232 interface. Even better, the Elektor website contains a project page [4] plus a well frequented forum [5] that's full of listings, answers to queries, and tips and tricks for this popular controller!

Software

Pain always precedes pleasure so we must first install the software before we can start to enjoy the delights of programming. This means sticking rigidly to the prescribed order of tasks. First we must install the Monitor/Debugger (KD30) and after this the C Compiler (NC30) with the development environment (HEW). Installing the Debugger first enables the HEW to tie in with it properly. The next installation task is the Debugger package, in order to integrate the Debugger into the IDE. After this, all you need do is boot up the HEW and you'll have everything visible on the screen. Last of all we must install the Flash Development Toolkit (FDT) from Renesas, used for loading finished programs into the Controller.
The Renesas software can be downloaded conveniently from the Elektor website — the noted distributor Glyn [6] has kindly compiled this package especially for this project. The project page for this article [7] contains not just downloads but also an installation manual.

Circuitry

The M16C contains an integrated Debugging interface that handles both synchronous and asynchronous Ports. The asynchronous mode is particularly simple to use because all we need do is match this to RS-232 levels. For this we use a couple of transistors, with our old friend the MAX232 also making an appearance in this circuit. The CLK input of the ICs must be tied to ground whenever asynchronous mode is employed. The hook-up (see **Figure 2**) is really very simple. The PC is connected to K1 and the Display Board to K2. A piece of 10-way flat ribbon cable is ideal for this purpose, equipped with the necessary connectors (pins connected like-for-like or 1:1). The 'CNVss' and 'CE' pins determine what the processor does after applying operating voltage or a Reset command. If both are logic High, then the Processor starts up in programming mode. If the CNVss pin is low, the application software kicks into action (we use a jumper plug to set the CNVss pin to either logic High or Low). Without the jumper, the input is taken to ground via a 10 kΩ resistor. To put the device into programming mode the jumper JP1 must be in place and then the Reset button pressed. After the application software has been flashed, the jumper is removed again. Following a second push of the Reset button the program will begin.

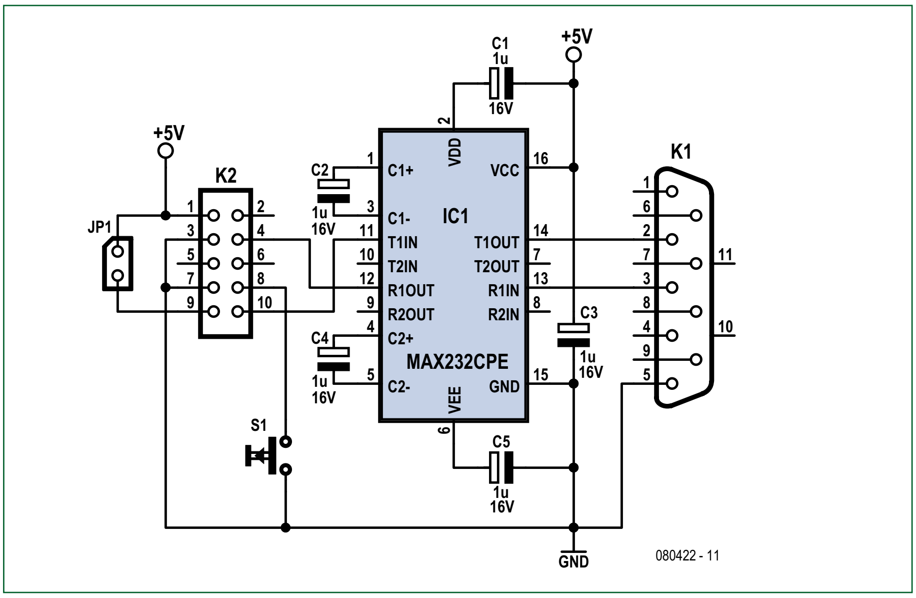
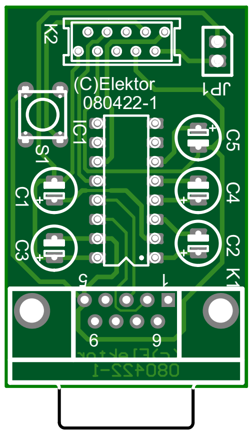


Figure 2. Just a handful of components is all you need for our programming interface.

Your first project

When you start up the 'High-performance Embedded Workshop' a selection window appears, with a choice of starting a new project or loading and existing one. The command 'File/Open Workspace' opens an existing project. To try this out you can use our test program, which you can download from the project website [7]. Opening this displays all the files that belong to the project. The source text is in the file that ends in .c (see **Figure 3**).
Before compiling you are asked whether you wish to produce a Debug version or a Release version. For the Release version choose 'Build/Build Configurations' and select 'Release'. You can now start the conversion with 'Build/Build All'. The C source code is translated, linked and written as a .mot file in the example directory \Release. The whole process is listed below in the Build window. After all this you will hopefully see the desired message: Build Finished 0 Errors, 1 Warning.
The alert message '*Warning (ln30): License has expired, code limited to 64K (10000H) Byte(s)*' is nothing to worry about, by the way. Although the free version of the compiler is lim-



COMPONENTS LIST

Capacitors
C1-C5 = 1µF 16V

Semiconductor
IC1 = MAX232CPE

Miscellaneous
K1 = 9-way sub-D socket (female)
K2 = 10-way AMP Micro-MaTch connector, PCB mount
JP1 = jumper
S1 = press-button switch
PCB, ref. 080422-1 from www.thepcb-shop.com

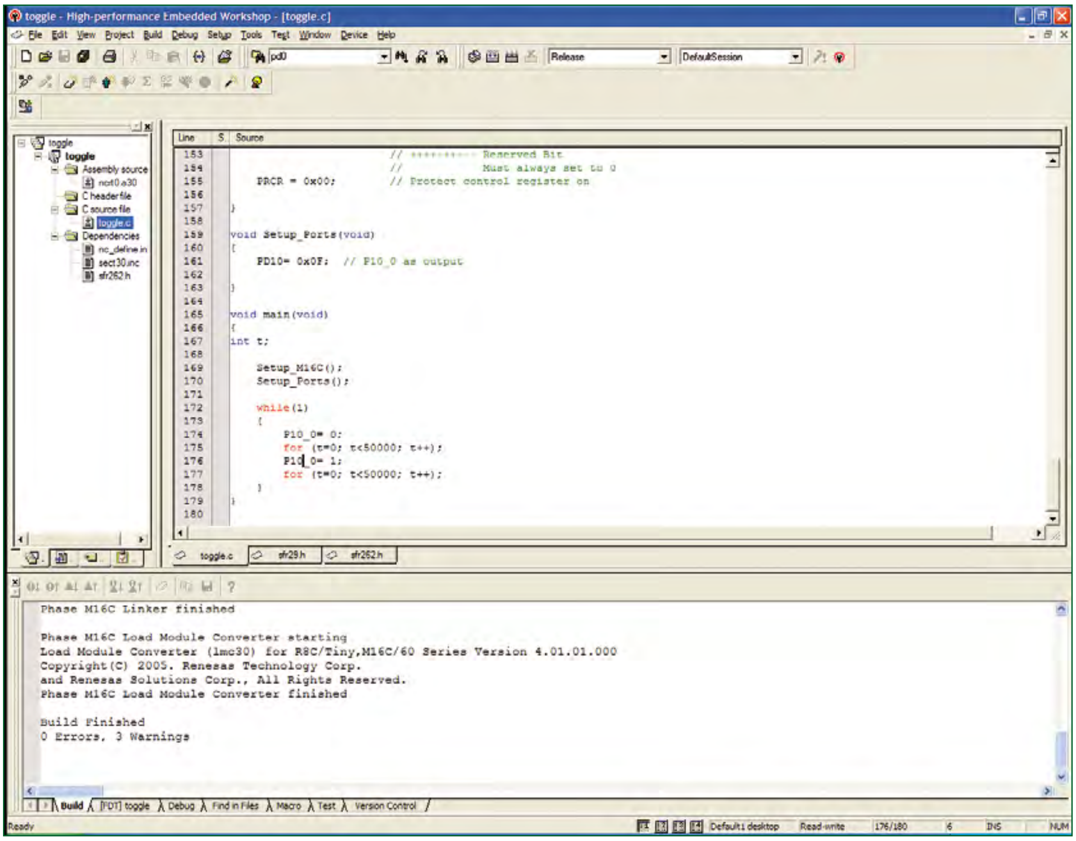


Figure 3. Here's a shot of the development environment HEW.

ited to 64 kB, this should be more than enough for most projects!

Time to fire it up!

The 'Flash Development Toolkit' is the way to load a completed program into the Controller. The program comes in both a complete version and a compact 'Basic Version', which will suit most purposes. Starting the first time you will need to enter the necessary settings (you can alter these later using the menu via 'Options/New Settings'). Next, select the Controller type (M30291) and the upper of the two Kernel protocols offered (see **Figure 4**). The next window is for selecting the interface to be used. The third window requires you to enter a Baud rate for the link to the Controller (select 9,600 baud).
Now we link up the M16C Display Board to the programming interface and to the interface with the COM port indicated. Insert jumper JP1 and give the Reset button a short push. The microcontroller is now in Boot mode and waits for you to give it some data. Programs in Motorola-Hex-Format (note the .mot file suffix) can be loaded into the Controller direct. Having indicated the path to these files, you can start the loading process with the command 'Program Flash'. The whole thing takes just a couple of seconds. First the Flash is cleared, then the new program is transferred. If all goes well, a 'success' notification will appear. Remove jumper JP1 and operate the Reset button briefly. And that's it — your program is up and running!

(080422-I)

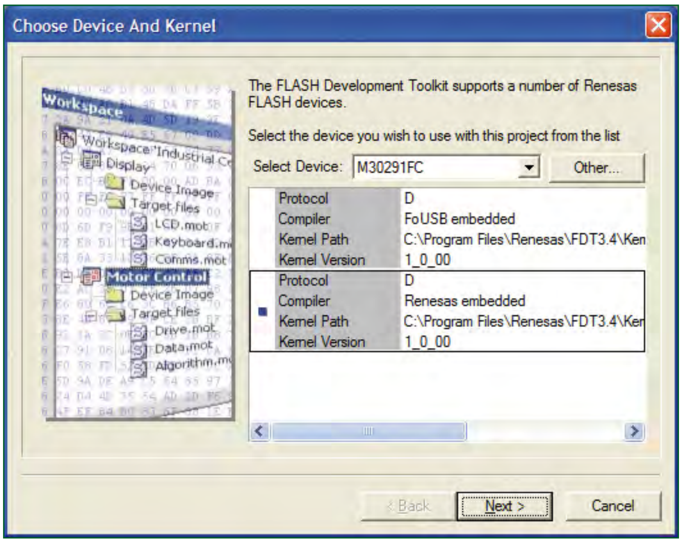


Figure 4. The free-of-charge Flasher FDT enables you to set the type of Controller device.

Note

The M16C Display Board 'Display-Computer' is available in the Elektor Shop as item no. 070827-91 [1].

Web Links

[1] www.elektor.com/products/kits-modules/modules/display-computer-(070827-91).426130.lynkx

[2] www.tinybasic.de

[3] www.m16c.de

[4] www.elektor.com/magazines/2006/january/the-r8c-family.58011.lynkx

[5] www.elektor.com/forum/elektor-forums/archive/r8c-16-bit-micro-starter-kit-(february-2006).164479.lynkx

[6] www.glyn.de (click on English flag)

[7] www.elektor-usa.com/080422

[8] http://en.wikipedia.org/wiki/M16C (M16C); http://en.wikipedia.org/wiki/R8C (R8C).

FM Stereo Decoder

For our Mini FM Receiver

Ton Giesberts (Elektor Design Labs)

In February 2009 we published a monaural mini FM receiver. A matching stereo decoder will naturally make this receiver complete. In this mini project we deploy an IC for this purpose. This IC has been available for quite a few years already and has by now amply proven its capabilities.

The VHF FM radio published last month (Elektor February 2009) has a mono output only. At the time we mentioned that it was also possible to make a stereo version and that we would describe the details in a future mini project. Promise is debt, so hereby we present a stereo decoder which is intended to be used in combination with our FM radio to make a stereo FM receiver — a kind of 'upgrade', if that's okay with you.

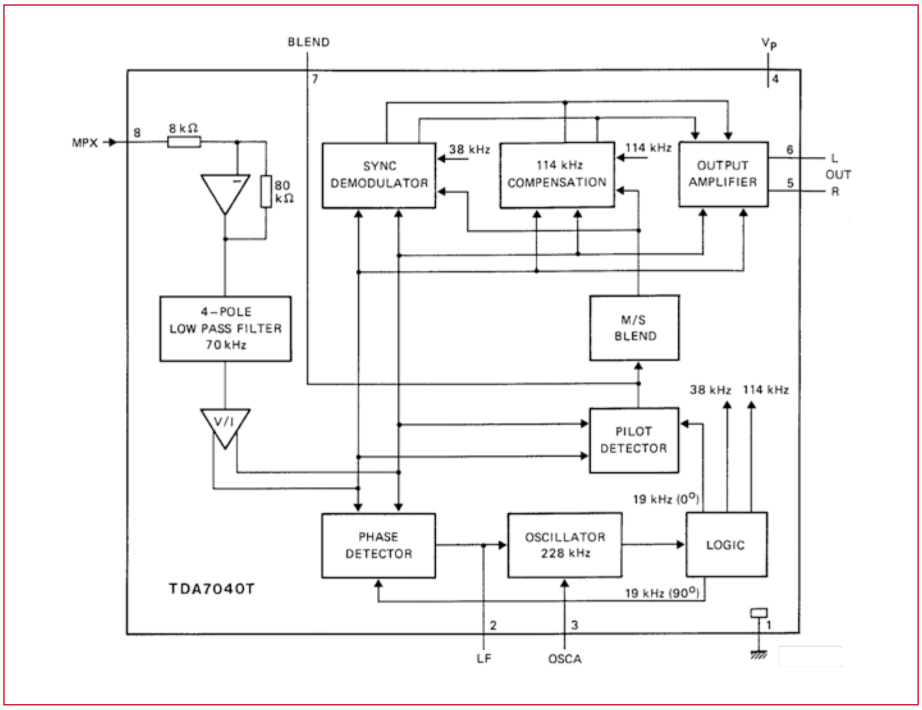


Figure 1. In this block diagram we see the internal design of the TDA7040.

Old but not yet worn out

The stereo decoder we use here is a TDA7040T made by NXP (formerly Philips Semiconductors). The design of this chip has not changed since 1986 (!). This IC, just like the chip in the receiver, is now only available in an SMD version. The old, familiar DIP package is no longer produced.

Just as with the FM radio, we have also designed a miniature PCB for this circuit to make building much easier. We have attempted to make the PCB as small as possible. The result of this is that SMD parts have been used as much as possible. The only through-hole components are a few electrolytic capacitors. As a consequence the dimensions of this PCB are only 2.5 by 4 centimetres (approx. 1 by 1.6 inches).

Signal processing

The decoder works according to the PLL (phase locked loop) principle and

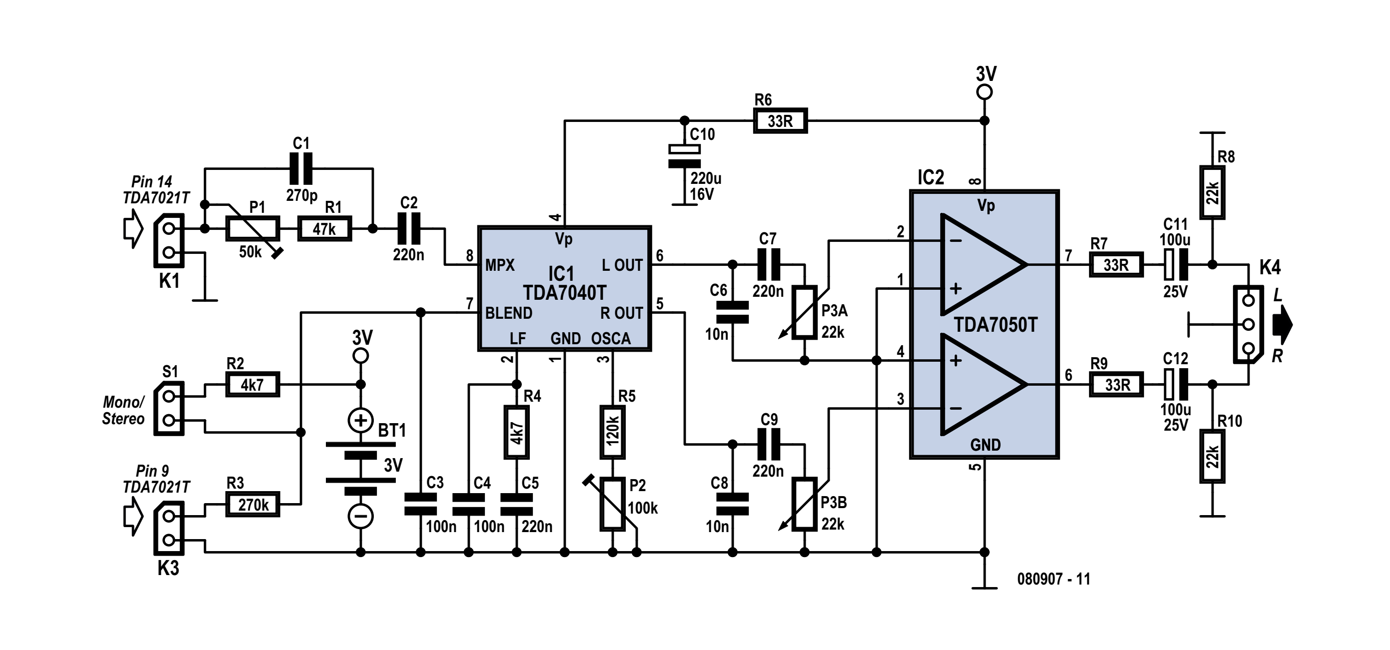


Figure 2. The schematic of the decoder does not differ much from the test circuit in the data sheet.

hardly requires any additional components. **Figure 1** shows the block diagram. You connect the output from the tuner (via a filter) to the MPX input of the chip. After amplification and filtering the signal is split into three.
First, there's with the pilot tone detector. This determines whether we have a stereo signal and operates the (internal) mono/stereo switch accordingly. Switching to mono can also be done manually, with S1, but that's an aside.
From the filter the signal also goes to the PLL, which consists of a phase detector, a voltage controlled oscillator (VCO) and a divider. The output of the divider comprises the frequencies that are used to decode the stereo information. This decoding is done in the third and final block to which the filtered signal is sent. The (stereo) audio signal finally leaves the chip via two buffers.
To make the signal suitable for driving headphones or two small loudspeakers, we use a TDA7050T. This is a small amplifier IC that, at a power supply voltage of 3 V, can deliver two times 5 mW into 32 ohms .

Circuit

The entire schematic for the circuit can be seen in **Figure 2**. The design differs only slightly from the example in the data sheet, and just like the circuit for the receiver, there is not much scope for improvement here either.

K1 of the decoder is connected to K1 of the receiver, and K3 is connected to K2 (the circuit also works without this connection). The mono/stereo switch S1 is connected to K2 (even though the schematic only shows S1, this is actually K2). Output K4 is intended to drive headphones with an impedance of 32 Ω or more, but for testing you can also connect a couple of small loudspeakers. Output resistors R7 and R9 protect the outputs of IC2 against overloading. R8 and R10 ensure that C11 and C12 are always charged so that a switch-on plop is prevented when the headphones are plugged in.

The output power of the TDA7050 is inadequate for serious use with loudspeakers, and it would be better in that case if you used an additional power amplifier. The stereo potentiometer for the volume control (P3) is connected to a 6-way pinheader. If the wires are kept short there is no need to use screened cable.

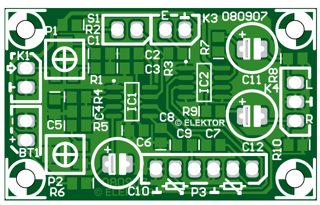


Figure 3. The decoder PCB is not much bigger than the receiver PCB.

All connections are implemented as pinheaders. But you can also insert the wires directly into the corresponding holes and solder them. Because the use of pinheaders also allowed the use of other through-hole components, we used ordinary radial electrolytic capacitors. These use a little less space and are generally of a better quality than their SMD counterparts. Make sure you take note of their maximum diameter (is shown in the parts list). The component overlay is shown in **Figure 3** and the copper track layout can be downloaded from the Elektor website.

At 6 V the total current consumption of the receiver and decoder together is a little higher than at 3 V: 17.3 mA instead of 12.5 mA. For testing we connected two 8 Ω loudspeakers to the outputs. The current consumption at highest volume peaked at 70 mA.

The average was a little over 40 mA. You will have to decide for yourself whether you would like to use two or four penlight batteries. If you use four you will get more from the batteries because together they will only have to supply a minimum of 2 V (minimum power supply voltages for the stereo decoder and receiver are 1.8 V and 1.6 V respectively). During testing it was found that the tuning is a little more dependent on changes of the supply voltage when the voltage is low than when it is high.

Correction

To ensure that the FM radio works correctly with the decoder module, a small correction needs to be carried out: C15 and C16 must be removed and a 100 pF capacitor must be connected between pins 14 and 15 of the IC. If you use a 0603 size SMD capacitor for this, it can be soldered directly between these two pins (see **Figure 4**).

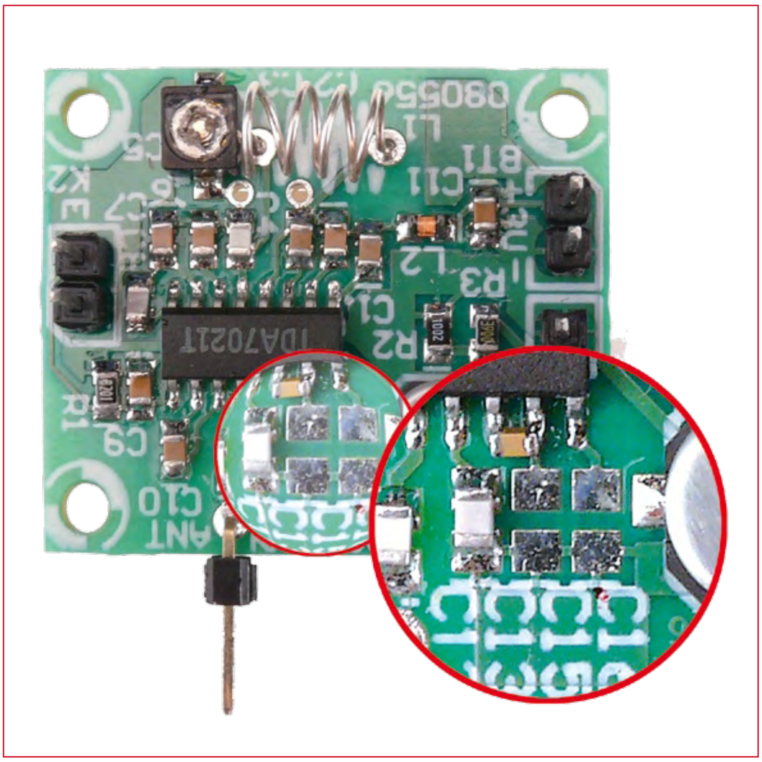
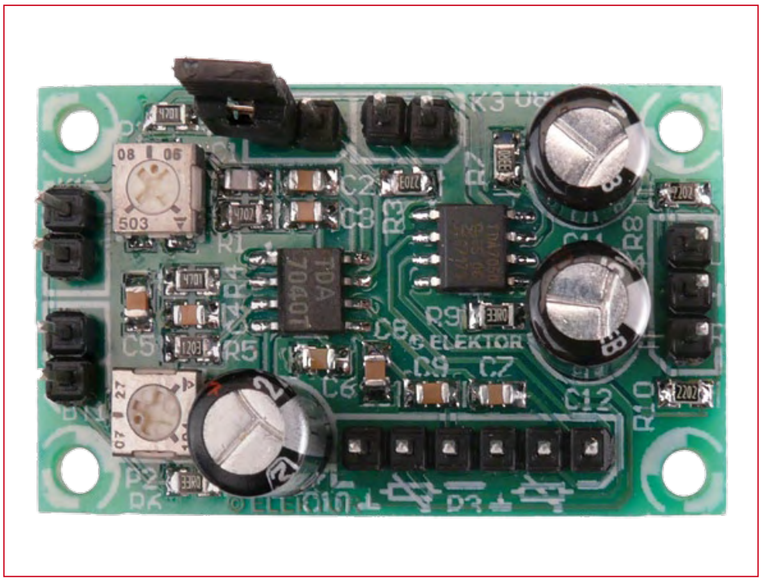


Figure 4. A few changes have to be made to the receiver board, such as fitting a capacitor between the pins of the TDA7021T.



The reason for this modification — which is necessary because without it the decoder won't work — is that the output filter in the receiver no longer needs de-emphasis (C15) and also requires less gain (C16). In its place the filter is changed to a second-order low-pass type with a bandwidth of about 53 kHz. This bandwidth is necessary to pass the entire multiplex signal (AM modulation at 38 kHz with a suppressed carrier) to the stereo decoder.

Calibration

In the stereo decoder the multiplex signal is accentuated with a passive network (P1/R1/C1) and must be adjusted for optimal channel separation (the first of two calibration points). An incorrect setting for P1 means either a mono sounding sound or the effect of a stereo base width control. With the latter the mono information is suppressed more and the stereo effect sounds somewhat exaggerated. The best setting (without test equipment) is somewhere in between. This, of course, requires a good stereo broadcast signal and ditto music.

The second calibration is also easy to do. With a strong signal, the correct setting for the VCO can be found by turning P2, midway between the positions where the decoder switches to mono.

(080907-I)

COMPONENT LIST

Resistors
(all SMD shape 0805)
R1 = 47kΩ
R2,R4 = 4kΩ7
R3 = 270kΩ
R5 = 120kΩ
R6,R7,R9 = 33Ω
R8,R10 = 22kΩ
P1 = 50kΩ preset, SMD, e.g. Vishay Sfernice TS53YJ503MR10 (Farnell # 1557940)
P2 = 100kΩ preset, SMD, e.g. Vishay Sfernice TS53YJ104MR10 (Farnell # 1557934)
P3 = 6-way pinheader and stereo 22kΩ (25kΩ) logarithmic potentiometer

Capacitors
C1 = 270pF, SMD 0805 case
C2,C5,C7,C9 = 220nF, SMD 0805 case
C3,C4 = 100nF, SMD 0805 case
C6,C8 = 10nF, SMD 0805 case
C10 = 220µF 16V, radial, lead pitch 2.5 mm, diameter 6.5 mm max.
C11,C12 = 100µF 25V, radial, lead pitch 2.5 mm, diameter 6.5 mm max.

Semiconductors
IC1 = TDA7040T, SMD SO8 case
IC2 = TDA7050T, SMD SO8 case

Miscellaneous
K1,K3 = 2-way pinheader
S1 (K2) = 1 make contact with 2-way pinheader
K4 = 3-way pinheader
BT1 = 2-way pinheader and 3-6 V battery (pack) and battery holder
PCB ref. 080907-1, available from www.ThePCBShop.com

Get a Grip on LED Dr

Simple SPICE model predicts hysteretic LED driver behavior

Fons Janssen (The Netherlands)

In the process of designing a LED driver circuit, various things can go amiss. To help the designer understand what is happening, a simple SPICE model helps out to pinpoint the effect of different individual component values upon the circuit operation.

Hysteretic High-Brightness (HB) LED drivers offer simple and low-cost implementations requiring a minimum of external components. They differ from fixed frequency drivers by the absence of a local oscillator that sets the switching frequency. The hysteretic circuit actually forms a self-oscillating system and the switching frequency is determined by a number of system parameters such as input voltage, output voltage, and inductance. The relation between these system parameters and the switching frequency is often not clearly understood by electronics designers.

Owing to this lack of understanding, they have trouble defining the right components to obtain the desired switching frequency, which most designers would like to maximize in order to minimize external component size (especially for the inductor).

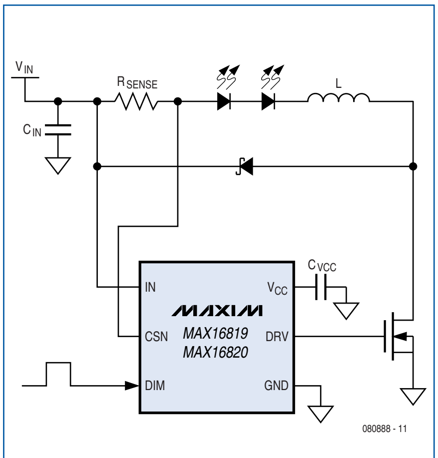


Figure 1. A typical hysteretic HB LED driver solution based on the MAX16820 driver chip requires only a few external components.

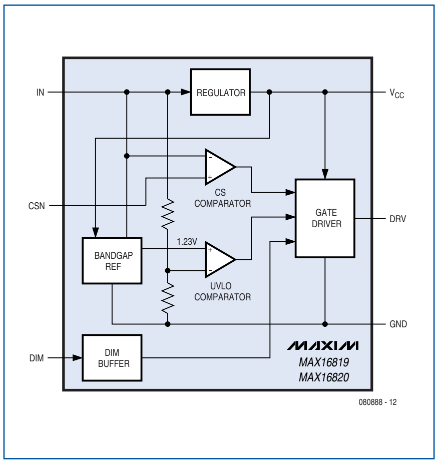


Figure 2. Block diagram of the type MAX16820 hysteretic LED driver.

Basic principles

The hysteretic HB LED driver circuit shown in **Figure 1** is based on the MAX16820 [1], which is driving a string of LEDs using an external inductor and a power MOSFET. However, the same analysis will hold true for any vendor's hysteretic driver.

On start-up, the controller switches on the N-channel MOSFET, so that the current is ramping up through R_{sense}, the HB LEDs, and the inductor. As soon as the current reaches the upper trip point (sensed by R_{sense}), the FET is switched off and the current ramps down via the rectifier diode. When the lower trip point is reached, the FET is switched on again, causing the current to ramp up. The hysteresis defined by the upper and lower trip point makes the system oscillate and a triangular shaped current is fed through the LEDs.

To facilitate the circuit design, you can calculate the component parameters by creating a spreadsheet similar to the Excel-based example developed by Maxim Integrated Products [2]. In such a spreadsheet you would enter the system specs such as input voltage, LED current and LED forward voltage, and the spreadsheet would calculate the

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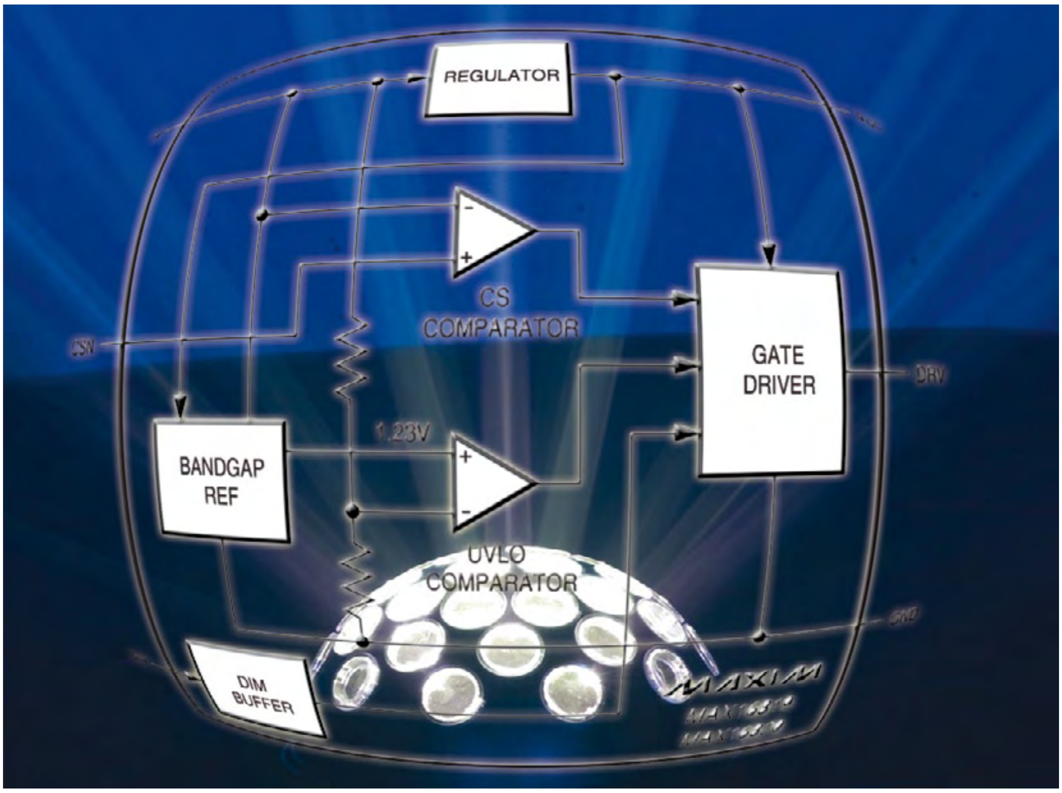


values as well as create a list of recommended component values. Although it is a useful tool, it does not actually clarify how the different specifications relate to each other. To see the relationships, it's best to go back to SPICE and examine the circuit model.

Simplified PSPICE model

To help understand the circuit better, a simple SPICE model was developed at Maxim to simulate the basic functionality of the MAX16820. With the model, the designer can vary system parameters with the click of a mouse and immediately see the effect it has on the LED current, switching frequency, etc. This will help the designer understand how the system parameters relate to each other, which makes the circuit design much easier.

The model is simple enough to be simulated on the demo version of Cadence PSPICE, which is available from Cadence free of charge after registration [3]. The demo version of PSPICE is a fully functional version with limitations in circuit complexity only. These limitations allow the use of standard SPICE circuit elements including some popular semiconductor components such as the 1N4148, 2N3904, uA741, etc.

The basic function of the MAX16820 is to switch on a MOSFET if the LED current is below a certain value, and switch it off again if the current is above the desired value. The built-in hysteresis allows the circuit to achieve stable, predictable oscillation. **Figure 2** shows the block diagram of the MAX16820 and **Figure 3** shows the simplified model including the external components. The model only includes the current-sense (CS) comparator – the gate driver, UVLO (Under Voltage Lock Out) comparator, regulator, and DIM (dedicated PWM dimming input) buffer are left out to keep the analysis simple.

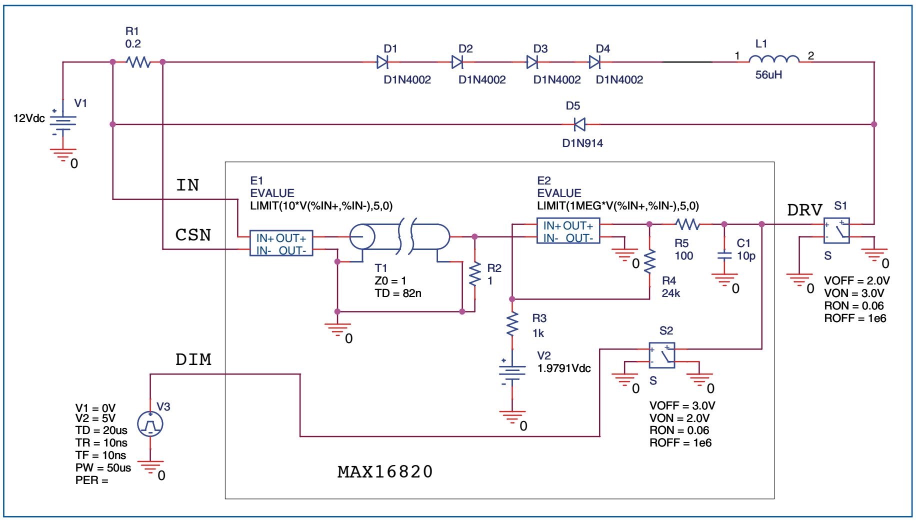


Figure 3. Simplified PSPICE model of MAX16820 hysteretic LED driver circuit.

In the model, the voltage-controlled voltage source E1 is configured as a current sense amplifier that amplifies the voltage across current sense resistor R1 by a factor of 10. Transmission line T1 introduces a delay of

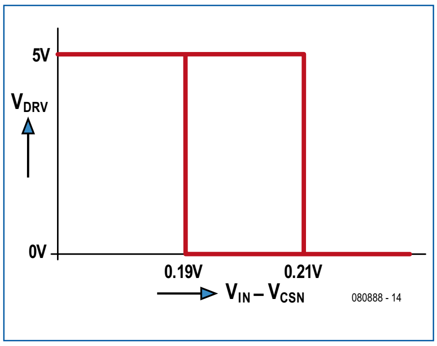


Figure 4. Hysteretic transfer function sub-circuit (DIM = High).

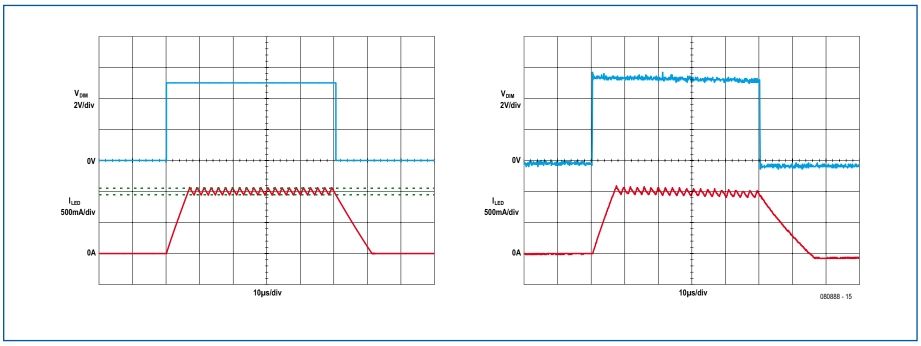


Figure 5. Simulation (left) and measurement (right) results. The blue graphs show the dimming signal and the red graphs, the LED currents.

82 ns, which is the actual propagation delay of the MAX16820. E2, V2, R3, and R4 form a hysteretic comparator with trip levels at 1.9 V and 2.1 V (R5 and C1 were added to prevent signal discontinuities creating conversion problems during simulation). The cascade of these three building blocks creates the transfer function depicted in **Figure 4**. Switch S2 models the DIM functionality. If DIM is logic High, S2 shorts the DRV signal to ground.

The rest of the circuit is pretty straightforward. Switch S1 represents the switching MOSFET and L1 the inductor. It is perfectly possible to define a diode model for the HB LED and the rectifier diode, but one can also pick a standard diode such as the 1N4002 and 1N914, whose models are included in the PSPICE demo version. Since the forward voltage of an HB LED is of the order of 3.5 V, several silicon diodes (D1 to D4) need to be cascaded (to form an equivalent to the HB LED) to match this forward voltage.

Simulations versus measurements

A 100 µs transient response simulation was done with the circuit in Figure 3. The results can be found in **Figure 5**. To compare the results to actual measurements, a measurement was done using a MAX16820 evaluation kit [4]. This kit has a 56 µH inductor and a 200 mΩ sense resistor, so it matches the values used in the simulation. The measurement results are also in Figure 5.

It is good confirmation to see how well the simulated and measured results match. Both results have the exact same amount of 21 switching pulses. The only clear difference is the fall time of the current after DIM goes Low.

A good example to understand the impact of the 82 ns propagation delay is to use an inductor that is much

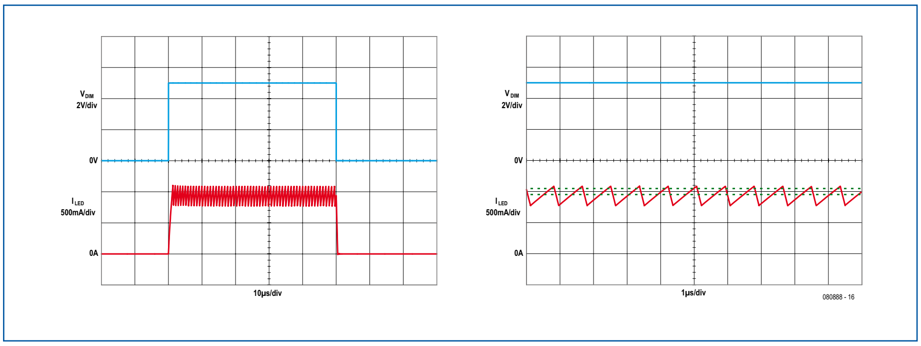
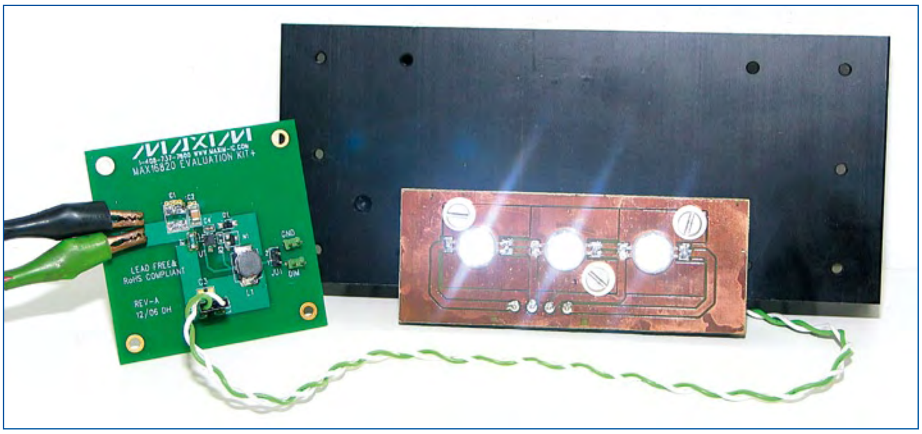


Figure 6. Simulation result with too small inductor. The right graph has a decreased time scale to show more detail. Clearly the 10% extinction ratio (indicated by the green dotted lines) is no longer met due to the severe under- and overshoots.



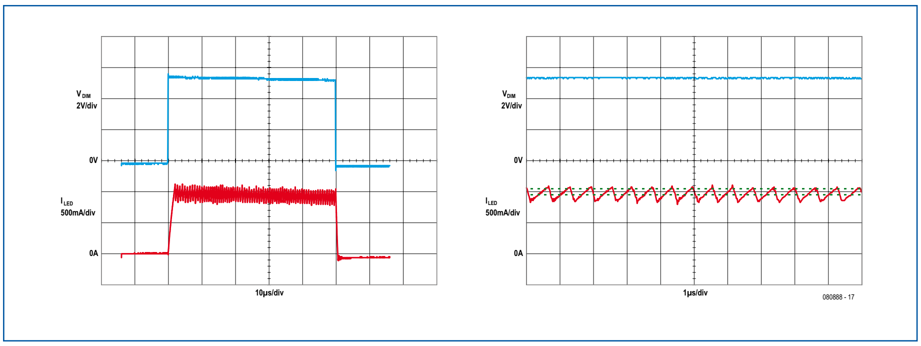


Figure 7: Measurement result with 5.1 µH inductor. The severe under- and overshoots predicted by the simulation are clearly present. The right graph has a decreased time scale to show more detail.

smaller than it should be. A circuit that needs to drive three LEDs from 12 V with 1 A of LED current requires an inductor that is at least 36 μH. This value is calculated by the Excel tool. If the simulation is done with an inductor that is much smaller, say, 5.1 μH, the result looks like the graphs in **Figure 6**.

Since the total forward voltage comes close to the input voltage, the current ramp-down is much steeper than the ramp-up. Secondly, due to the low value of the inductor the slopes are so fast (i.e. steep) that due to the propagation delay of 82 ns, over and undershoots occur. Due to the difference in slope, the undershoot is much more severe than the overshoot, resulting in a downshift of the nominal 1 A LED current. In other words: the accuracy is heavily compromised and the current variation is much higher than the intended 10%.

Again, this simulation was verified with an actual measurement and the results are shown in **Figure 7**. Again, there is a high degree of resemblance.

Conclusion

The simple SPICE model is a very easy way to predict the basic behavior of the MAX16820. It is not intended to very accurately simulate the chip, but it can be used to understand the concept of hysteretic LED drivers. By varying parameters, such as input voltage, sense resistor, and inductance, the model shows how this impacts for instance the switching frequency. The circuit can easily be adapted to model the MAX16819, which has 30% hysteresis *vs* 10% for the MAX16820. Simply change R4 to 7.333 k and V2 to 1.9318 V.

If conversion problems occur during simulation, the best remedy is to skip the initial transient bias point calculation and to reduce the total simulation time (SKIPBP and TSTOP parameters in simulation settings).

The OrCAD project files including the simple SPICE model can be downloaded from the project page on Elektor website. A detailed version of the MAX16820 SPICE model can be downloaded from Maxim [5].

(080888-I)

Internet Links

[1] www.maxim-ic.com/MAX16819

[2] www.maxim-ic.com/tools/other/software/MAX16819_CALC.XLS

[3] www.cadence.com

[4] www.maxim-ic.com/MAX16820EVKIT

[5] www.maxim-ic.com/tools/spice/led_drivers/macro/MAX16820.LIB

About the author

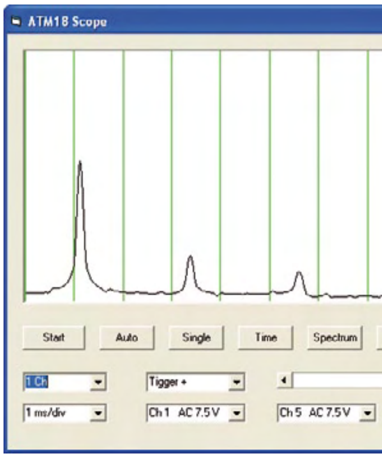
Fons Janssen studied Electrical Engineering at Eindhoven University of Technology (The Netherlands) and graduated in 1993. Post-graduate studies at the same university led to a master degree in technological design in 1996.

Prior to Maxim Fons worked at ThreeFive Photonics from 2001 to 2003, developing integrated optical circuits, and prior to that, from 1997 to 2001 he was employed by Lucent Technologies, working on optical access networks.

Scoping with the AT

A digital storage oscilloscope based on the Mega88

Wolfgang Rudolph and Burkhard Kainka (Germany)



Although oscilloscopes are less expensive now than a few years ago, we can devise something even more economical. Our ATM18 project gives you everything you need for a simple oscilloscope, and even if you already have a 'scope, the ATM18-digiscope is a welcome addition.

Many of our readers can doubtless remember how EEGs and ECGs were recorded not all that long ago, using an instrument fitted with moving pens to trace curves on a sheet of paper traveling at a constant speed. This instrument made it possible to observe time-varying electrical signals. As electronics specialists, we have something in common with medical specialists: we cannot see or hear currents or voltages, although we can feel them if they aren't too weak. Our problem is that we work with something we cannot perceive with our five senses.

The first attempts to display and record voltages date back more than 150 years. The earliest oscilloscope was an electromechanical instrument. It was coarse, insensitive and slow, but it could make voltages visible. With the invention of the cathode ray tube by Karl Ferdinand Braun, the mechanical oscilloscope yielded to the electronic version, which embarked on a triumphant career that only now, after more than 100 years, is slowly coming to an end.

The seventh sense

Voltmeters are unquestionably useful instruments. However, in most cases we are dealing with AC voltages or time-varying signals. With a video signal, for example, a simple voltage measurement is not of much use. We have to see the course of the signal over time in order to decide whether it is OK. Even signals at relatively low frequencies, in the audio range, can only be viewed with an oscilloscope. When you're used to working with a 'scope, you also use it to measure DC voltages, and in many cases you notice that your DC signal also has some sort of AC component.

Nowadays there are basically two types of oscilloscopes: beside the tried and true analog instruments, we encounter digital oscilloscopes more and more often.

Analog

With an analog oscilloscope, the signal is first amplified by an adjustable amount and then used directly to deflect an electron beam. The simplest types have only one channel and can thus display only one signal. However, we often need to compare two or more signals. A dual-channel oscilloscope is currently the most common type, and such instruments are affordable even for electronics hobbyists.

The bandwidth of the instrument is important. It specifies the maximum signal frequency that can be displayed. Time-varying signals with a frequency no more than 10% of the bandwidth of the oscilloscope are represented faithfully. Another important factor is the triggering capability. Here you can choose a positive or negative level for starting the display. With a variable time base, you can display the signal stretched in time. Analog oscilloscopes are best suited to displaying periodic signals, which means signals that constantly repeat themselves and thus appear as an essentially static image.

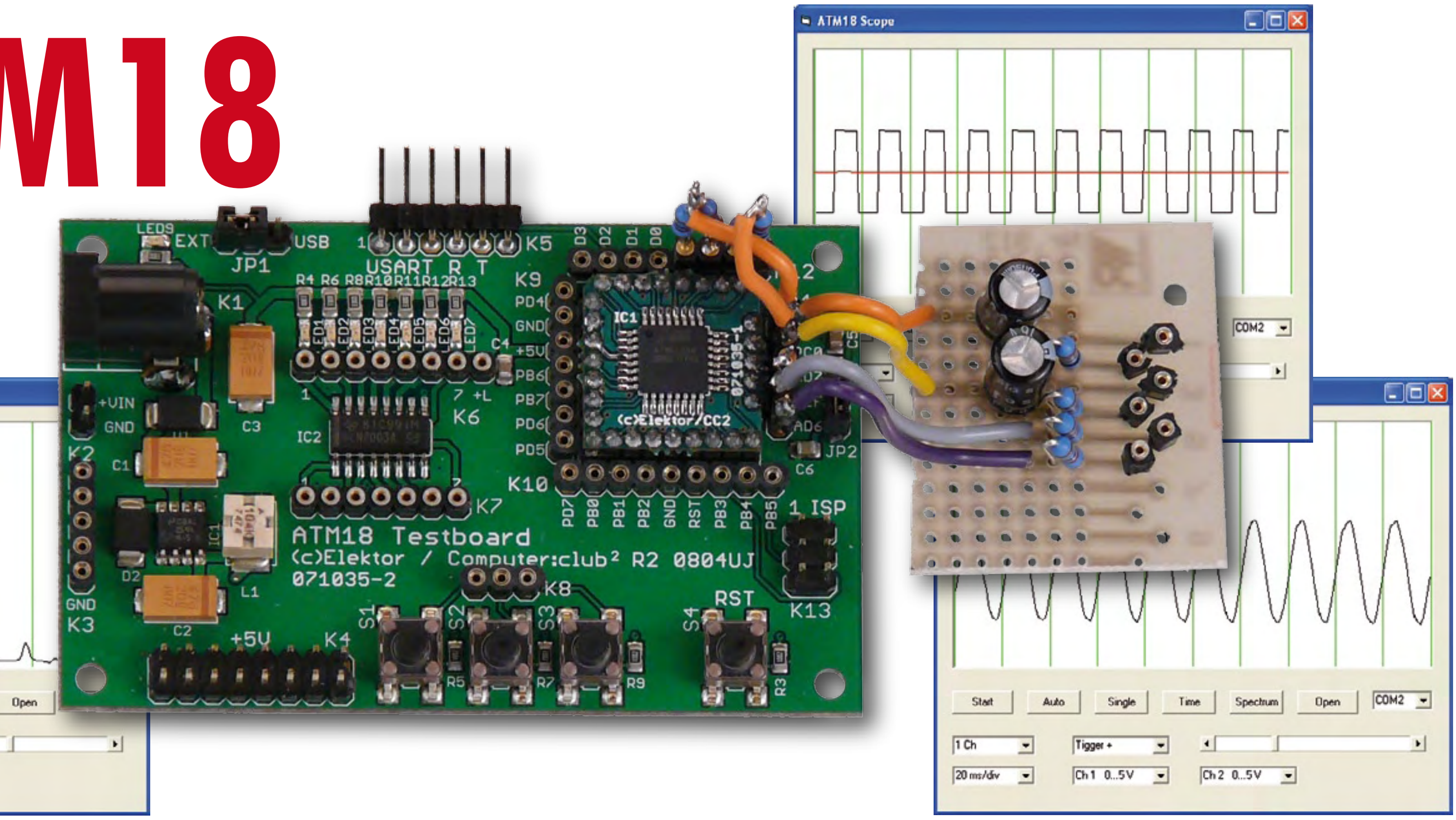
Digital

A digital storage oscilloscope, or DSO, uses an analog-to-digital converter to digitise the input signal and stores the digital values. It can thus display instantaneous samples of a signal and one-time events. Especially with digital circuitry, it is often helpful to be able to study the stored signals afterwards at your leisure. Nowadays the stored signal is presented on a liquid-crystal display, and it can be edited and printed out as desired.

An important factor with digital oscilloscopes is the sampling rate, which specifies how often the signal is digitised. For good representation of the measured signal, the sampling rate should be ten times the signal frequency.

The storage depth and A/D converter

M18



resolution are also important factors. An oscilloscope with a resolution of 8 bits and a 1024 × 8-bit storage capacity can store 1024 samples. This corresponds to a display with a resolution of 1024 × 256 pixels.

Various methods are used for conversion and storage. Simple (older-model) oscilloscopes use CCD memories. With this arrangement, the measured signal is first stored in analog form and then digitized. This results in a high noise level, limited storage depth, and dead times, since converting the measured signal from the analog memory to digital form takes longer than storing the signal.

More expensive (and more recent) models convert the measured signal to digital form in real time and store the measured data directly in working memory. With this arrangement, the storage depth is only dependent on the amount of memory available. Especially fast DSOs use A/D converters with sample-and-hold stages. Signal samples can be stored in several sample-and-hold stages and then digitised by slower A/D converters.

DIY

The ATmega88 can be used to put together a nice little digital oscilloscope. A project of this sort always arouses the desire for more channels, more bandwidth, better triggering, the ability to record slowly changing signals, long-term recording, and so on — a long list. You might also ask yourself whether it's worth the effort of developing a microcontroller project when you can use a PC sound card instead. This is a valid question; some sound cards can even manage a higher sampling rate than the ATmega88. However, the input voltage range is very limited with a sound card, and excess voltages at the input can damage not only the sound card, but also the entire computer. In addition, true DC measurements are not possible with a sound card, and you are limited to two channels. The microcontroller scores better in this regard. With this issue out of the way, we can get started with building our own digital oscilloscope.

ATM18 DSO

Speed is good, and more speed is better. How fast can an ATmega88 sample signals? To answer this question, we can run a simple program (**Listing 1**) that does nothing more than sample a single channel as fast as possible. It stores 500 samples and then transmits the data at 115,200 baud. Each measurement series is initiated by a start command from the PC. All we need to

Listing 1

Basic code for an M88 'scope.

```
'Bascom ATmega88, Scope
   Speed Test
$regfile = "m88def.dat"
$crystal = 16000000
Baud = 115200
Open "com1:" For Binary As #1
Dim D As Word
Dim B As Byte
Dim Ram(500) As Byte
Dim Adr As Word

Config Adc = Single , Presca-
   ler = 32 , Reference = Off
'ADC clock = 500 kHz
Start Adc
Config Portb = Output

Do
  Get #1 , B
  If B = 1 Then
    Portb.0 = 1
    For Adr = 1 To 500
      D = Getadc(0)
      Shift D , Right , 2
      Ram(adr) = D
    Next N
    Portb.0 = 0
    For Adr = 1 To 500
      D = Ram(adr)
      Put #1 , D
    Next N
  End If
Loop
End
```

Listing 2

Pulse generator (1 kHz on PD3)

```
Config Timer2 = Pwm , Pre-
   scale = 32 , Compa-
   re B Pwm = Clear Down
Start Timer2
Ocr2b = 128
```

Listing 3

Interrupt-driving measurement

```
Config Timer1 = Ti-
   mer , Prescale = 8
Start Timer1
On Ovf1 Tim1_isr
Enable Timer1
Enable Interrupts

Timebase = -20
Oneshot = 0
Channels = 1
Trigger = 0
Saveram = 1
…
Tim1_isr:
  '50 µs
  Timer1 = Timebase
  Portb.0 = 1
  'Chan 0
  D = Getadc(0)
  Shift D , Right , 2
  If Saveram = 1 Then
     Ram(adr) = D
     Adr = Adr + 1
  Else
     Put #1 , D
  End If
```

Listing 4

Sending the measured data

```
  If Adr > 501 Then
    For Adr = 1 To 501
      D = Ram(adr)
      Put #1 , D
    Next Adr
    Adr = 1
    If Oneshot = 1 Then
       Stop Timer1
    End If
  End If
```

Listing 5

The second measuring channel

```
    If Channels > 2 Then
      'Chan 2
      D = Getadc(2)
      Shift D , Right , 2
      If Saveram = 1 Then
         Ram(adr) = D
         Adr = Adr + 1
      Else
         Put #1 , D
      End If
    End If
```

run this test is a terminal emulator program. We send a single byte ('1') to the board and receive 500 data bytes.
The test program uses port B.0 to indicate the measuring time. With an oscilloscope, we measure a pulse length of 17 ms here. In this time interval, a total of 500 samples are acquired, converted into bytes (shifted left by two bits), and stored in RAM. This corresponds to 34 µs per sample, or a sampling rate of approximately 29 kHz. If a signal with a known frequency is connected to the analog input, the sampling time can also be seen from the measurement results.
The crucial factor here is the setting of the prescaler for the A/D converter clock signal. The following command sets the prescaler to 32:

```
Config Adc = Single , Pres-
caler = 32 , Reference = Off
```

With this setting, the A/D converter clock rate is 16 MHz ÷ 32 = 500 kHz. The data sheet recommends a clock rate in the range of 50 kHz to 200 kHz when high resolution is important. However, a higher clock rate can be used if the resolution is less than 10 bits. Consequently, we used a 500 kHz clock for our initial tests with the 'scope project. Each sample requires 13 A/D clock cycles, which yields a sample time of 26 µs. As we previously measured a sample time of 34 µs, apparently 8 µs is taken up by processing the sample.
However, the data sheet also specifies the conversion time as 13–260 µs. From this, we can conclude that an A/D converter clock rate of 1 MHz should not cause any problems. A test with a prescaler value of 16 shows that a sampling rate of approximately 50 kHz can be achieved with this setting, with the result that it takes around 10 ms to acquire 500 samples.
Maybe it can go even faster? There's no harm in trying, so we ran a test with the prescaler set to 8, which yielded an A/D clock rate of 2 MHz. With this setting, we did not see any signs of degradation of the 8-bit results. The measurement time for 500 samples was reduced to 6.5 ms, corresponding to approximately 13 µs per sample. A sampling rate of up to 77 kHz is nothing to sneeze at, so let's do it!
Not everyone has all the instruments on hand that are actually necessary for developing an oscilloscope. Here the Mega88 can be of further serv-

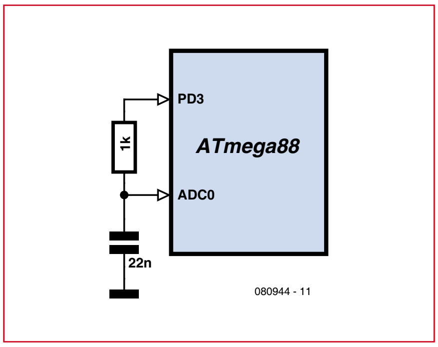


Figure 1. Generating a rounded sawtooth waveform.

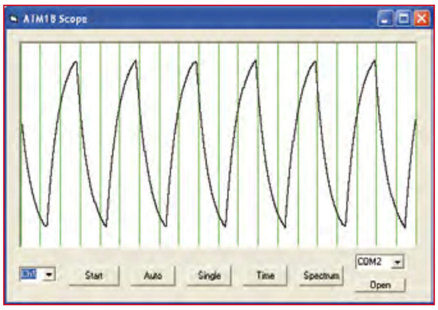


Figure 2. A measurement made at the highest sampling rate.

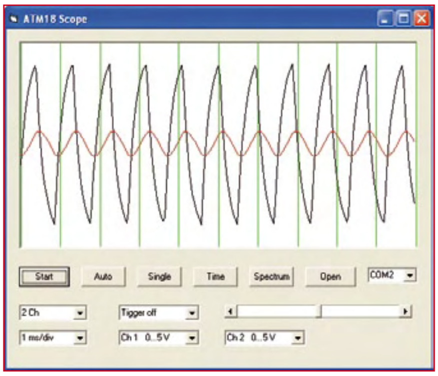


Figure 3. Two-channel measurement.

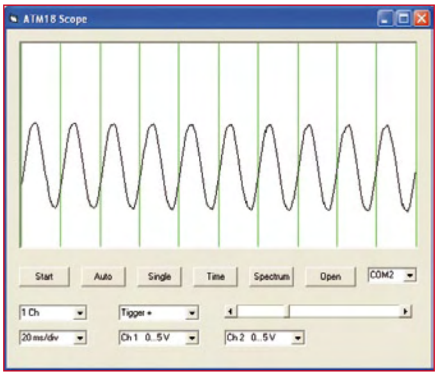


Figure 4. A triggered measurement.

ice. In addition to its main task, it can quite easily – and without affecting the computation time – generate a square-wave signal at around 1 kHz (**Listing 2**). For this purpose, we use Timer 2 as a PWM unit with the PWM2b signal on PD3. The exact frequency is 977.6 Hz (16 MHz ÷ (32 × 256 × 2)), which is reasonably close to 1 kHz. To get a better idea of the performance of the oscilloscope, we pass this signal through a low-pass filter (**Figure 1**). This converts the square-wave signal into a rounded sawtooth waveform (**Figure 2**).

As with the R8C/13 'Tom Thumb' article published in the April 2006 issue of *Elektor Electronics*, the PC software for the oscilloscope is written in Visual Basic. We borrowed the simple Fourier analysis routine from the previous application for our present 'scope application.

What we have now is only a single-channel oscilloscope. For each measurement, we send it a single byte ('1') and receive 500 bytes, which are then plotted on the screen. In this case approximately seven cycles of the waveform are plotted, which means that the measuring time is approximately 7 ms.

There are still several features that we want to have in the final version of the ATM18 oscilloscope:

- More input channels
- Variable input range
- Adjustable time base
- Triggering

The actual sampling process runs in a timer interrupt routine (**Listing 3**). This gives it the required timing accuracy and allows the sampling rate to be adjusted. For this purpose, Timer 1 (a 16-bit timer) is clocked at 2 MHz. Each time the timer overflows, the timer register is first loaded with the timebase value. The time increment is 0.5 µs, so with a timebase value of –40 the interrupt occurs every 20 µs. This corresponds to 10 ms for a full set of 500 samples, or 1 ms/div on the screen.

In theory, the time increment can be extended to approximately 16 ms. For this purpose, the main routine must set the Timebase to the appropriate value and then start Timer 1. In addition, values must be assigned to the following variables: Channels (the number of channels desired; range 1 to 4), Oneshot (record a single event), and Saveram (intermediate storage).

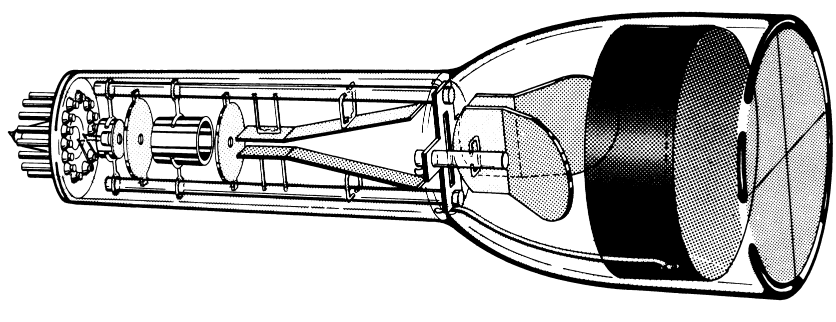
If Saveram is set to 0, the samples are transmitted immediately, while if it is set to 1, the samples are stored in memory. The timer is then stopped as soon as 500 samples have been taken. In addition, the program transmits the data via the serial interface (**Listing 4**).

The timer routine provides almost all the desired features. If more than one channel is configured, the samples are acquired sequentially and stored

Karl Ferdinand Braun (1850-1918).

Karl Ferdinand Braun was born on June 6, 1850 in Fulda (Germany) and attended upper secondary school there. In 1865, he began a course of study in the sciences and mathematics, at first in Marburg and then (after one year) in Berlin. There he worked in the private laboratory of Heinrich Gustav Magnus, and after the death of Magnus he continued his studies as the assistant of the physicist Hermann Georg Quincke. Among other things, he studied vibrations of strings, and he was awarded a PhD degree in 1872. In Marburg, Braun sat the state exam for upper secondary school teachers, and in 1873 he accepted a position as a teacher at the Thomasschule in Leipzig. In his free time, he pursued scientific studies of the conduction of vibrations and electricity. He discovered the semiconductor effect in metallic sulphur compounds, although this did not especially interest him or his scientific contemporaries.

In 1877, Braun was appointed to the position of extraordinary professor of theoretical physics in Marburg. In 1880 he moved to Strasbourg, and in 1883 he was appointed to the position of regular professor of physics at the University of Karlsruhe. In 1887 he was called to Erberhard-Karls University in Tübingen, where he was active as one of the leading founders of the Physical Institute. In 1895 he was appointed director of the Physical Institute and a regular professor at the University of Strasbourg.



Construction of a cathode ray tube.

Braun is presently known as the inventor of the cathode ray tube (CRT), which is often named after him in German-speaking countries. He developed one of the first functional prototypes in Karlsruhe in 1897. This early model had a cold cathode and a weak vacuum, and it required an acceleration voltage of 100,000 V to produce a visible trace on the screen using a magnetically deflected beam. Magnetic deflection was used in only one direction, with deflection in the other direction provided by an externally mounted rotating mirror. In 1899, Braun's assistant Zenneck added magnetic deflection in the Y direction using a sawtooth waveform. This was subsequently followed by a heated cathode and the Wehnelt cylinder, and the tube was further developed into a high-vacuum version. In this form, the cathode ray tube formed not only the basis for oscilloscopes, but also for television sets (after 1930).

After the invention of 'his' tube, Braun began research on wireless telegraphy. He replaced the 'coherer' commonly used at that time with a crystal detector. Crystal detectors were used for a considerable time after this, until they were replaced by thermionic valves. Braun also researched transmitter technology and made major contributions to the progress of radio engineering. In the area of antenna technology, he was one of the first to succeed in achieving directional radiation.

In 1909, Braun and Guglielmo Marconi were jointly awarded the Nobel Prize in Physics for the development of wireless telegraphy. In 1898, Braun was one of the founders of Funkentelegrafie GmbH in Cologne (Germany), and 1903 he was one of the founders of the Gesellschaft für Drahtlose Telegrafie Telefunken (the Telefunken Wireless Telegraphy Company) in Berlin. He died on 20 April 1918 in New York (USA) as a result of an accident.

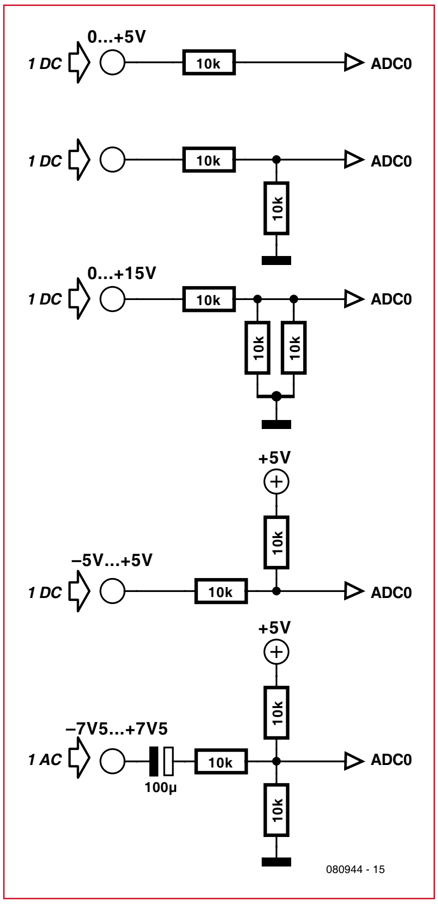


Figure 5. Five measuring ranges.

(**Listing 5**).

All we need now is a suitable main routine (**Listing 6**). Its function is to receive commands from the PC, interpret them, and execute them. The most important command is '1'. It starts a measurement session with the current set of parameters. The samples are first acquired and then transmitted. The timer is then disabled, so that a new measurement session can be started by the next '1' command.

Another command ('10') is used to configure the sampling interval. The program receives an integer value in two bytes (high byte and low byte) and assigns it to the Timebase variable as a negative number. Finally, there is the command '20', which is used to set the desired number of channels.

Listing 6

The Start command and parameters

```
Do
  Get #1 , Command
  If Command = 1 Then
     Oneshot = 1
     Adr = 1
     Saveram = 1
     Start Timer1
  End If
  If Command = 10 Then
     Get #1 , Hi
     Get #1 , Lo
     Timebase = 256 * Hi
     Timebase = Timebase + Lo
     Timebase = 0 - Timebase
  End If
  If Command = 20 Then
     Get #1 , B
     Channels = B
  End If
Loop
```

Triggering

You're probably familiar with the triggering functions of analog oscilloscopes. They have lots of knobs and buttons that you can play with, and usually you get it wrong and the screen remains blank. This is because the triggering condition can be set such that it is never satisfied. For this reason, it's always a good idea to first make a measurement without triggering. After this, you can select the appropriate trigger slope and adjust the trigger level to obtain a visible signal.

In the worst case, a software oscilloscope can wait forever if the trigger conditions are set incorrectly, without giving you any opportunity to correct the situation. This is certainly not what we want, so it must be possible to interact with the program while the microcontroller is waiting for a trigger event. The obvious way to achieve this is to use another interrupt. No sooner said than done: the triggering process runs as an interrupt routine with Timer 0 (one timer was still free — see **Listing 7**). Now you can adjust the trigger level 'live' in the main routine until you get it right.

Here's how it works: when the program is supposed to look for a trigger, the main routine starts Timer 0. Timer 0 in turn starts Timer 1 when the desired event occurs. The 'Trigger' control byte is set to 1 for triggering on a positive slope (rising edge). The first time that a measured value below the trigger threshold is found, the value of 'Trigger' is changed to '11'. This arms the routine for the next trigger edge. As soon as a measured value above the trigger level occurs, the trigger timer is stopped and the measuring session is started. If you want to trigger on a negative slope (falling edge), 'Trigger' is assigned an initial value of '2' and changes to '12' when it is armed.

The main routine now recognizes two additional start commands ('2' and '3') for triggered measurements, as well as a command ('30') for passing the setting of the trigger level parameter (**Listing 8**). Incidentally, the first channel is always used for triggering.

Listing 7

Triggering

```
Tim0_isr:
  D = Getadc(0)
  Shift D , Right , 2
  If Trigger = 1 Then
    If D < Triggerle-
   vel Then Trigger = 11
  End If
  If Trigger = 11 Then
    If D >= Triggerlevel Then
      Stop Timer0
      Timer1 = -1
      Start Timer1
    End If
  End If
  If Trigger = 2 Then
    If D > Triggerle-
   vel Then Trigger = 12
  End If
  If Trigger = 12 Then
    If D <= Triggerlevel Then
      Stop Timer0
      Timer1 = -1
      Start Timer1
    End If
  End If
Return
```

Measuring range

Have you noticed that there's still something missing? That's right — a normal 'scope has several input

Listing 8

Trigger commands

```
  If Command = 2 Then
     Oneshot = 1
     Adr = 1
     Saveram = 1
     Trigger = 1
     Start Timer0
  End If
  If Command = 3 Then
     Oneshot = 1
     Adr = 1
     Saveram = 1
     Trigger = 2
     Start Timer0
  End If
  If Command = 30 Then
     Get #1 , B
     Triggerlevel = B
  End If
```

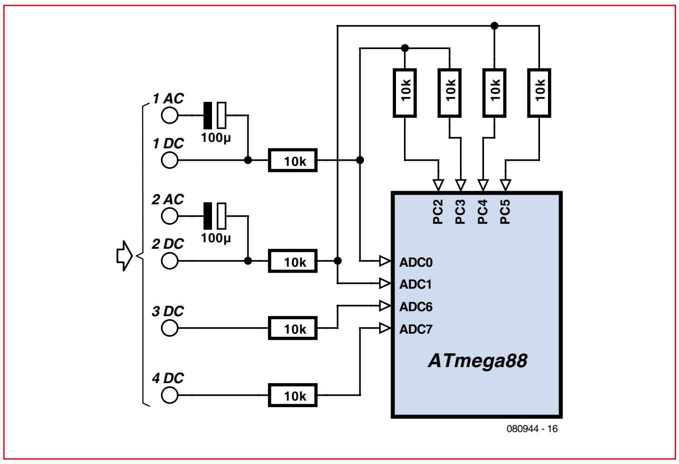


Figure 6. The four inputs of the ATM18 DSO.

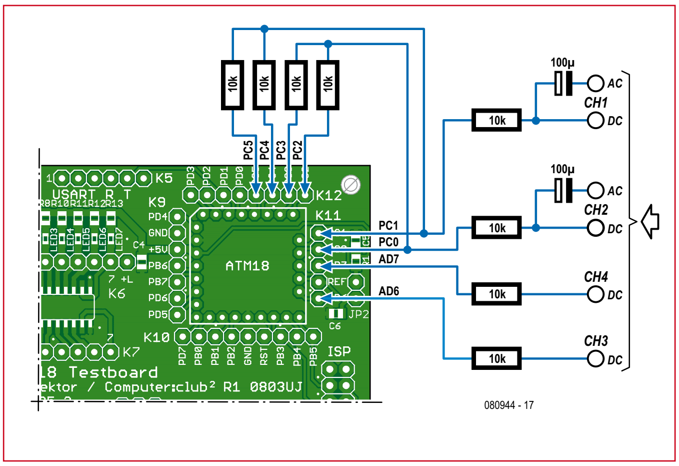


Figure 7. Wiring diagram of the circuitry connected to the ATM18 module.

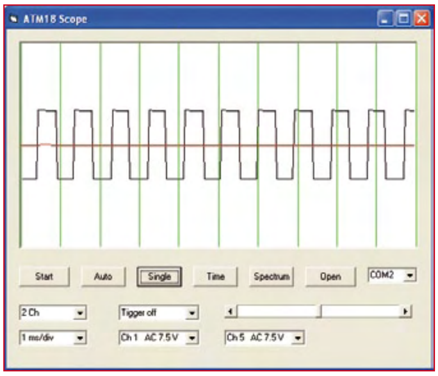


Figure 8. AC measurement using two channels.

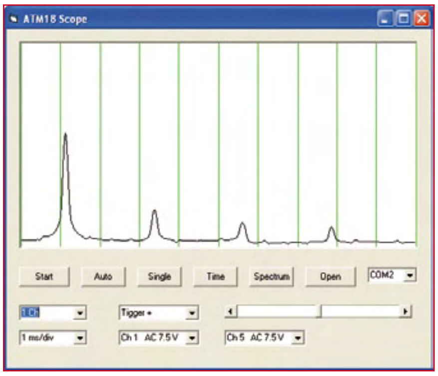


Figure 9. Plot of the frequency spectrum of a square-wave signal.

ranges. One way to select input ranges is to use relays or analog switches, but another option is to use the regular I/O pins of the ATmega88 as analog switches. This is because they have three usable states:

1. High-impedance
2. Low-impedance connection to GND
3. Low-impedance connection to V_{CC}

They can thus be used to control a voltage divider. **Figure 5** shows the possible combinations with three resistors and two I/O pins if the A/D analog input has a range of 0–5 V. A coupling capacitor is also necessary for true AC measurements. **Figure 6** shows the implementation using port C. The third and fourth channels are connected to the ADC6 and ADC7 inputs and operate with a fixed input voltage range of 0–5 V.

The program can be used to perform one-shot (Single) or repetitive (Auto) measurements with a repetition rate of two measurements per second. It also includes a frequency analysis (Spectrum display) function. For meaningful results, this can only be used with single-channel measurements. By contrast, the normal oscillograms show the signals plotted versus time (Time display).

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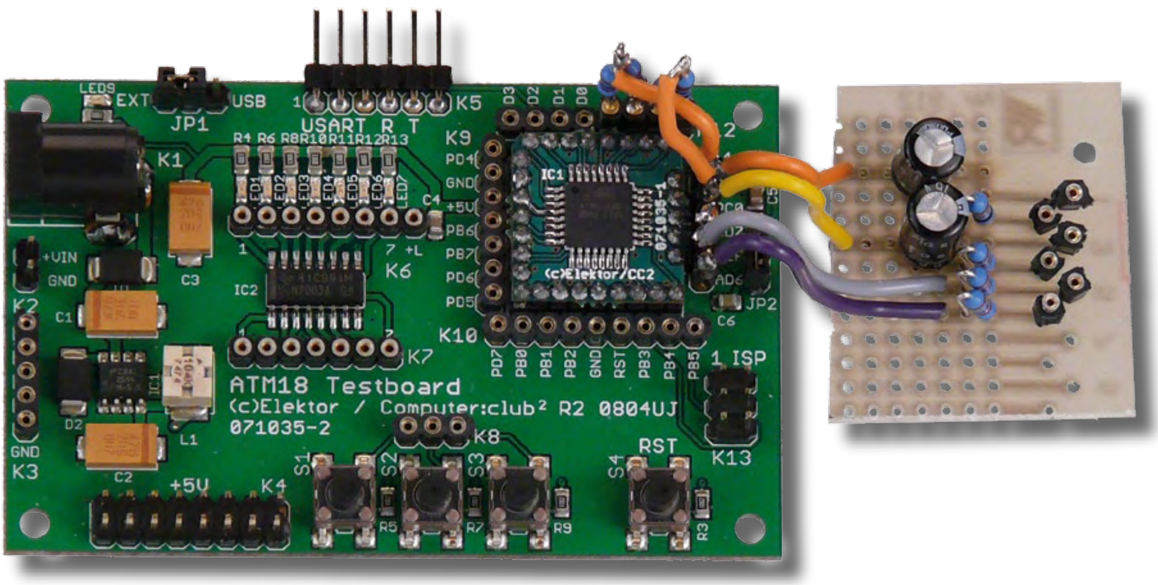


Rocket Motor Test Rig

Kitchen scales make thrust measurement a piece of cake

Dr. Jürgen Giersch (Germany)

Electronic kitchen scales are now reasonably priced and are good for accurately measuring cake ingredients but add this ATmega8 equipped interface card and you have a model rocket motor test rig which displays the motor's static thrust profile on a PC.

Figure 1. The test rig in operation.

Those of you who dabble in the hobby of model aircraft construction will be aware of how important it is to know how much thrust a motor can generate. This is even more true for model rocket design and construction. Model rocket motors develop their thrust by burning a solid propellant material within an motor casing, the resulting hot gases and combustion particles are expelled at high speed through an exhaust nozzle producing thrust (**Figure 1**). The characteristics of thrust are not linear during the burn phase; the type of fuel, the shape of the exhaust nozzle and combustion path all contribute to the thrust profile. Apart from the rocket body aerodynamics and the shift in the center of mass which occurs during burn, the thrust characteristics have the greatest influence on a rocket's trajectory.

In law, model rocket motors are classed as explosives so in most countries it is an offence to try and make one yourself. Commercial rocket motors are however widely available in hobby shops but they are generally supplied with very rudimentary technical data, often just quoting the average thrust, burn duration and time delay to ejection. Rocket constructors are sure to appreciate the test rig suggested here, complete with PC interface it will answer any questions they may have about the burn characteristics of a model rocket motor.

Thrust measurement

Fortunately we do not need to look too far to find a suitable sensor/transducer to measure thrust. A standard set of electronic kitchen scales is able to measure a maximum weight of a few kilograms. 1 kg here on earth exerts a downward force of approximately 10 Newtons. This measurement range will be sufficient for the majority of model rocket motors currently on the market. As a rule, a standard set of kitchen scales will not be fitted with a connector to allow a PC to take readings but it is not be too difficult to make the required modifications. With screwdriver in hand it was necessary to dismantle a low-cost set of scales to try to identify a point in the circuit where a voltage proportional to the measured weight is generated.

After looking at several different models it became clear that they do not all use the same measurement method. One of the most common techniques uses a bending beam type of load cell with strain gages bonded around a cut-out in the beam to measure bending (compression and extension) caused by a weight placed on the scale. The electrical resistance of the strain gages alter as the beam bends. This method of measurement is ideal for our application; all we need now is a circuit to form the interface between the strain gage and PC. It was not possible to find a point on the existing circuitry to tap off measured values. The scales use custom ICs so that all signals are totally encapsulated except for the wiring to the gage. It is therefore necessary for our interface circuit to connect directly to the strain gage wiring.

Bridge configuration

The use of four strain gages and a bending beam is probably the most common arrangement of weight measurement transducer (**Figure 2**). Two of the strain gages are cemented on the surface above a cut-out in the beam and two along the lower surface. When a weight is placed on the scales the beam bends, putting the top gage under tension (ε) and the bottom gage under compression (–ε). The four strain gages are wired in a full bridge configuration to help compensate for temperature effects and give good measurement accuracy (**Figure 3**).

A DC supply voltage is applied to opposite corners of the bridge (U0+ and U0–) while the voltage difference measured between the other two corners (UB+ and UB–) is proportional to the beam loading. In the kitchen scales the wires to these four points are brought out to a connector (**Figure 4**) so that they can be connected to an external interface circuit. A four-pole switch connected in between enables the scales to be switched back to their normal operational mode (**Figure 5**) for mom to use.

It is possible to purchase a bending beam type load cell from a specialist transducer supplier (try Googling strain gage, load cell and bending beam). However the cost of these components individually is more than buying a complete set of kitchen scales. The advantage would be that you can use the technical data sheets to select a load cell better suited to your particular application. Better temperature stability, linearity or higher load capacity may all be important considerations. A high-quality commercial example which can measure up to 300 N is shown in **Figure 6**. The shape of the sensing beam positioned between the upper and lower plates allows measurement of both vertical and horizontal forces. Measuring thrust with this type of load cell and with a horizontally mounted motor would have the advantage that the change in mass caused by the propellant being used up is effectively added to the thrust, unlike our inverted motor test rig.

Data Flow

In principle it is only necessary to connect a DC supply across U0 of the measurement bridge and hook up a storage scope probe across UB to record the thrust measurement. Not everyone however has access to such equipment and it would then be necessary to calibrate the display to get any meaningful results which can be quite laborious. A better solution is to build this relatively simple interface card which converts the kitchen scales into a thrust measurement test rig with a serial PC interface (**Figure 7**). The card supplies a reference voltage U0 to the bridge while a microcontroller, together with an instrument amplifier and an on-board A/D converter samples the voltage at UB and sends the digitized values to a PC over a serial interface.
The circuit diagram is shown in **Figure 8**. The microcontroller at the heart of the circuit is an ATMEL ATmega8, which reads the analog signal on its ADC4 input pin. The value is continually sampled and digitized with 10-bit resolution. The hexadecimal value of each sample is sent over the serial interface and the ASCII value for carriage return (CR) is appended to each sample. This process repeats in a continuous loop achieving a sample rate of approximately 3 kSamples/s. RS232 to TTL signal level conversion for the serial interface is performed (as ever) by a MAX232 interface driver.

Boosting the signal

It is often said that any piece of test equipment is only as good as its signal amplifier. Any non-linearity means that you are not just measuring the signal under test but also imperfections in the test equipment signal path. The design of the amplifier between the strain gage bridge and the A/D converter is therefore important. It is required to boost the small signal generated by the change in resistance of the bridge up to the input voltage range of the A/D converter (a few volts). The change in gage resistance caused by typical beam deflections is in the order of a few parts per thousand. Using a bridge supply voltage of a few volts

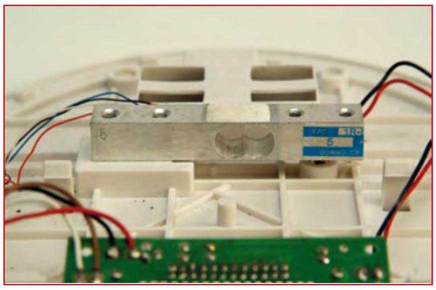


Figure 2. The bending beam with strain gages.

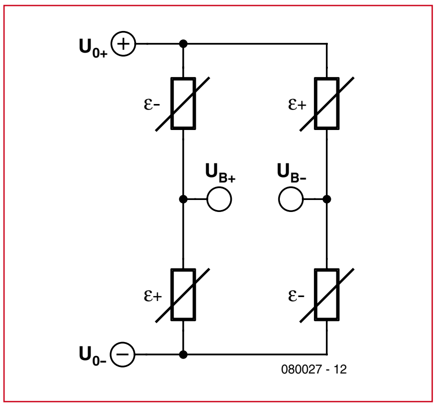


Figure 3. Four strain gages arranged in a full bridge configuration (ε+ = tension, ε– = compression).

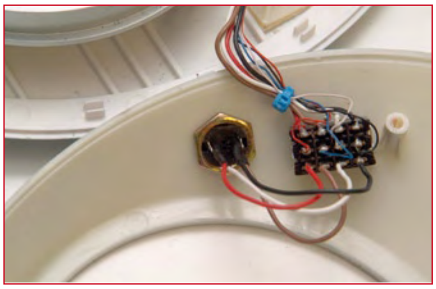


Figure 4. Mounting the 4-pole switch and 4-pin mini DIN connector.

Figure 5. The switch allows the scales to revert back to normal weighing duties.

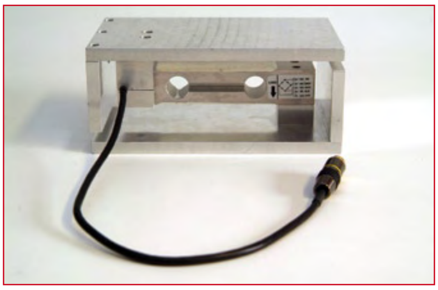


Figure 6. This commercial bending beam strain gage measures both horizontal and vertical force.

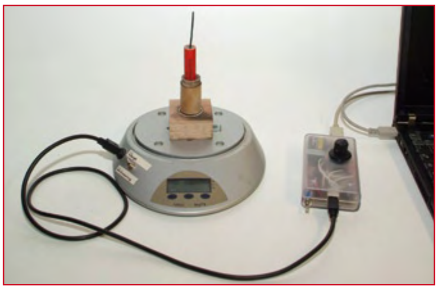


Figure 7. The finished test rig.

this means that the bridge output signal will be in the millivolts (mV) range. Before the sensor signal can be digitized in the A/D converter it will therefore need to be amplified by a factor of three orders of magnitude. Anyone wishing to measure smaller values of thrust more accurately would require additional amplification. With this high level of amplification it is important to pay attention to reducing noise in the circuit. Capacitor C18 at the circuit input together with the internal impedance of the strain gage bridge form a low pass filter. A typical value of bridge resistance is a few hundred ohms which together with C18 (100 nF) gives an upper cut-off of several kilohertz which is suitable for the sample rate used here. To check the strain gage impedance short together points U0+ and U0- and measure between UB+ and UB- with an ohmmeter. When for any reason a different sampling rate is used it would be necessary to make a corresponding change in the value of the filter capacitor.

A second low-pass filter formed by R8 and C5 on the output of the instrument amplifier has a cut-off frequency of approximately 3 kHz and serves to further attenuate any noise signals. Again any change in the sampling rate will require the filter to be changed accordingly.

Use shielded wiring such as S-video cable between the scales and interface card. Keep the cable length to a minimum to reduce electrical noise pickup. The cable is terminated with mini DIN connectors. The pin layout for this connector is given in **Figure 9** shown from the soldering-side.

Amplification of the strain gage signal is performed by an instrument amplifier type AD620AN. This IC is specifically designed to operate with a bridge sensor and has a low-noise figure. The amplifier gain is set with just a single resistor (see data sheet). A charge-pump IC type LT1054 is used to pro-

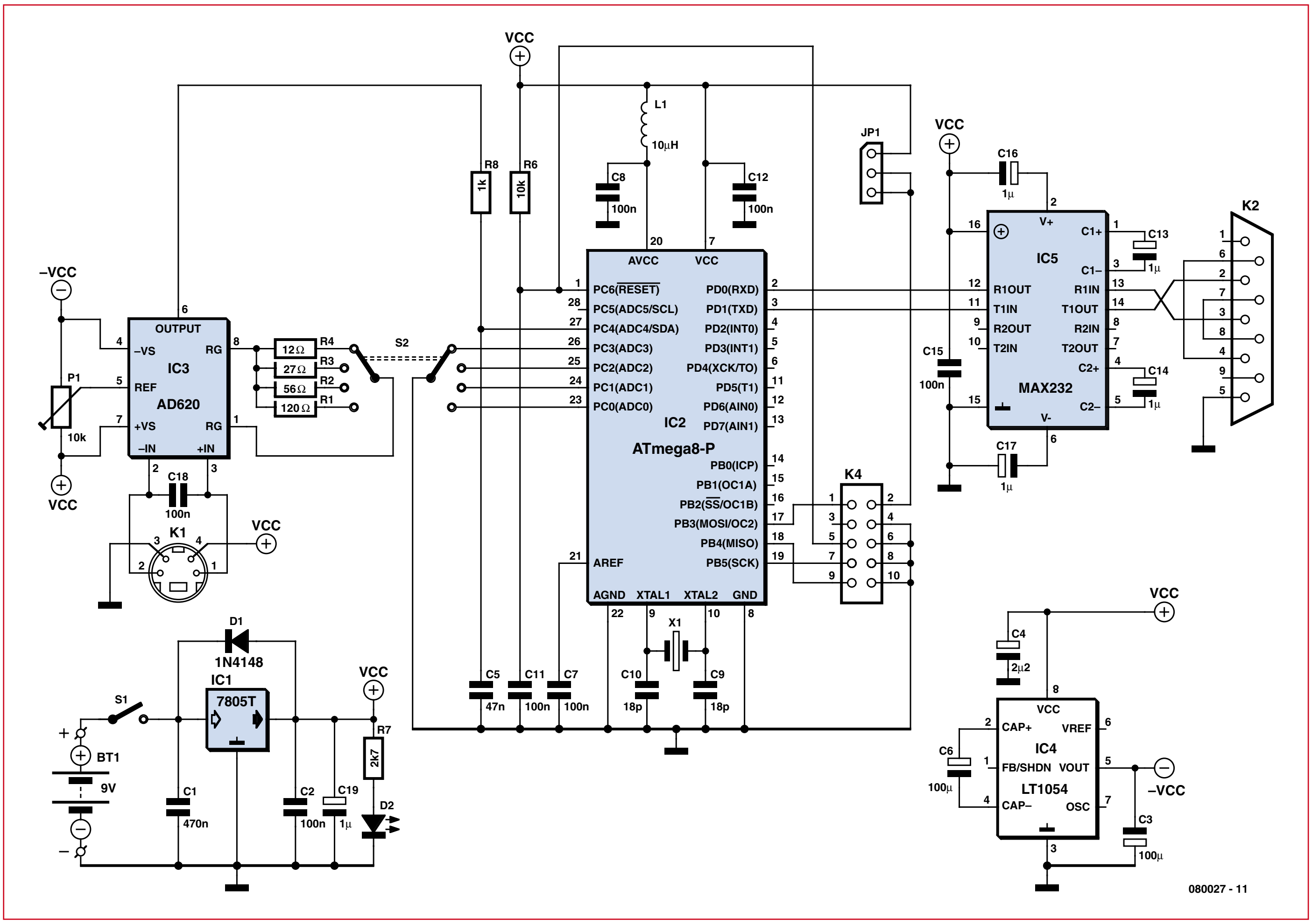


Figure 8. The circuit diagram.

duce the negative supply rail for the amplifier. Preset P1 is used to null any quiescent voltage offset in the bridge output.

Measurement range

The signal amplifier IC uses four resistors R1 to R4 selected by the four-position switch S2 to select one of four levels of gain. The resistor values chosen give switchable values of amplification in the range from 400 to 4000 times (these values proved useful for measuring standard rocket motors with the 'OTC KV 2001' model of kitchen scales used in the prototype by the author). The resistor values can of course be changed if you require some other gain values. Metal-film resistors are recommended throughout to help minimize noise.

In order for the analysis software running on the PC to be aware of the position of the amplification selector switch the second pole of this switch is used to ground one of the port pins of PC0 to PC3. These four pins are configured in software as inputs with pull-up resistors; only one pin will be pulled low depending on the measurement range selected.

The ATmega8 generates a 10-bit digital value for each sample then adds two bits to indicate the selector switch position. This is converted into three hexadecimal values which are then sent over the serial interface to the PC as ASCII characters. Together with the CR character which terminates each sample this gives four ASCII characters for each sample. An advantage of using ASCII coding is that the values can be displayed on a PC by running a simple terminal emulator program.

Construction

For the sake of simplicity and ease of construction a single-sided PCB has been developed which does not use any SMD packaged components. The author's PCB layout files are available for download from the Elektor website [2]. The PCB dimensions and position of the mounting screw holes are designed to fit in a translucent plastic enclosure type 2515KL made by Strapubox.

All of the project files can be freely downloaded from the Elektor website [2]. The same for a free supplementary document covering the operation of the analysis software. The connector K4 allows in-system programming (ISP) of the controller firmware. The connector pin definitions follow the standard layout which is compatible for example with the STK200 AVR starter kit made by Kanda [3]. While many programming adapters use this ISP convention their use of the Vcc connection is not consistent. Some adapters are powered by the target system while others supply power to the target system. Jumper JP1 allows both types of adapter to be accommodated.

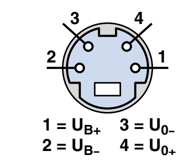


Figure 9. Pinouts of the mini DIN connector (viewed from solder side).

Software

Measurement data is sent over a serial interface cable to a PC (or to a USB port if a suitable USB/RS232 adapter is used, e.g. the Keyspan High Speed USB Serial Adapter USA-19HS [4]). A conversion program running on the PC reads the ASCII characters. The author has written the program in LabView and the .exe file can be downloaded from the Elektor website (**Figure 10**). The digitized measurement values have an accuracy based on the resolution of the A/D converter and must be scaled to take into account the bridge supply voltage and the constant of proportionality of the strain gage. In practice it will be necessary to null any offset caused by manufacturing tolerances in the bridge strain gage resistance and the mass of the weighing platform itself. The offset can be nulled with preset P1; each change in range requires readjustment. The software includes a method of calibrating the scale using known reference weights. This allows any zero offset to be nulled, and also the constant of proportionality for the load measurement transducer to be ascertained.

After calibration the software can plot the entire burn phase of the motor showing force against time. The results of each test can be stored for more detailed analysis later on. A description of this software can be downloaded from the project pages [2] (a LINUX version is also available on request from the author [5]).

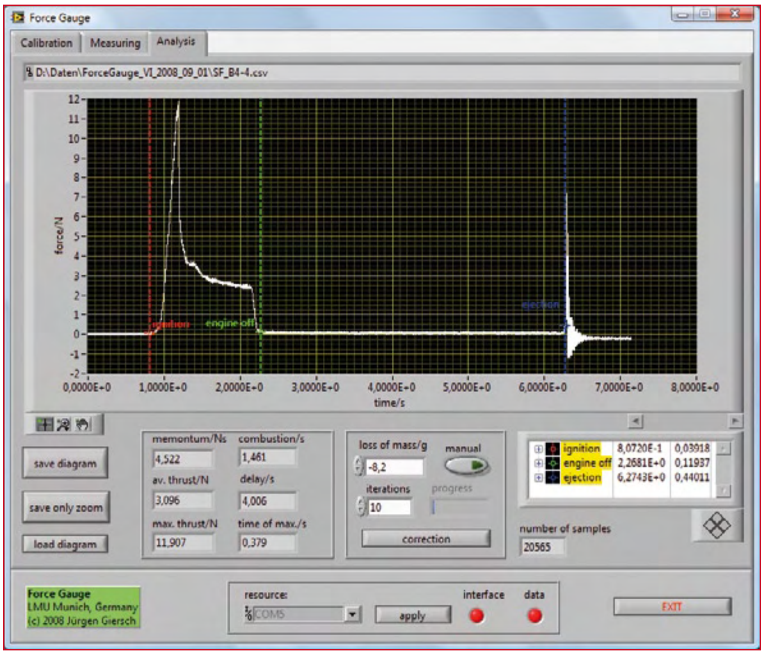


Figure 10. The author's analysis program.

(080027-I)

Internet Links

[1] www.analog.com/static/imported-files/data_sheets/AD620.pdf

[2] www.elektor-usa.com/080027

[3] www.kanda.com/products/kanda/STK200.html

[4] www.keyspan.com

[5] juergen.giersch@physik.uni-muenchen.de

Macros for ASM programming

Gert Baars (The Netherlands)

Through the use of directives found in the integrated assembler (version 2) of AVR Studio we can create instructions using macros that make it possible to have structured programming similar to that found in C or Basic. In computer science a macro is a set of instructions that can be assigned a unique name. In the program this set of instructions can be called using this name (this is not the same as a sub-routine where a set of instructions is called by jumping to its address).
When a macro is called the set of instructions following the name of the macro is inserted at the location where the macro is called. A macro can only be called during the assembly of the source and never during the execution of the program. The following example illustrates this.

First we define the macro:

```
.Macro swap
       push   @0
       mov    @0,@1
       pop    @1
.endm
```

The terms @0 and @1 used here are macro parameters that are passed to the macro when it is called. In this case they are two registers. The macro can now be called from anywhere in the program's source code to swap the contents of two registers. As an example:

```
       lsr    r17
; first a few arbitrary
lines of the source
       add    r17,r18
       swap   r17,r16
; and this is where the macro
is called with registers
r17 and r16
```

When the code is assembled the macro definition is put in place of the macro. Once it's been interpreted, the source code where the macro was now looks as follows:

```
       lsr    r17
; first a few arbitrary
lines of the source
       add    r17,r18
       push   r17
; "swap        r17,r16" has
been replaced according
to the macro definition
       mov    r17,r16
       pop    r16
```

The reason for using macros is that they make the source code easier to read, especially because the name given can identify their purpose. Macros are particularly useful in cases where a small number of instructions has to be called a number of times, where they can be replaced by a macro using an explanatory name. When there is a larger number of instructions, a subroutine is normally used instead.

It becomes possible to make your own instruction with the help of macros, as we've done in the previous example. It is also possible to define other instructions, such as 'Repeat-Until' or 'if-then-else' constructions, which are often found in higher-level languages. Here we'll give an example of the construction of a 'For-Next' macro. The For macro requires three parameters: a register for use as a counter, a constant for the initial value of the counter and a label with a unique name. This label has been added to enable the nesting of macros. The macro assigns the initial value to the counter and gives the address of the next instruction to 'lbl'.

```
;********************************
; FOR
;
; Usage: FOR <reg>,<k>,<lbl>
; reg = r16..r31
; k = initial value
; lbl = any name (but the
same as that used in Next)

;********************************

.Macro For
       ldi           @0,@1
       .set   @2 = PC
.endm
;********************************
```

The accompanying Next macro has the same parameters as the For macro, but here the constant holds the final value of the counter. This macro increases the counter by one and then compares it with the final value. As long as the value of the counter is smaller, the program jumps back to the address immediately following the For macro.

```
;********************************
; Next
;
; Usage Next  <reg>,<k>,<lbl>
; reg = r16..r31
; k = final value
; lbl = any name (but the
same as that used in For)

;********************************

.Macro Next
       inc           @0
       cpi
@0,low(@1+1)
       breq   Enxt
       rjmp   @2
Enxt:
.endm
;********************************
```

The macros can be used in the following manner:

```
       For    r16,0,movedata
           lpm          r0,Z+
           st     Y+,r0
           For
     r20,200,nxloop
                    lsl
         r21
                    eor
         r21,r18
           Next
     r20,245,nxloop
       Next   r16,255,movedata
```

Because of the additional labels the instructions can be nested in combination with other macros. Indenting the lines creates a clearer structure as is often seen in for example Pascal and C. It is somewhat unusual to add structure to assembly language in this way, but it almost becomes second nature when you use these macros.
Another example of a macro where a clear structure appears is the 'if-then-else' macro. The following example illustrates that the use of indentations with nesting also creates a clear structure, as is often found in higher-level languages.

```
       if  r17,he_,19
       begin label
           nop
           nop
           nop
       end label

       else lz2
          if r17,eq,r18
          begin nxt_
              nop
          end nxt_

          else nn12
                mov r17,r18
                inc r16
           end nn12

           nop
           nop
       end lz2
```

We can't really think of any disadvantages, except that labels have to be used with the begin and end instructions. Although these labels can be given any name, if we use names that are appropriate to the function of the code, they'll even improve the readability of the code when it is referred to again at a later date.

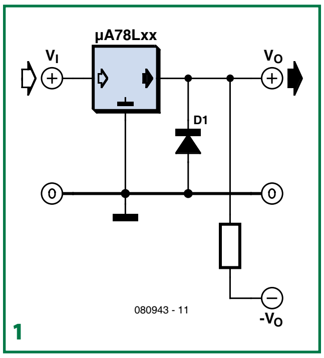
(070888-I)

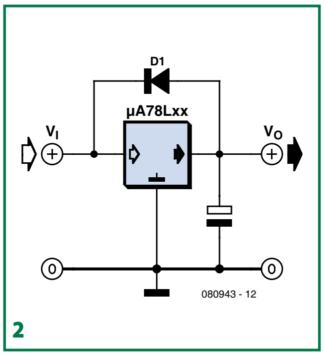
Protection for voltage regulators

Ton Giesberts

(Elektor Design Labs)

In many cases, the load connected to a voltage regulator is not returned to ground but to an even lower voltage or perhaps even the negative power supply voltage (here we make the assumption of using positive voltages; when using voltage regulators with negative output voltages the reverse is true).





Opamps, level-shifters, etcetera come to mind. In such cases, a diode (1N4001 or equivalent) connected across the output of the regulator IC usually provides sufficient protection (see Figure 1). Polarity inversions which could occur, for example, during power on or during a short circuit could prove fatal for the regulator IC, but such a diode prevents the output of the IC going lower than ground (well, minus 0.7 V, to be accurate). A short-circuit proof voltage regulator (such as the 78xx series) survives such a situation without any problems.

It is also possible for the input voltage of a voltage regulator to drop quicker than the output voltage, for example when there is a protection circuit which shorts the input power supply voltage as a result of an overvoltage at the output.

If the output voltage of the regulator is more than 7 V higher than the input voltage then the emitter-base junction of the internal power transistor can break down and cause the transistor to fail. To prevent this condition a shunt diode can be used (see Figure 2). This ensures that any higher voltage at the output of the regulator is shorted to the input.

(080943-I)

New Annual DVD 2008

Harry Baggen (Elektor Netherlands Editorial)

Elektor's new annual DVD 2008 appeared at the same time as the March 2008 issue. The DVD contains all the articles published during the previous year in pdf format. Since our magazine is published in an increasing number of languages, the capacity of a CD is now insufficient to store them all on one disk.

The annual CDs from Elektor are a very convenient way of storing all the issues of Elektor and search through all of them quickly, without the need to store stacks of paper and thumbing through many pages. Any particular article is located very quickly and displayed on the screen using Adobe Reader.

This is the first time that the entire Elektor annual volume is published on a DVD instead of the usual CD. Up till now all the articles were published in four languages: Dutch, German, English and French. Beginning last year a Spanish version was added. All of this together no longer fits on a disk with a capacity of 650 MB. Because changing to a DVD immediately increases the available capacity to 4.7 GB, this also gave us a great opportunity to improve the quality of the pdf files compared to those of last year. The result is a disk, containing Elektor in 5 languages, with a total file size of about 2.2 GB.

The structure of the annual DVD is unchanged from last year's CD. You only need and Internet browser which can use ActiveX or a computer which has the Java environment installed. Also make sure that these are enabled in your browser.

The DVD has an auto-start function for Windows computers. If this doesn't work, or you use another operating system, find the file index.html in the root of the DVD file structure and double-click this file. The default browser will open and display the start page. First select the desired language. By ticking the box at the bottom of the page, the selected language will be stored in a 'cookie' and the next time the program is started up it will start automatically with the selected language. Should you want to change the language after that, then click on the Elektor logo to return to the start page.

The features and usage of the DVD are identical to last year's version, so we do not need to say much about that. There is also an index function for older annual volumes, so that you can easily find older articles. It is possible to copy all the articles from the annual CDs since 1998 to the hard disk. This saves you from having to change the CD all the time.

From the hard-disk

Make a folder on you hard disk (for example C:\Elektor). Copy the entire contents from the 2008 DVD to this folder on your hard disk.

The folder \Elektor now contains five sub folders. Click the folder for the desired language (in our case \uk). At the top of the list of sub folders that now appears there will be the folder named \articles. This folder contains a number of sub folders with are named 1998 through 2008. The folder named 2008 is already filled with the articles from last year. If you have older annual CDs then you can copy the pdf files from those CDs to the folders with the corresponding year. For the 2005 annual CD you go to sub folder articles and then to sub folder E. In this folder select all files that have the pdf extension and drag these to the folder C:\Elektor\uk\articles\2005. If the question pops up whether to overwrite the existing files, answer with Yes (to all). This is because all these annual folders already contain a number of dummy pdf files, which will now be overwritten with the actual articles.

In this way you can combine the contents of the older annual CDs starting from 1998 into the new system. If, when you are searching for an old article, you arrive at an article that you do not have, then you will have the opportunity to click through to the Elektor website where you will have the option of buying and downloading the article.

(090170-I)

Hexadoku

Puzzle with an electronics touch

Sure, we've said it before: puzzle solving is good for brain stimulation. A Hexadoku is just the ticket — it's free, fun and represents a mental challenge if solved the hard way. So put your grey matter to work! All correct solutions we receive enter a prize draw for an E-blocks Starter Kit Professional and three Elektor Shop vouchers. Have fun!

The instructions for this puzzle are straightforward.

In the diagram composed of 16 × 16 boxes, enter numbers such that **all** hexadecimal numbers 0 through F (that's 0-9 and A-F) occur once only in each row, once in each column and in each of the 4x4 boxes (marked by the thicker black lines). A number of clues are given in the puzzle and these determine the start situation.

All correct entries received for each month's puzzle go into a draw for a main prize and three lesser prizes. All you need to do is send us the numbers in the grey boxes. The puzzle is also available as a **free download** from the Elektor website

SOLVE HEXADOKU AND WIN!

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

E-blocks Starter Kit Professional

worth **£300**

and three **Elektor SHOP Vouchers** worth £40.00 each.

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

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

PARTICIPATE!

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

hexadoku@elektor-usa.com - Subject: hexadoku 04-2009 (please copy exactly).

Note: new email address as of this month!

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

Alternatively, by fax or post to: **Elektor Hexadoku**

PO Box 876 - Peterborough NH 03458-0876 USA

Fax 603-924-9467

The closing date is **1 May 2009.**

PRIZE WINNERS

The solution of the February 2009 Hexadoku is: **3097D**.

The **E-blocks Starter Kit Professional** goes to:

Davy Van Belle (Belgium).

An Elektor SHOP voucher worth £40.00 goes to:

Andrés Tabernero García (Spain); Hans-Jörg Büning (Germany); Dudley Nichols (UK).

Congratulations everybody!

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0		3	E	F	D			A	B			C			

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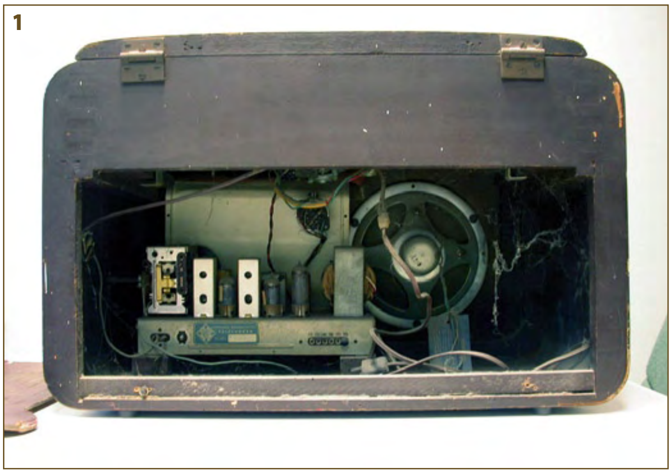

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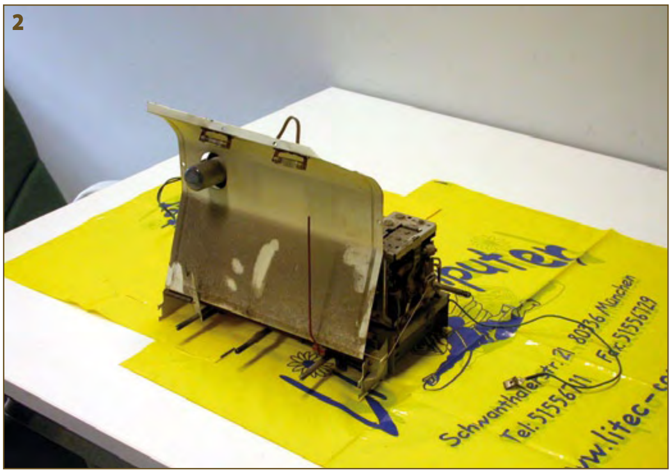

2

An old radio brought back to life

Joseph Kreutz (Germany)

A two page instalment of Retronics this month, originally written in French. *Ed.*

My colleague Giancarlo came into my office telling me he'd picked up an old tube radio that had been sitting for ages in his parents' kitchen. It wasn't working any more, and he asked me if it was possible to get it going again. I asked him to bring it to me. The patient I had to revive was a Telefunken model T 33 B RFS in a wooden cabinet, fitted with a turntable, and made in Italy around 1953. Lots of Internet sites offer circuits for these old receivers [1][2], so I had no trouble getting hold of one for it. The Internet also enabled me to download the datasheets for the tubes it was fitted with [3]. Surprisingly, certain firms still sell hardware for tube radios, among them [4]. Of course, these websites are far from being exhaustive. A few hours spent exploring the Internet is bound to turn up a lot more information, and will get you in touch with a fraternity marked by cheerful comradeship and old fashioned gentlemanly behaviour for the most part.

After several decades in the kitchen, the inside of the radio was covered with a thick layer of dust (**photos 1, 2, 3**) and the varnish on the cabinet had been dulled by a film of grease. So the first thing I had to do was dust out the receiver using a paintbrush and a vacuum cleaner (**photo 4**). Once this had been done, I removed the turntable and withdrew the chassis so I could clean it carefully, taking care not to rub off the markings on the components. I also cleaned the grease off the cabinet using isopropyl alcohol. I left the glass dial bearing the names of the stations and frequency indications well alone. The paint used for these markings usually becomes sticky or fragile as it ages, and any attempt to clean it ran the risk of destroying them for good. The turntable fitted to the receiver was also given a thorough cleaning. The original rubber belt had gone hard and was unusable. Luckily enough, I was able to find a substitute for it. I couldn't find out the make and type of the crystal cartridge fitted, and we weren't able to find any replacement styluses. Once I'd finished these cosmetic operations, I was able to turn to the electronics (**photo 5**).

As always, safety first! Tubes typically operate at voltages between 150 and 300 V, and instead of having power transformers, many of these old receivers are supplied directly from the AC power line. Even with the ones that do have a transformer, you never know if it may not have an insulation fault. So there's a real danger of getting a nasty shock, and you really can't take any risks! In the case of the Telefunken T 33 B RFS, the tube heater voltage is tapped off the primary of the transformer (!) whose secondary provides the HT supply.

The first operation was to replace all the electrolytic capacitors. These components don't last long, and typically fail after 20 or 30 years owing to degeneration, deformation or drying out of the electrolyte inside. The dial lamps were changed and the receiver powered up. The glow of the tube heaters showed they were working… but there was no sound coming out of the loudspeaker. The voltmeter showed the HT supply to be at its nominal value. Closer investigation revealed that one of the power resistors in the supply rail was open-circuit. Replacing this brought the receiver back to life. The UM35 'magic-eye' tuning indicator had lost its brightness, so a new tube was fitted. All that

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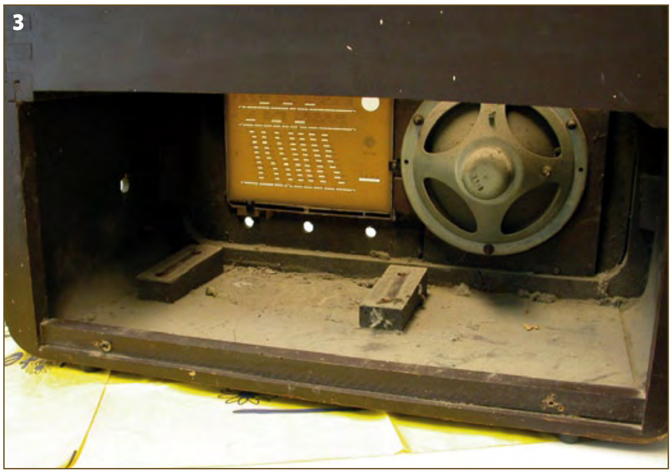

3


4

now remained to be done was to re-align the IF stage for best selectivity. But here, a nasty surprise was awaiting me — the adjustable cores of the IF transformers were secured using a little strip of rubber, which had hardened with age. It was impossible to loosen the cores with causing damage, so the adjustment could not be made [1]. As the receiver was already functioning very satisfactorily, we left things as they were. All that remained was to adjust the RF and local oscillator stage to maximize the sensitivity and to make sure that the dial indications corresponded to the frequency actually being received.

Now it was time to reassemble the receiver (**photos 6, 7, 8**). The chassis and turntable were fitted back into the cabinet and the connections re-made. The manufacturer hadn't provided any short-circuit protection for the receiver supply — in those days, such a precaution was not considered necessary. For safety's sake, two fuses were added into the power line cables. Following this rejuvenation, the receiver is now sitting in my colleague's flat, where I trust it will continue to give good, loyal service for several more years yet.

These old broadcast receivers have just as much of the charm of objects steeped in history as old items of furniture. And restoring them can be very educational too. When they were made, the engineers had to come up with an optimum but economically-viable result using just five or six active components. A far cry from today's MP3 players with tens of millions of transistors that fit in your pocket… Of course, tube technology is obsolete — but don't think of it as being more primitive than transistor technology. Quite the reverse — the engineers who developed it based themselves on an intimate knowledge of the laws of physics, and their sole resources were a sheet of paper, a pencil, their slide-rule… and lots of bright ideas. A long way from the digital methods nowadays that mean our computers can find the solutions to complex problems in just a few minutes.

Finally, this story covers the way the radio was made to operate again — no attempt was made to do a full restoration job. Several excellent books are available on restoring vintage radios and other venerable audio equipment; [5] and [6] are highly recommended.

(081140-I)

Internet Links and References

[1] www.justradios.com

[2] www.oldradioworld.de

[3] www.tubedata.info

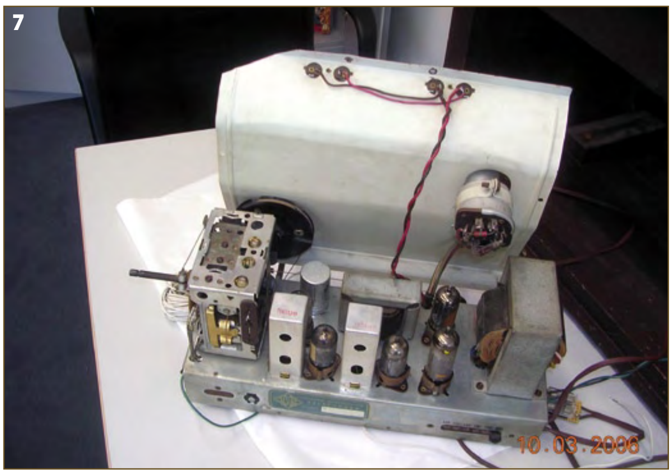
[4] www.tubesworld.com

[5] *Electronics Classics, Collecting, Restoration and Repair* (second edition). Andrew Emmerson, Newnes (ISBN 0-7506-3788-9).

[6]: *Tube Radio & Audio Repair Handbook*. Chas E. Miller, Newnes (ISBN 0-7506-3995-4).

[1] Editor's note: apply a drop of baby oil to the top of each ferrite core and allow the oil to travel down along the core thread. When the oil emerges at the underside, heat up the core gently with a blow dryer and attempt to loosen it with **two non-metallic** adjustment tools accurately fitting the slots provided, turning simultaneously at the top side and underside of the core.

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



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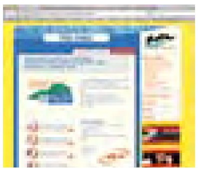

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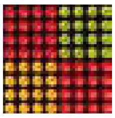

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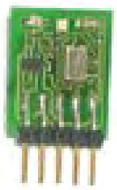

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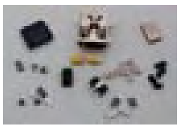

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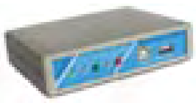

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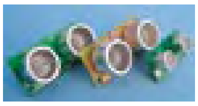

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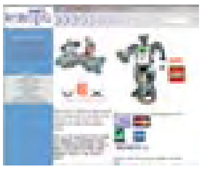

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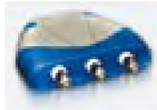

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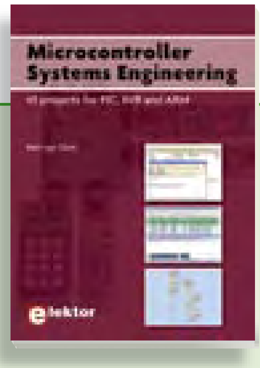

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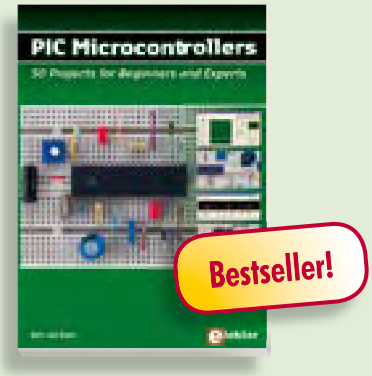

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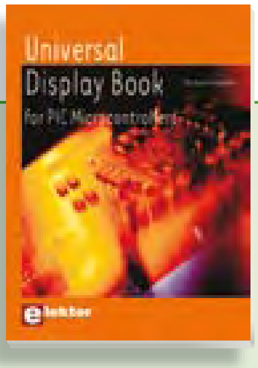

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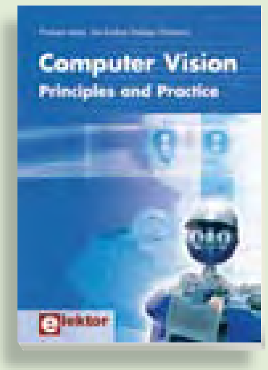

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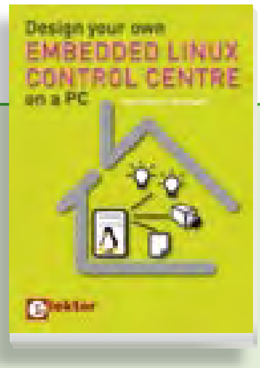

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February 2009 (No. 4)

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080689-41 .... PIC12F683, programmed 9.50

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080068-1 ...... Main PCB 42.00
080068-91 .... PCB, populated and tested 82.50

January 2009 (No. 1)

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December 2008

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November 2008

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071135-41 .... Programmed controller ATMEGA8-16PU 11.80

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071152-91 .... VDIP1 module 45.00

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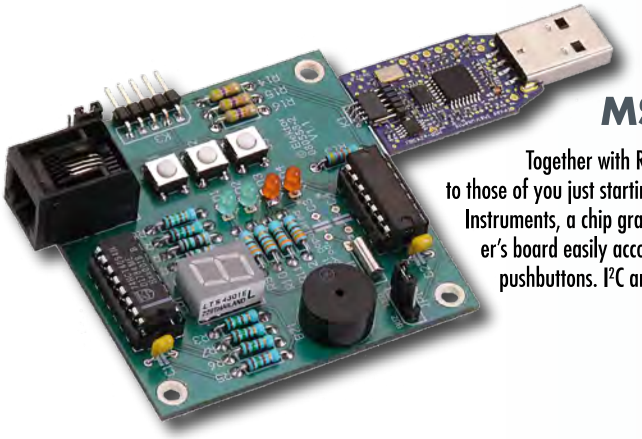
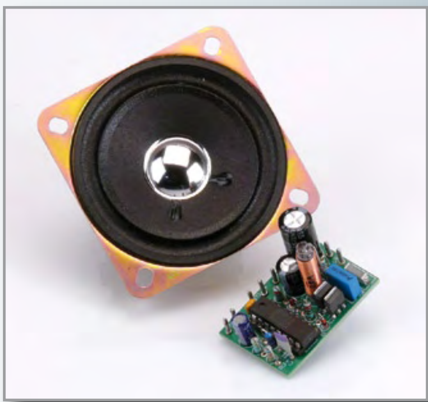


MSP430 Low-cost Development System

Together with Rotterdam's Technical College Elektor developed a low-cost development system that should appeal to those of you just starting out into microcontroller land. The basis of the system is the MSP-eZ430 USB-stick from Texas Instruments, a chip graced by a free development platform and a programming language (C). The associated experimenter's board easily accommodates the hardware for the project examples like a buzzer, a 7-segment display, some LEDs and pushbuttons. I²C and SPI connectivity is also provided.

True-rms Voltmeter with Frequency Meter

Test and measurement equipment for home construction is among our all-time favourites. Next month we present a digital voltmeter with four ranges covering 0.1 to 100 V. The instrument can show the rms value of sinewave inputs signals up to 1 MHz, while the frequency meter reaches up to 30 MHz. The circuit consists of a screened instrumentation amplifier and a readout section based on an R8C/13 micro linked to a 2-line LCD and an RS232 interface.



Mini PWM Audio Amplifier

Admit it — you too have one or more MP3 players idling about. Although these are great for train journeys or jogging tracks, you sometimes want to play that MP3 stuff out loud without having to use the headphones, or linking the player to the PC. A small amplifier is then called for, preferably one with high efficiency so why not go for state of the art PWM (pulsewidth modulation). The circuit is extremely simple and marked by sound reproduction not unlike that of a small tube amp. Battery-powered, this little amp can supply up to 1.5 watts into 4 ohms.

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