elektor electronics

leading the way

MAY 2007

£3.80

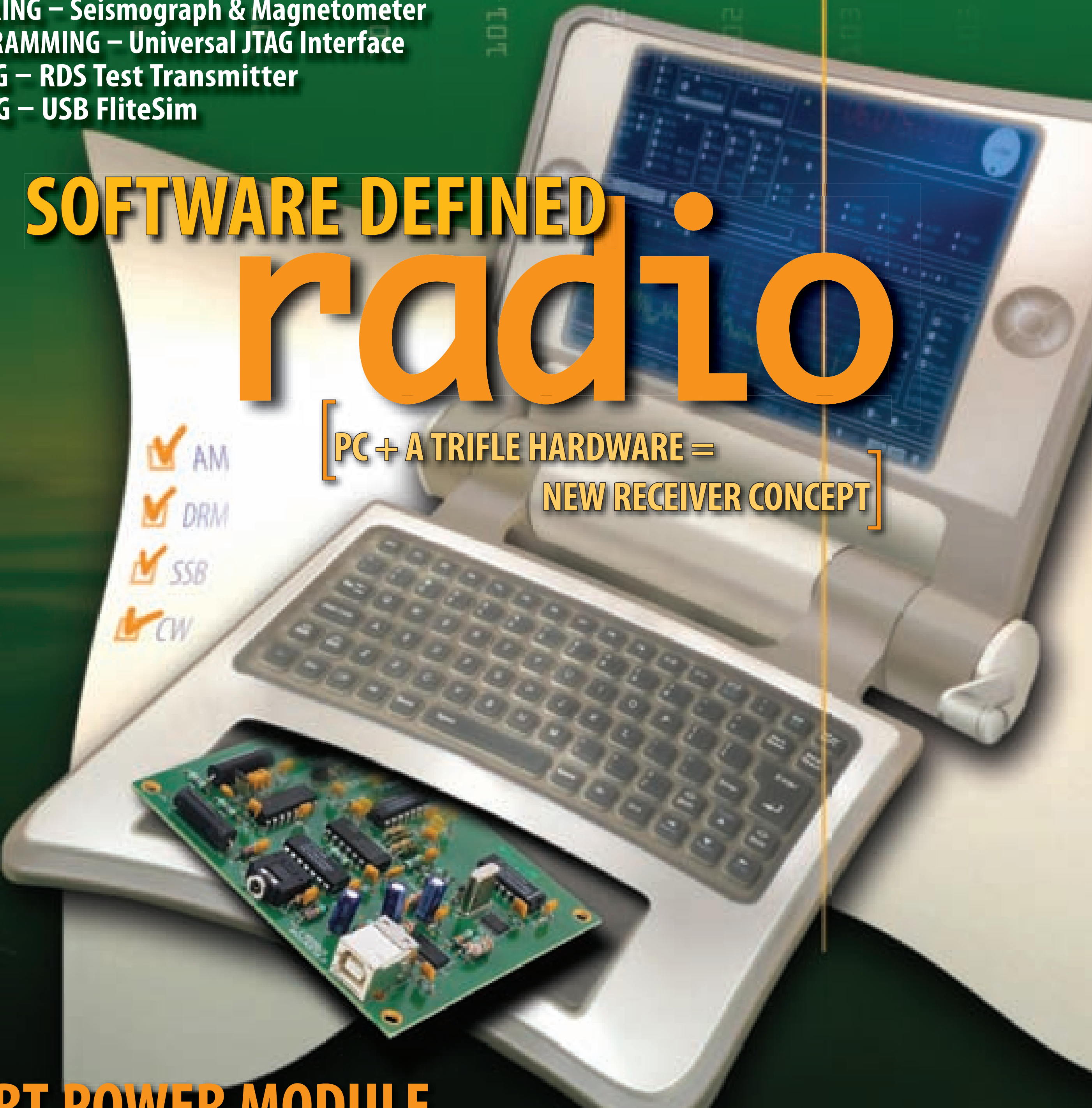
www.elektor-electronics.co.uk

PROJECTS

- SHOCKING – Seismograph & Magnetometer
- PROGRAMMING – Universal JTAG Interface
- TX-ING – RDS Test Transmitter
- FLYING – USB FliteSim

SOFTWARE DEFINED radio

[PC + A TRIFLE HARDWARE = NEW RECEIVER CONCEPT]



SMART POWER MODULE

FAIRCHILD ASYNCHRONOUS MOTOR CONTROL

E•L•F RECEPTION

MOTHER EARTH ON THE RADIO

R21
05

Ten Commandments of Electronics

1. Beware the lightning that lurketh in an undischarged capacitor, lest it cause thee to be bounced upon thy buttocks in a most ungentlemanly manner.

2. Cause thou the switch that supplies large quantities of juice to be opened and thusly tagged, so thy days may be only on this earthly vale of tears.

3. Prove to thyself that all circuits that radiateth and upon which thou worketh are grounded, less they lift thee to high frequency potential and cause thee to radiate also.

4. Take care thou useth the proper method when thou taketh the measure of high voltage circuits so that thou doth not incinerate both thee and the meter; for verily, thou hast no account number and can easily be replaced, the meter doth have one, and as a consequence, bringeth much woe unto CEO, Accounts & the Supply Department.

5. Tarry not amongst those who engage in intentional shocks, for they are not long for this world.

6. Take care thou tampereth not with interlocks and safety devices, for this will incur the wrath of thy Seniors and bringeth the fury of the Safety Officer down about thy head and shoulders.

7. Work thou not on energised equipment, for if you doth, thy buddies will surely be buying beers for thy widow and consoling her in other ways not generally accepted by thee.

8. Verily, verily I say unto thee, never service high voltage equipment alone, for electric cooking is a slothful process and thy might sizzle in thine own fat for hours on end before thy Maker sees fit to end thy misery and drag thee into His fold.

9. Trifle thou not with radioactive tubes and substances, lest thou commence to glow in the dark like a lightning bug, and thy wife be frustrated nightly and have no further use for thee except thy wage.

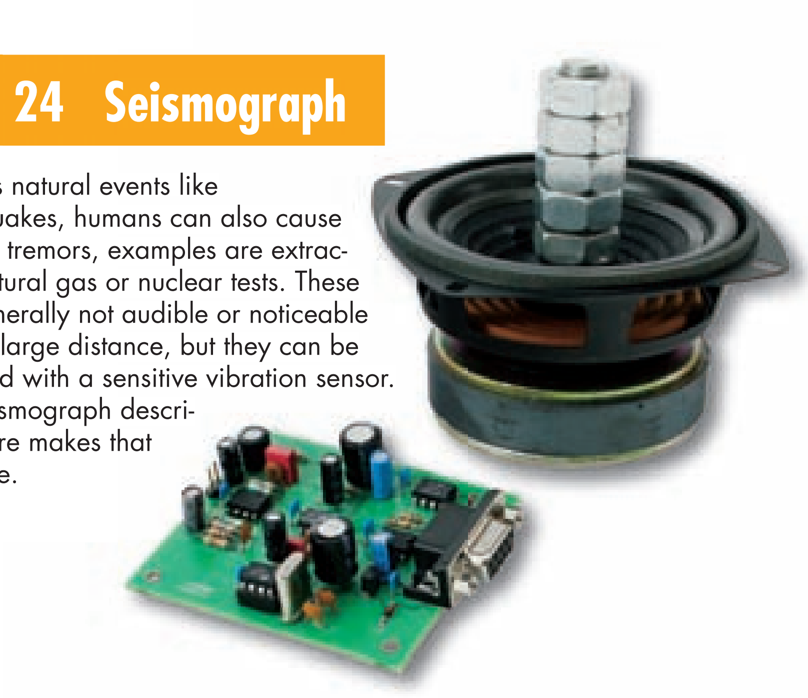
10. Commit thou to memory the works of the Prophets, which are written in the Instruction Books, which giveth the straight dope and which consoleth thee, and thou cannot make mistakes — yeah, well, sometimes, maybe.

(author unknown)

Software Define

SD radio receivers use a bare minimum of hardware, relying instead on their software capabilities. This SDR project demonstrates what's achievable, in this case a multi-purpose receiver covering all bands from 150 kHz to 30 MHz. It's been optimised for receiving DRM and AM broadcasts but is also suitable for listening in to the world of amateur transmissions.

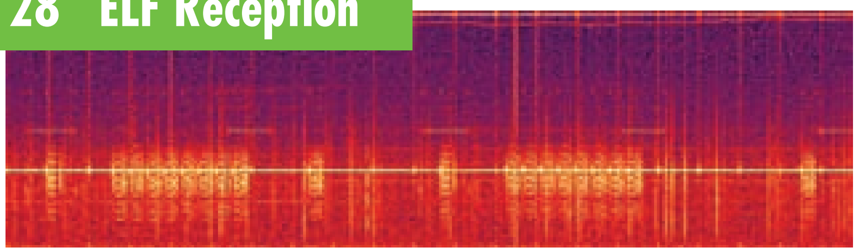
24 Seismograph



Besides natural events like earthquakes, humans can also cause seismic tremors, examples are extracting natural gas or nuclear tests. These are generally not audible or noticeable from a large distance, but they can be detected with a sensitive vibration sensor. The seismograph described here makes that possible.

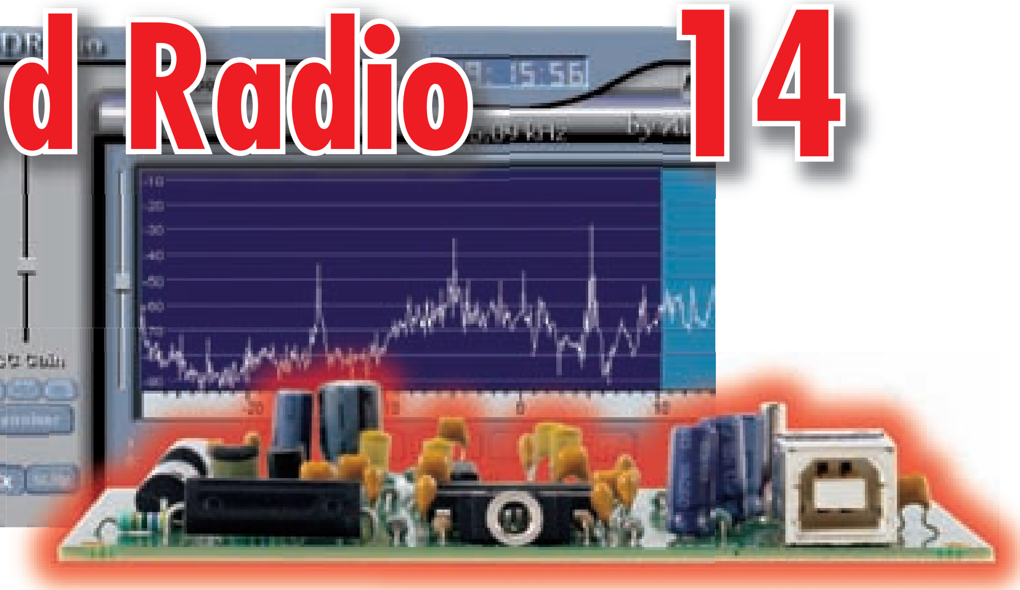
Mobile phones, Wi-Fi and satellite communications are increasingly making use of ever higher frequencies stretching up into the Gigahertz bands. That doesn't mean that there is nothing interesting going on at the other end of the radio spectrum. We build a simple receiver and tune into some of the more bizarre signals in the extremely low frequency (ELF) domain.

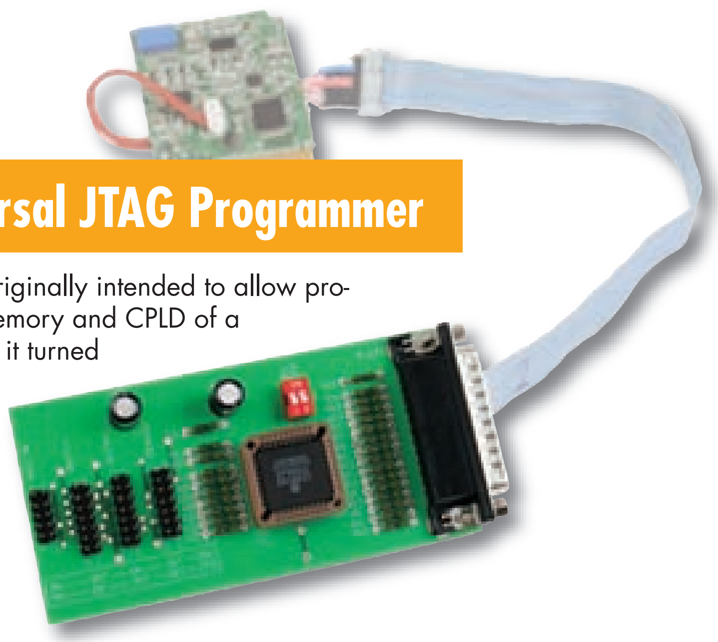
28 ELF Reception



CONTENTS

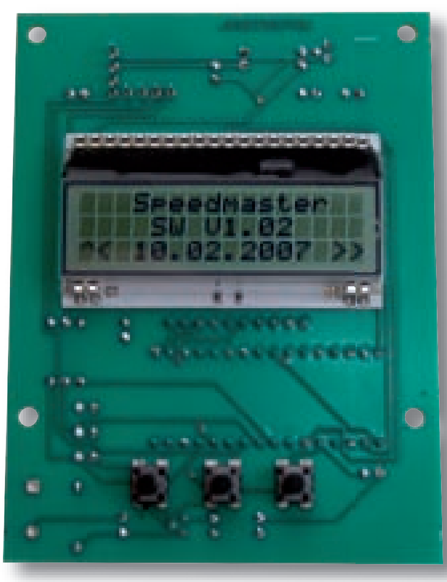
Volume 33
May 2007
no. 365





56 Universal JTAG Programmer

This adaptor was originally intended to allow programming of the memory and CPLD of a PSD813 device. As it turned out, it's much more universal than that! Our adaptor connects to a PC parallel port and uses the JTAG IEEE 1149.1 protocol.



50 Speedmaster

Here is the circuit voted winner of the International R8C Design Competition by *Elektor Electronics* readers: an intelligent 3D accelerometer that not only measures acceleration on all three spatial axes, but also calculates the total distance moved. And, as promised, a ready-assembled printed circuit board!

projects

technology

info & market

infotainment

elektor electronics — leading the way

Volume 33, Number 365, May 2007 ISSN 0268/4519

Elektor Electronics 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 Electronics (Publishing), Regus Brentford, 1000 Great West Road, Brentford TW8 9HH, England. Tel. (+44) 208 261 4509, fax: (+44) 208 261 4447 www.elektor-electronics.co.uk

The magazine is available from newsagents, bookshops and electronics retail outlets, or on subscription. *Elektor Electronics* is published 11 times a year with a double issue for July & August.

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

International Editor: Mat Heffels (m.heffels@segment.nl), Wisse Hettinga (w.hettinga@segment.nl)

Editor: Jan Buiting (editor@elektor-electronics.co.uk)

International editorial staff: Harry Baggen, Thijs Beckers, Ernst Krempelsauer, Jens Nickel, Guy Raedersdorf.

Design staff: Antoine Authier, Ton Giesberts, Paul Goossens, Luc Lemmens, Jan Visser, Christian Vossen

Editorial secretariat: Hedwig Hennekens (secretariaat@segment.nl)

Graphic design / DTP: Giel Dols, Mart Schroijen

Managing Director / Publisher: Paul Snakkers

Marketing: Carlo van Nistelrooy

Customer Services: Margriet Debeij (m.debeij@segment.nl)

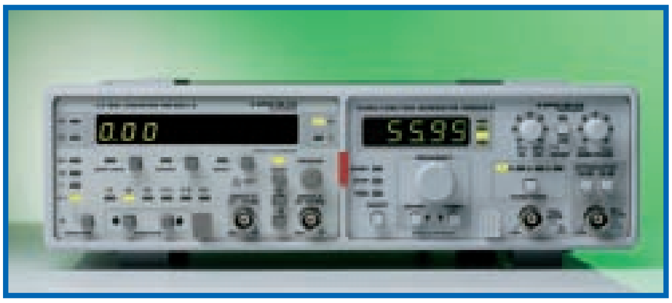
Subscriptions: Elektor Electronics (Publishing), Regus Brentford, 1000 Great West Road, Brentford TW8 9HH, England.
Tel. (+44) 208 261 4509, fax: (+44) 208 261 4447
Internet: www.elektor-electronics.co.uk
Email: subscriptions@elektor-electronics.co.uk
Rates and terms are given on the Subscription Order Form

Head Office: Segment b.v. P.O. Box 75 NL-6190-AB Beek The Netherlands
Telephone: (+31) 46 4389444, Fax: (+31) 46 4370161

Distribution: Seymour, 2 East Poultry Street, London EC1A, England
Telephone:+44 207 429 4073

UK Advertising: Huson International Media, Cambridge House, Gogmore Lane, Chertsey, Surrey KT16 9AP, England.
Telephone: +44 1932 564999, Fax: +44 1932 564998
Email: p.brady@husonmedia.com
Internet: www.husonmedia.com
Advertising rates and terms available on request.

International Advertising: Frank van de Raadt, address as Head Office
Email: advertenties@elektuur.nl
Advertising rates and terms available on request.



Hameg function generator

Dear Jan — I read with great interest your overview of function generators (March 2007, *Ed.*). I spotted an error though in the specs you printed for the Hameg HM8030-6. As the designer of the instrument, I should point out that the 8030-6 does have a VCF input — it is accessible at the rear side of the motherboard module HM8001-2. This function is also described in the user manual. Also at the rear side is the output supplying the sawtooth used by the swept frequency generator. This signal ensures the correct triggering during the swept frequency measurement and is particularly useful for bandwidth measurements.

Michael Waleczek (Germany)

Thanks for that Michael, you are right, the VCF input should have been included in the table. The two outputs are mentioned in the user manual. Interested readers may find the 8030-6 specs sheet and manual on the Hameg website at www.hameg.com.

Freescale at last

Dear Editor — I was thrilled to see Elektor taking the lead again by covering Freescale micros in a way suitable for beginners. I just wanted to let you know that I worked on a compact baseboard for the Freescale 9S08GB60. My 'GB60 Board' is compatible with the open-source BDM you mentioned, as well as the SpYder BDM you sell (well done on the low pricing for that!). My homepage is at www.qdev.de for all interested readers to visit.

Stefan Robl (Germany)

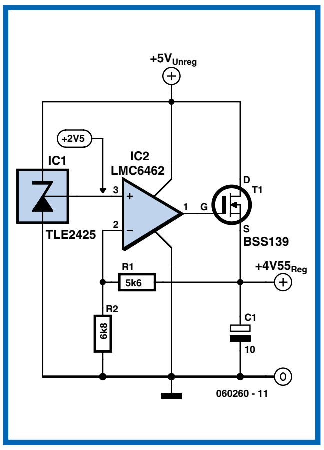
We are pleased and not a little proud that our publications on Freescale micros and the accompanying low-cost SpYder kit have been received with great enthusiasm from our readers. Freescale, as part of a new strategy to broaden their markets, has chosen Elektor as one of their vehicles to reach tens of thousands of electronics enthusiasts, lab workers and students, rather than a handful of high-end professional customers. Elektor will publish further MC9S08 projects later this year.

Wrong circuit symbol

Dear Jan — may I just point out that in your article 'LDO Regulator' (Design Tips, February 2007) you used an incorrect circuit symbol for the FET. The BSS139 is a 'depletion-mode' MOSFET; your symbol is for an enhancement-mode device.

Dave Moffat (UK)

You are right Dave. The correct device symbol is printed here. Note the solid line between drain (D) and source (S) terminals, indicating the self-conducting FET, which starts to work at UGS=0 V.



Corrections & Updates

Shortwave Capture

December 2006, p. 24-33, ref. 030417-I.

Inductors L11 and L14 have been transposed on the component overlay. This may be corrected by transposing the component references in circuit diagram Figure 2. In the components list, L11 should be marked as 1µH2.

The PCB design has a length of copper track missing at pin 19 of the MAX7219. The connection should be made with a piece of wire. Updated Gerber files were sent to ThePCBShop on 2 March 2007 The corrected parts list and PCB artwork (pdf file) may be downloaded from our website.

Depending on the response of the readout to fast turning of the rotary encoder, and the encoder used, the value of capacitor C40 may be changed a little.

Although on MIX1 the marking is with pin 6 instead of pin 1, the device can be mounted as shown because of its internal symmetry.

For SSB reception, the amount of frequency pull that can be obtained from the CSB455 device (X3) will depend on the exact type and brand. The CSB455 supplied by Barend Hendriksen and used in our prototype gave good results. Suggested methods of obtaining sufficient pull from nondescript CSB455 devices may be found on our Forum.

AVR drives USB

March 2007, p. 34-38, ref. 060276-I

In the components list, IC4 should be marked ULN2803, not ULN2003. Also, R4 should be 1kΩ5, not 1kΩ.

Sputnik Time Machine

January 2007, p. 42-45, ref. 050018-I

In the components list, 'R15' should read 'R9'. Capacitor C8 is listed as 4µF7 400V, but appears as 10µF/350V in the schematic. Either value will work as only little current is drawn from the high-voltage supply, and even 4µF7/180V will work in this circuit.

Battery voltage from the USB?

Dear Jan — I found a website showing details of a battery supply implemented by 'stealing' power from the USB port, see www.hackaday.com/2005/01/20/how-to-make-a-usb-battery/. Can you tell me if this is and good and safe to use as a power source for my MP3 player? The original battery lasts for a good half hour only. I'm sure Elektor readers will also find this of interest.

Fred Jackson (USA)

Although the method described on the site will work in practice, it is a tad wasteful of energy. One of the comments under this DIY tip hints that it is better to connect four penlight batteries in series and then add a diode in series with the USB connector. This will yield a supply voltage close to 5 V. Another option is to line up four penlight rechargeables in series (NiMH or NiCd), this should also give you about 5 volts but without the diode in series.

RFID Reader fine tuning

Dear Jan — I read with great interest your article on improving the sensitivity (or, detection range) of the Elektor RFID reader (Labtalk, January 2007, *Ed.*). I only have a grid dipper available for my measurements and I have resolved resonance at 12.1 MHz with about 400 kHz worth of incertitude. The coupling between the etched coil on the RFID Reader board and the meter coil has to be very light and you need to take the average of the 'rising' and the 'falling' dip observed on the meter ('rubber band' effect, *Ed.*). The accuracy so obtained I reckon is sufficient for amateur use, also considering the *Q* factor.

I have also tested one of your RFID cards and found it to resonate at about 14.8 MHz ±200 kHz using the above method. Unfortunately only one card was available. Would you be so kind as to inform me about the exact resonance frequency of your cards, mine is a Philips MyFare supplied with the magazine (September 2006, *Ed.*).

Thanks for your interest and please inform me if my measurements are any good.

Patrick Dourlet F4EKN (France)

Thanks for your response to my article and glad to see that you confirm my findings.

The resonance frequency of the printed coil on the MyFare RFID cards is purposely set slightly higher than the theoretical value of 13.56 MHz because detuning (down pulling) occurs when the card is within the E/M field of the transmitting coil. Once E/M coupled, the two coils form a mutually damping, overcoupled L section. So, although you (and we) correctly measure about 14-15 MHz with a lightly coupled dip meter, in actual fact optimum resonance occurs at a slightly lower frequency (13.6 MHz approx.) when the card is actually read. As I wrote in my article, the frequency that gives the largest card detection range can only be found empirically. I stopped my experiments once a range of about 5 cms was achieved but more may well be possible.

Due to the production methods and components used, a tolerance of about 1 MHz (i.e. 7%) should be taken into account in the resonance frequency of our RFID cards. This is well within the standards for 13.56 MHz RFID systems.

The dip meter in our laboratory is about 25 years old, cheap and flaky and I would not expect it to offer an accuracy that's anywhere near the figures you mention. I can confirm however that a resonance was measured just above 14 MHz.

Patrick responds:

Dear Jan, thank you for your reply wich was very pertinent and interesting. That's just funny to say 13.56 with 7% tolerance. Why not 13.5612263 ± 1 MHz hi!

As we say in our ham community, HF articles are scarce in Elektor but they are always of quality.

Best regards, Patrick.

Solution to Hexadoku March 2007

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

Elektor Flash Micro board (1999)

Hello Jan — Further to my e-mail earlier today regarding my comms problems with the Flash microcontroller Starter Kit. I looked on Burkhard Kainka's own web site & found a FAQ for 'Microcontroller Basics'. It makes reference to updates to ATMELISP, MicroFlash, & TASMEdit specially for use with the updated AT89S82**53** microcontroller. I downloaded these and.... success!

Once I knew the file names, I found MicroFlash53, & TASMEdit53 on your supplied CD in a separate directory. I did not realise the significance of the '53' to match the controller's last two digits.

No versions of ATMELISP are on your CD (either for **AT89S8252** or **AT89S8253**), but that is OK if it is not your software.

However, perhaps a README.TXT file could be included on the CD to direct people to use the relevant software for TASMEDIT & MICROFlash and a link to the correct edition of ATMELISP, depending on their type of microcontroller.

I am now very much looking forward to learning about Microcontrollers.

Chris Johnson (UK)

Since publishing the article on the Flash Microcontroller Board in December 1999 (!), the AT889S8252 went obsolete. Several notices appeared in Elektor advising readers of the '53 device as a possible replacement for the '52, along with updated, improved, software. Chris is now one of about 3,600 happy users of the Elektor Flash Micro board.

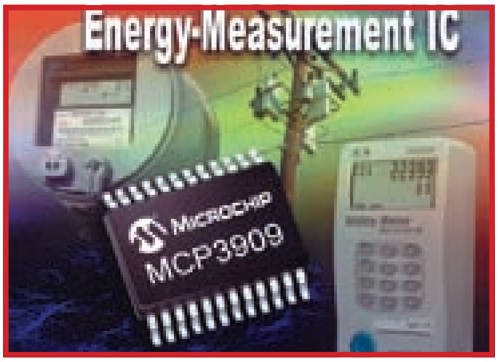
MailBox Terms

- Publication of reader's correspondence is at the discretion of the Editor.
- Viewpoints expressed by correspondents are not necessarily those of the Editor or Publisher.
- Correspondence may be translated or edited for length, clarity and style.
- When replying to Mailbox correspondence, please quote Issue number.
- Please send your MailBox correspondence to:

editor@elektor-electronics.co.uk or
Elektor Electronics, The Editor,
1000 Great West Road,
Brentford TW8 9HH, England.

Next generation energy-measurement IC and reference design

Microchip Technology. recently announced the MCP3909 energy-measurement IC and reference design. The highly accurate IC combines low power consumption with an SPI interface and active power-pulse output, making it adaptable to a wide variety of meter designs. Together with the MCP3909 3-Phase Energy Meter Reference Design, the IC enables designers to develop and bring meter designs to market quickly.



The MCP3909 IC has two 16-bit delta-sigma Analog-to-Digital Converters (ADCs) onboard that can be accessed through its SPI interface, while simultaneously providing a pulse output with a frequency proportional to the active-power calculation. This simultaneous output of data makes the IC flexible and easy to use, as well as adaptable to a variety of meter requirements. Additionally, with its very low, 0.1% typical measurement error over a 1000:1 dynamic range, the MCP3909 IC easily fits into meter applications requiring high accuracy. Its extremely low supply current of only 4 mA makes it suitable for many single- and three-phase energy meter designs, and helps customers remain within their power budget.

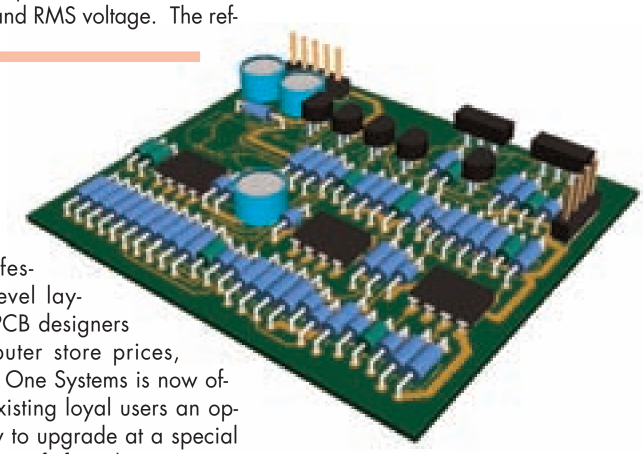
The MCP3909 3-Phase Energy Meter Reference Design (Part # MCP3909RD-3PH1) in-cludes three MCP3909 ICs, plus a PIC18F2520 and a PIC18F4550 microcontroller. The PIC18F2520 performs all power calculations in the reference design, while the PIC18F4550 provides a USB interface to desktop software. The software package that comes with the reference design enables meter calibration and the ability to read active and apparent power, as well as RMS current and RMS voltage. The reference design is expected to be available for purchase in March at www.microchipdirect.com, at a price of $175 each.

For additional resources, visit Microchip's online Utility Meter Design Center at

www.microchip.com/meter

(070017-III)

Easy- PC is more popular than ever



Demand for Easy-PC, the world's leading entry-level PCB design software continues to grow. New users are attracted by the fact it still continues to offer product features and options found in many of the world's leading PCB design systems for the price of standard PC software on the High Street.

Easy-PC For Windows may have been launched in the early Windows operating system days 10 years ago, but the release of V10 demonstrates it still leads this market sector. Windows Vista compatibility, Spice Simulation, Library creation Wizards and 3D Viewer are just some of the new features now available in this exciting product.

The original Easy-PC was launched in 1989, winning a British Design Award the same year. Easy-PC For Windows is Microsoft Accredited and there are has over 45,000 Easy-PC users across more than 100 countries.

Renowned for offering professional level layout for PCB designers at computer store prices, Number One Systems is now offering existing loyal users an opportunity to upgrade at a special price to benefit from the investment and features they've incorporated in Version 10.

New Easy-PC systems start at £227 for a 1000-pin limited version.

(070212-1)

www.numberone.com

Vero Technologies purchases moulded enclosures business from APW

Vero Technologies has acquired all the moulded enclosure and card guide standard product lines from APW (in administration), and manufacturing of all items has recommenced from the original tooling, guaranteeing continuity of supply. Such well know brand names as Veronex, IDAS, Apollo, General Purpose Box, Patina and many others are back in full scale production, enabling companies who had specified the products as the housing for their equipment to continue to purchase. A large number of accessories such as battery holders, various designs of card guides, both general purpose and specific to the KM6 subrack system, are also available.

In addition to supplying the enclosures as standard products, Vero Technologies offer the additional service of customisation, with drilling, punching, legend silk screening and custom front panel manufacture provided on short lead times.

Vero Technologies also manufactures the iconic Veroboard, also know as Stripboard, Verowire wiring pens, extender boards, loop terminal assemblies, PCB test points, solder pins and a wide range of electronic prototyping boards and breadboards for the electronics engineer.

(070212-3)

www.verotl.com

LP Radio system-on-a-chip named finalist of 2007 EE Times ACE Award for Ultimate Product of the Year

Cypress Semiconductor Corp. announced that its WirelessUSB(tm) LP radio system-on-chip was named as a finalist for CMP Technology's EE Times third Annual Creativity in Electronics (ACE) Awards for 2007 Ultimate Product of the Year in the RF/Microwave category. The Ultimate Products of the Year are awarded to the most significant product introduced in the last 12 months in each of seven categories, as determined by large-scale peer review.

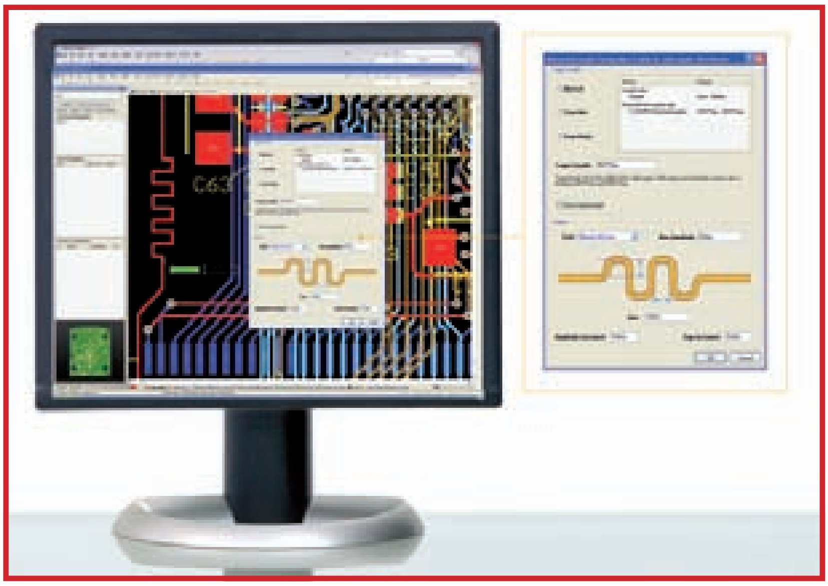
WirelessUSB LP (CYRF6936) is a highly integrated 2.4-GHz radio transceiver plus digital baseband that enables customers to replace cables without compromising end-user experience. Manufacturers of Human Interface Devices (HIDs) and other wireless applications avoid power-consumption issues with WirelessUSB LP's advanced power-optimization techniques that extend battery life to greater than one year. Likewise, the device addresses range and robustness concerns with Cypress's AgileHID(tm) protocol with patented frequency agile Direct Sequence Spread Spectrum (DSSS) technology for best-in-class interference immunity.

Cypress recently announced that WirelessUSB LP has earned over 175 design wins in under a year. Cypress's WirelessUSB LP offers an unparalleled feature set to enable superior interference immunity, low bill-of-materials (BOM) costs, higher data rate applications, and faster time-to-market for keyboards, mice, gaming devices, presenter tools, and remotes, as well as other simple, multi-point-to-point wireless applications. Featuring a highly integrated radio transceiver plus digital baseband on a single chip, it operates between 1.8 and 3.6 volts, using advanced power-saving techniques to extend battery life in devices such as wireless mice. WirelessUSB LP uses Cypress's patented frequency agile DSSS technology to offer best-in-class interference immunity for a 2.4-GHz radio system. This combination of low power consumption, interference immunity and low cost make it ideal for wireless HID applications

(070212-2)

www.cypress.com

Altium Designer busts high-speed design myths



Altium Limited announced the addition of a raft of new productivity-enhancing features for its Altium Designer unified electronics development system to assist engineers deal with the ever changing nature of today's mainstream board-level design and its convergence with the wider electronics development process.

With the latest electronic components offering a wide range of fast-switching I/O and dense packaging options, particularly in the latest generation programmable devices, Altium has focused development of its Altium Designer system to include a wide range of high-level interactive and automated tools designed to allow all engineers to assess, manage and troubleshoot signal integrity issues.

Altium Designer now adds interactive net length tuning, enhanced board layer navigation and more powerful polygon area fill placement modes to its arsenal of high-speed, high-density capabilities that already includes interactive differential pair routing, impedance-controlled routing, built-in signal integrity analysis and termination matching, automatic BGA escape routing, automatic FPGA board-level pin optimization and full PCB-FPGA bi-directional design synchronization.

Altium Designer's intelligent interactive routing system has been enhanced with the addition of a new interactive length tuning tool specifically for high-speed designs. This new feature allows designers to quickly optimize and control net lengths by dynamically inserting 'accordion' segments into a track. Tuning can be manual or rules-driven, and designers can select from a number of amplitude styles available in the system. This feature combines seamlessly with impedance-controlled, differential pair and multi-trace routing capabilities to give Altium Designer users a comprehensive interactive solution tuned for the high-speed, high-density board design projects that are being significantly impacted by modern day programmable devices.

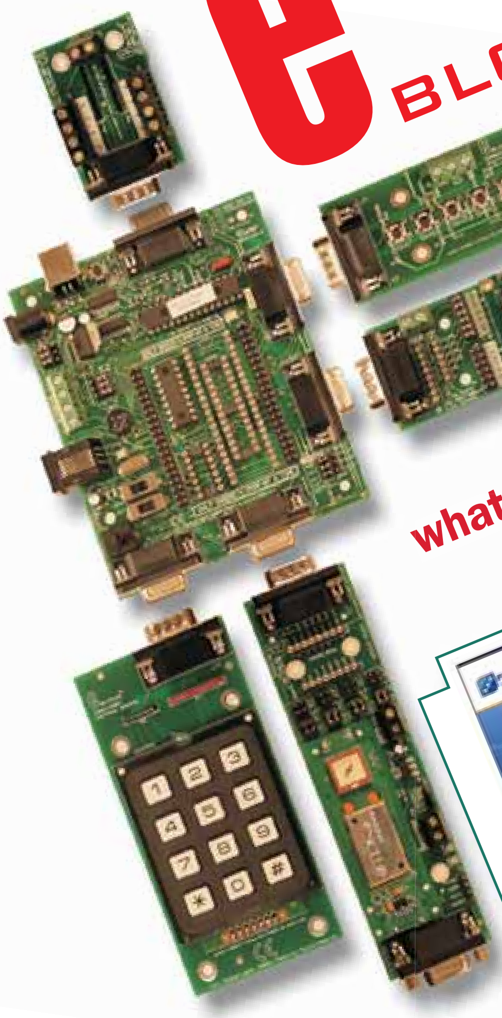
Several board-level system enhancements, and more, are now available with the latest software update called Altium Designer 6.7. All Altium Designer 6 license holders can download this update for free at www.altium.com/Community/Support/SoftwareUpdates/.

Altium Designer 6 is available for purchase through Altium's sales and support centres worldwide. For information on pricing and flexible product licensing options, customers should contact their local Altium sales and support center.

(070212-4)

www.altium.com/contacts.

E-BLOCKS™



whatever you want to make

£ 171.80

Easy ARM Kit

This bundle includes a copy of our C for ARM microcontrollers course (incl. full C compiler), an E-blocks ARM programmer, a LED board, a LCD board and a Switch board.

£ 166.00

Starter Kit Professional

This bundle includes Flowcode software, an E-blocks USB multiprogrammer, a LED board, a LCD board, a Switch board and a free PIC16F877 microcontroller.

£ 171.80

Easy AVR Kit

This bundle includes a copy of our C for AVR microcontrollers course (incl. full C compiler), an E-blocks AVR multiprogrammer, a LED board, a LCD board and a Switch board.

£ 171.80

Easy PIC Kit

This bundle includes a copy of our C for PICmicro microcontrollers course (incl. full C compiler), an E-blocks PICmicro multiprogrammer, a LED board, a LCD board, a Switch board and a PIC16F877 microcontroller.

NEW

£ 299.00

Easy CAN Kit

This bundle includes everything you need to develop CAN bus systems: Flowcode software, two E-blocks USB multi-programmers, a LED board, a LCD board, a Switch board, two CAN boards and two PIC16F877 microcontrollers.

£ 232.50

Easy Internet Kit

This bundle includes everything you need to develop internet systems: Flowcode software, an E-blocks USB multiprogrammer, a LED board, a LCD board, a Switch board, an Internet board and a PIC16F877 microcontroller.

Our range of more than 40 hardware circuit blocks, 6 CD-ROMs, 50 sensors and a host of accessories and support materials, means that whatever you want to make, you can make it with E-blocks.

If you are a beginner then we suggest you start with one of our E-blocks Starter Kits. These have everything you need for your first project. If you need to learn how to program in C for AVR, PIC, or ARM, or you want to connect your system to the internet, or develop CAN bus communication systems, then we have the right starter kit for you.

YOU'LL SAVE A MASSIVE 30% DISCOUNT W.R.T. INDIVIDUAL ITEMS!

If you want to make up your own kit then it is also easy: just select the items you need for your project from the list below.

Modules

ARM programmer	£ 89.20
AVR multiprogrammer	£ 77.65
Bluetooth board	£ 117.80
Bluetooth CODEC board **NEW**	£ 119.00
CAN board	£ 33.50
CPLD board	£ 117.95
FPGA daughter board	£ 104.50
Graphical LCD display **NEW**	£ 89.30
Internet board	£ 71.95
IR/IRDA transmitter receiver	£ 58.50
LCD board	£ 19.30
LED board	£ 14.65
MIDI board **NEW**	£ 35.70
Power board	£ 35.95
Prototype board	£ 20.50
Quad 7-segment display	£ 19.30
RS232 board	£ 29.95
Screw terminal board	£ 14.65
Switch board	£ 14.65
USB multiprogrammer	£ 77.30
X-10 home automation board	£ 15.95

Software (single user)

Assembly for PICmicro MCUs	£ 117.90
C for ARM microcontrollers	£ 118.00
C for AVR microcontrollers	£ 118.00
C for PIC microcontrollers	£ 118.00
Flowcode for PICmicro MCUs v3 (pro version)	£ 118.00
Programmable Logic Techniques	£ 117.90

Ordering

Use the order form at the back or go to www.elektor-electronics.co.uk (shop).
E-blocks will be shipped after receipt of payment. Prices are exclusive of postage.

elektor electronics — leading the way

Free downloads available on www.elektor-electronics.co.uk/eblocks!

Helping You Succeed

Does your business need more support and resources?

Successful organizations recognize the value of a strategic supplier relationship to help them deliver innovative products to their markets in a timely and cost-effective manner. Microchip Technology supports more than 45,000 customers worldwide, and we're committed to helping you succeed. In addition to our high-performance silicon solutions, Microchip provides a long list of support functions that reduce time to market and lower your total system cost. And we have significantly expanded our local technical resources.

Use microchipDIRECT to:

Register today!

- Order directly from Microchip, 24 hours a day, 7 days a week with a credit card or credit line
- Receive competitive, direct volume pricing on all devices
- Check our product inventory
- Order broken reels at steep discounts
- Use fast and inexpensive production programming (now available)
- Place and maintain your order securely from any network connection
- Assign a PO number to your order
- Create a unique part number for any item ordered
- Receive e-mail notification of orders, deliveries, quote status and more

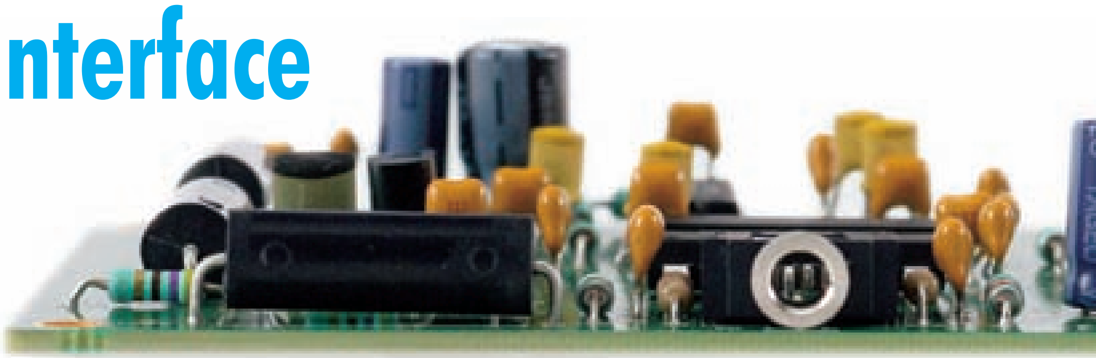
microchip DIRECT
www.microchipdirect.com

Now Pb-free! RoHS Compliant

MICROCHIP
www.microchip.com

Software Defined

With USB Interface



Burkhard Kainka

SD (software-defined) radio receivers use a bare minimum of hardware, relying instead on their software capabilities. This SDR project demonstrates what's achievable, in this case a multi-purpose receiver covering all bands from 150 kHz to 30 MHz. It's been optimised for receiving DRM and AM broadcasts but is also suitable for listening in to the world of amateur transmissions.

The designer's aim for this project was to create a receiver displaying high linearity and phase accuracy. Development was focussed on the characteristics that were most important for a top-notch DRM receiver and the end result is a receiver with remarkable interference rejection characteristics. Reception of DRM stations using DREAM software produced signal-to-noise ratio (S/NR) values of well over 30 dB. The design principle of the receiver guarantees an extremely flat filter-curve response. This works out rather well not only for DRM but also for the audio quality of AM broadcasts, which sound almost as good as VHF FM. It's worth noting too that some transmitters that do not conform to the normal bandwidths laid down for medium wave (9 kHz) and shortwave (10 kHz) as rigidly as perhaps they should. Whilst these stations produce no observable sound improvement for listeners using normal receivers (since their IF filters limit the bandwidth and in the process the frequency response too), this is not the case with SDR, where it's no problem to select a wider bandwidth at will. It gets even better: in software receivers the fine-tuning capabilities of PC decoder programs give you the capability of determining the desired bandwidth with notch filters to the automatic level control (ALC) settings along with selecting all the usual receive modes from AM by way of DRM and SSB to CW.

Further refinements can be added for SWL (shortwave listening) applications. If for instance you wish to increase the sensitivity on the upper amateur bands this is easily arranged by using two switchable antenna inputs and providing an optimised preselector circuit or preamplifier in one of them. The receiver's printed circuit board itself provides a pretty basic RF front end, which is nevertheless perfectly adequate for broadcast reception. A long wire antenna of adequate length will lift the strength of signals above atmospheric noise level to ensure you miss virtually nothing.

Hardware requirements

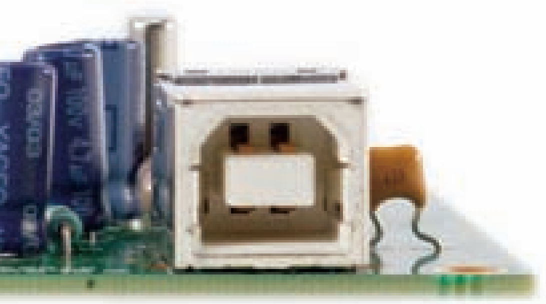
Most SDR programs [1] require the Windows XP platform to operate satisfactorily. The most important hardware necessary then is an SDR-capable sound card. We have developed a small circuit for testing sound cards, described elsewhere in this issue under the heading 'Developer Tips'. Without performing this test first it's utterly pointless starting to make the SDR receiver!

All about USB

The receiver is controlled over a USB connection and powered with +5 V in the same way (no additional mains power supply needed). For the USB interface in the receiver circuit (Figure 1) we selected the FT232R from our Scottish friends at FTDI. This modern USB-to-serial converter works without the need for a quartz crystal, as it is equipped with an internal R-C oscillator of adequate stability. The module (IC4) is used here in its 'bit-bang' mode along the lines of a fast parallel port. Eight data lines are available for use and these can be driven in whichever way we choose. Two of the lines are used as an I²C Bus and control the frequency of the receiver. Three wires connect the input multiplexer to one of up to eight antenna inputs with and without filtering. Two additional inputs serve to control the IF amplification of the receiver. In this way the receiver operates entirely under remote control. Kiss good-bye to all those knobs and controls of bygone radio days…

Please pay particular attention to decoupling the power supply. One reason for this is because the USB chip

Radio



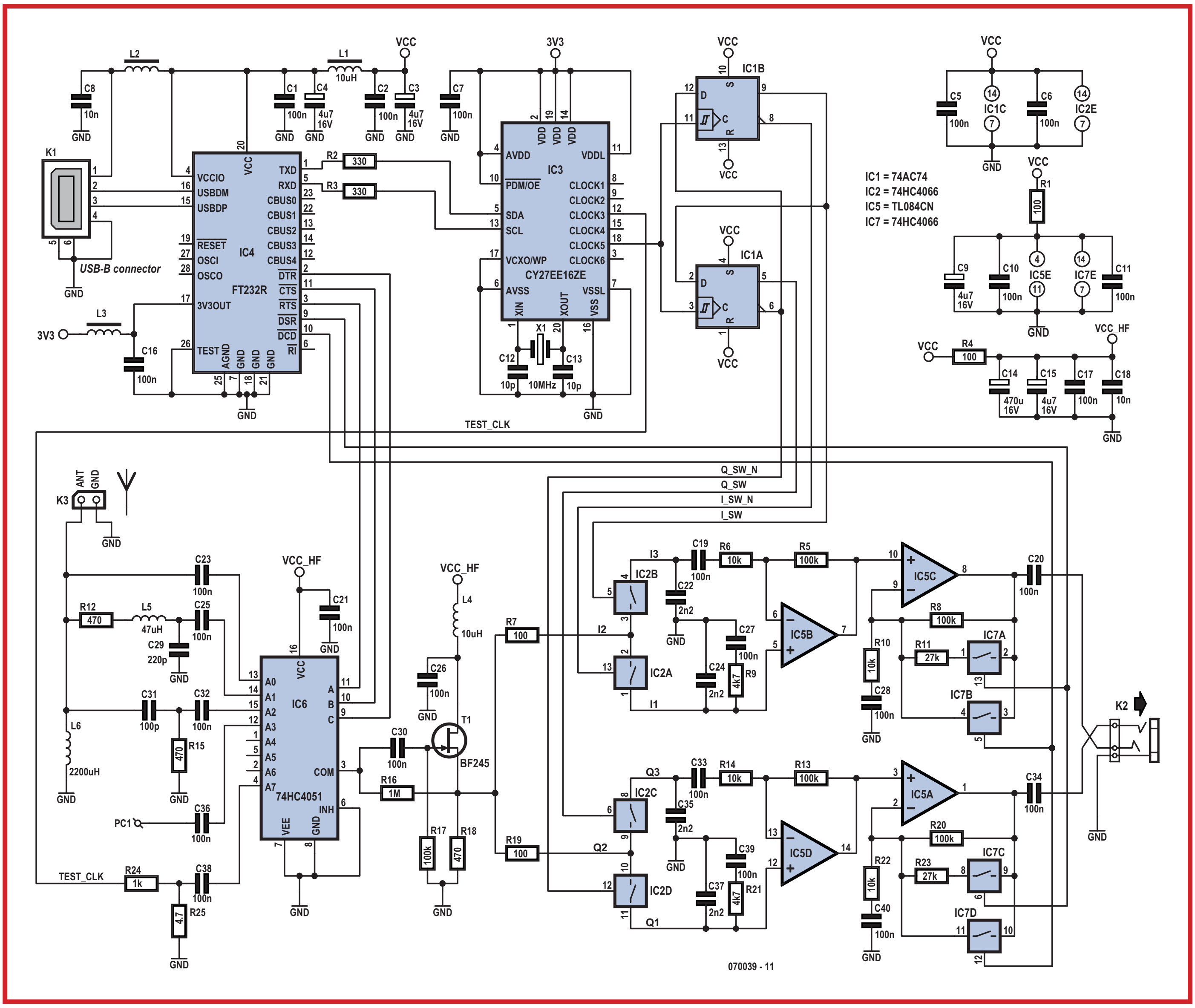


Figure 1. Diagram of the receiver circuit, which in fact comprises just a tuning oscillator and a mixer.

FT232R operates internally at the same frequency range that we are receiving through the antenna downlead and we don't want any of this RF to leak across from one stage to another. That said, the decoupling within the chip itself is remarkably good and the residual RF on the control port lines is barely detectible. Consequently we can control the HC4051 RF input multiplexer direct from the control port lines, without traces of the processor clock appearing in the wanted signal region.
Using its built-in 3.3 V voltage regulator, the FT232R provides the operating supply for the programmable clock generator CY27EE16ZE, avoiding the need for an additional voltage regulator. The rest of the circuit (**Figure 1**) operates exclusively on 5 V. Several different smoothed and filtered voltages are produced, to guarantee good RF decoupling on one hand and to ensure suppression of audio frequency interference on the other. This is particularly crucial at the RF input stage of the receiver, from which the signal is fed via the mixer to the IF circuitry. For this reason a large electrolytic is provided at this point (VCC_HF) to ensure proper 'peace and quiet'.

Programmable VFO

The SDR calls for an oscillator frequency running four times higher than that of the signal received, in order that the necessary phase filtering can be divided by four. If we are aiming to receive signals up to 30 MHz, then the oscillator needs to run right up to 120 MHz. DDS oscillators are very popular in HF projects today but at 120 MHz a DDS is dearer, more power-thirsty and far less controllable. Accordingly we shall look away from DDS oscillators and use a programmable clock oscillator with internal PLL here. Many Elektor Electronics readers will remember the CY-27EE16ZE back from the February 2005 issue. This clock oscillator, developed specially for digital applications, performs equally well in RF circuitry. The frequency resolution does not quite match that of a DDS but the phase accuracy of the output signal achieves comparable results. Restricting power consumption to a relatively modest amount is important with this project, since we must not draw too much current from the USB port.
The chip is programmed over the I²C-Bus using lines SCL and SDA. The internal VCO operates in the frequency range 100 to 400 MHz, stabilised by means of the 10-MHz crystal and a PLL. Its output signal then goes via counters to the desired outputs. Here we select the clock output Clock5, where a VFO signal between 600 kHz and 120 MHz is available for further processing in the 74AC74 counter.
The principle of the I-Q mixer has been described already in Elektor Electronics 12/2006. A two-stage mixer is created here from a total of four analogue switches inside an HC4066 IC. This is controlled by two phase-shifted oscillator signals, which themselves are produced with a 74HC74 counter. Supposing the programmable clock oscillator produces 24 MHz, then the mixer would need a drive of 6 MHz. The receiver would in this case operate in a region of around ±24 kHz either side of the centre frequency of 6 MHz.
Vital here is a phase shift of exactly 90 degrees between the two oscillator signals. Any deviation will lead to reduced suppression of the image frequencies. A 74HC4053 or 74HC4052 integrated changeover switch device would not make a good choice for the analogue switch because the signal transit delays in the internal decoders would then cause different phase errors to appear in every frequency range. Our chosen solution using the rather more basic switches of an HC4066 retains all four phases in sync. Since the 74AC74 counter is configured as a synchronous counter we would not expect to find any phase errors here either. In fact the receiver displays image frequency suppression of around 40 dB up to 15 MHz or so, although this value decreases beyond about 20 MHz (which we can tolerate given that these frequencies are not so heavily occupied).

Signal processing

The receiver is provided with several inputs, selected by the 74HC4051 input multiplexer (IC6). The antenna input ANT is fed by way of filters to the first three inputs. The first switch setting (wideband) uses only one input choke (L6), which shunts any audio frequency signals at the input to ground. In the second position (Medium Wave) there is a low-pass filter with a boundary frequency of 1.6 MHz, using resistor R12 to attenuate excessive resonance. This filter suppresses interference to medium wave reception from overtone mixing with stations in the short wave range. The third position makes use of a simple R-C high-pass filter to attenuate strong medium wave signals.
An additional input (PC1) can be selected if you wish to connect external tuned input circuits or preamplifiers. Finally three more inputs are provided for future developments. The input filters on the printed circuit board are good to be getting on with and are certainly adequate for most applications. You can of course introduce steep low-pass filtering ahead of the filters provided if you want to be certain of blocking out overtone mixing in every possible situation. Or you might choose to fit different resonant circuits, selected by input switching.
The particular input that is active at any given time is connected to the common output COM (pin 3). Coupling capacitors are provided either side of the switch. A bias voltage of about 2.5 V is provided to the switch from the source connection of the BF245 via a 1-megohm resistor. This eliminates any distortion from large input signals that might arise when signals are limited by the protection diodes on the analogue inputs to the ICs.
Input A7 delivers a calibration signal from Output 3 (Test-Clk) of the programmable crystal oscillator. The oscillator produces a square-wave signal of 3.3 V peak-to-peak at 5 MHz. A signal voltage of around 5 mV at 5 MHz is produced at the voltage divider, corresponding to a signal strength of S9 + 40 dB. This enables the field strength meter created in software to be calibrated without any further expenditure.
JFET BF245 on the output of the input multiplexer serves as an impedance transformer. This provides a relatively high impedance termination of 100 kΩ for the RF signal, enabling for instance a high-Q resonant circuit to be connected even to input In2. At the low-impedance output of the source follower we arrange to have a voltage of circa 2.5 V, fed via the mixer and the following op-amp all the way to the output. It is important that no audio frequency signal remnants appear at the source connection and for this reason the 'critical' supply Vcc_HF is also filtered very thoroughly. The FET itself provides additional decoupling of the supply voltage, but we don't want any signal escaping from the Gate either that might fall in the IF region below 24 kHz. This is why an RF choke is connected directly to the antenna input, to shunt for instance any 50 Hz mains hum signal.
Leading off from the Source connection are two 100-Ω resistors that go to the two mixers for the I and the Q signals.

COMPONENTS LIST

Resistors
R1,R7,R19 = 100Ω
R2,R3 = 330Ω
R4 = 100Ω
R5,R8,R13,R17,R20 = 100kΩ
R6,R10,R14,R22 = 10kΩ
R9,R21 = 4kΩ7
R11,R23 = 27kΩ
R12,R15,R18 = 470Ω
R16 = 1MΩ
R24 = 1kΩ
R25 = 4Ω7

Capacitors
C1,C2,C5,C6,C7,C10,C11,C16,C17,C19,C20,C21,C25-C28,C30,C32,C33,C34,C36,C38,C39,C40 = 100nF
C3,C4,C9,C15 = 4µF7 16V radial
C8,C18 = 10nF
C12,C13 = 10pF
C14 = 470µF 16V radial
C22,C24,C35,C37 = 2nF2
C29 = 220pF
C31 = 100pF

Semiconductors
IC1 = 74AC74
IC2,IC7 = 74HC4066
IC3 = CY27EE16 (Cypress)
IC4 = FT232R (FTDI)
IC5 = TL084CN with socket (see text)
IC6 = 74HC4051
T1 = BF245

Inductors
L1-L4 = 10µH
L5 = 47µH
L6 = 2.2mH

Miscellaneous
K1 = USB-B socket, PCB mount
K2 = stereo jack socket, 3.5mm, PCB mount
K3 = 2-way PCB terminal block, lead pitch 5mm
PC1 = solder pin
X1 = 10MHz quartz crystal
Ready-populated and tested PCB, order code 070039-91
Project software, free download 070039-11
Supplementary document, free download
PCB, bare, ref. 070039-1 from www.thepcbshop.com

They improve the symmetry of the mixers, the 'on' resistances of which let through a certain amount of leakage. The mixers themselves are HC4066 analogue switch ICs ganged as changeover switches. The voltage of these too is set around 2.5 V, allowing them to be controlled without overdriving up to about 5 V peak-to-peak.
The IF amplifier consists of two exact-

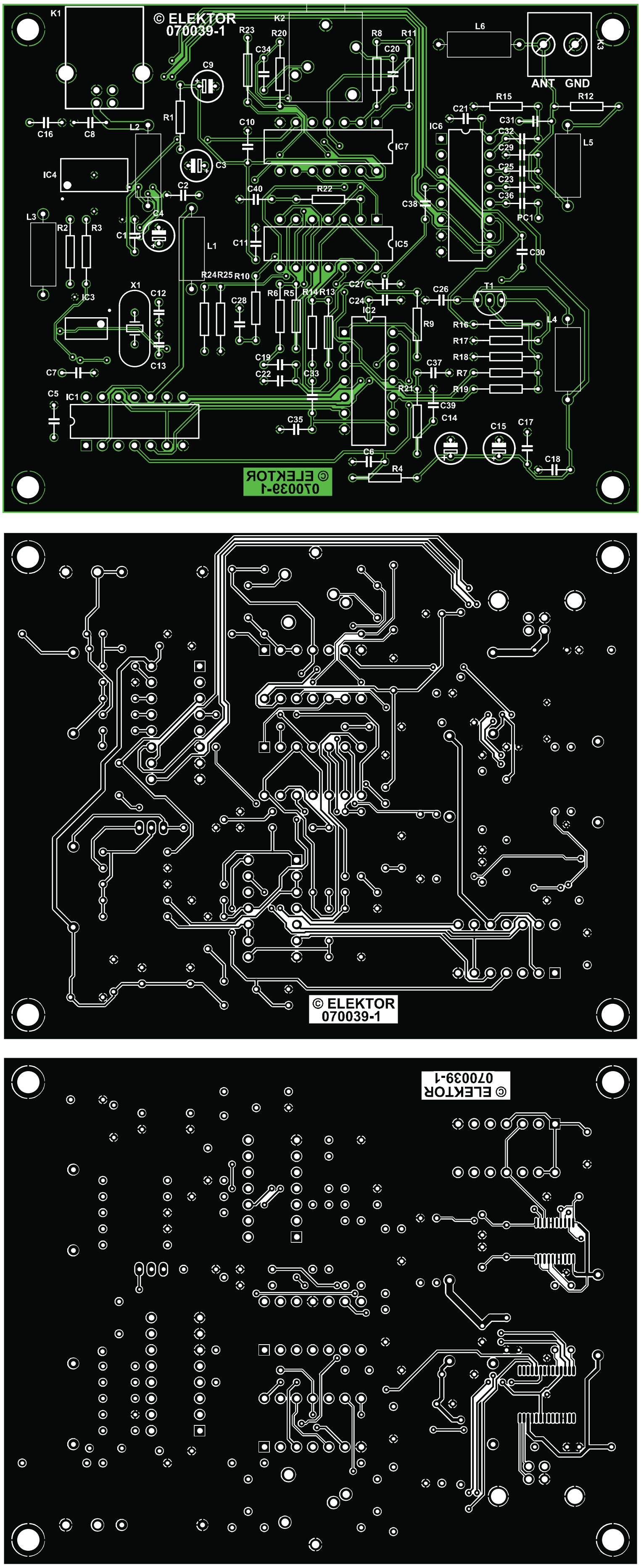


Figure 2. The SDR receiver board.

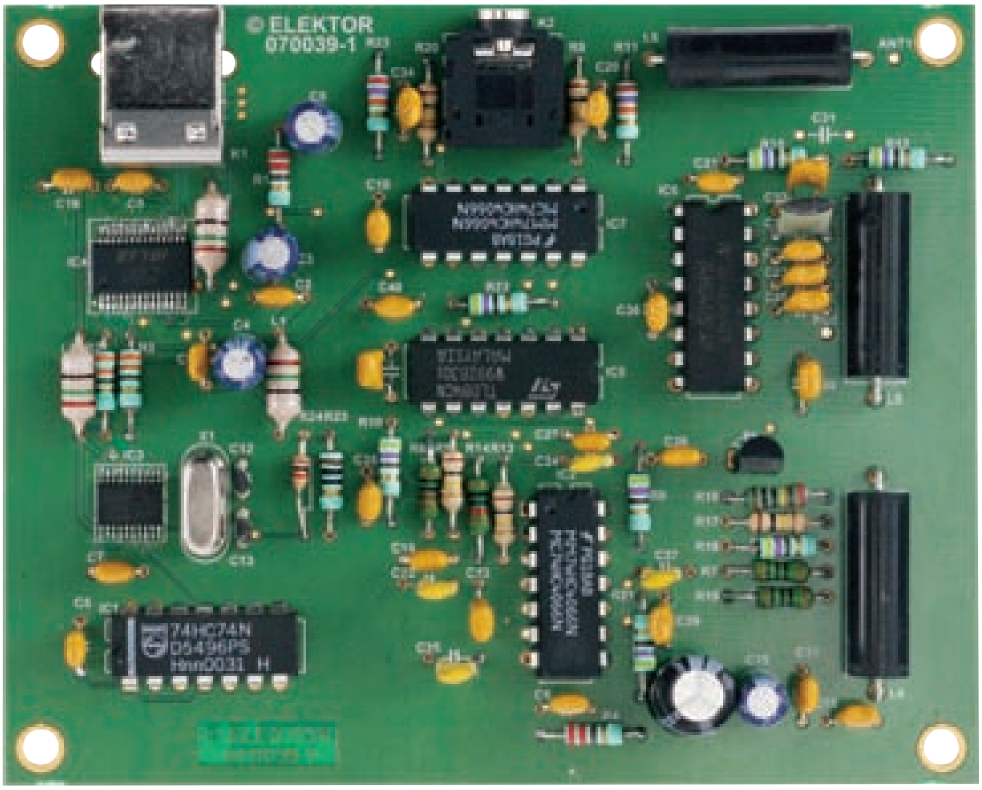


Figure 3. This lab sample board is not quite equivalent to the production version supplied through the Elektor SHOP.

ly equal branches that together produce an attenuation of up to 40 dB at all times. When you are using 5 V supplies, the gain bandwidth (GBW) of the selected op-amp is important, in order to achieve tenfold amplification without phase errors for signals around 20 kHz. In the author's test samples a TL084 turned out to be adequate. If you provide a socket for IC5 you will be able to try other, faster op-amps.

The input stage works as a differential amplifier. In dimensioning the resistors what we are looking for is not the best common-mode suppression but rather an input resistance that's as equal as possible across the inverting and non-inverting inputs. Tests show that good phase accuracy (and consequently high image-frequency suppression) depend on equal impedance existing on all four phases of the mixer. The input impedance amounts to around 5 kΩ at all of the inputs. Note the load resistance of 4.7 kΩ on the non-inverting input as opposed to 10 kΩ on the inverting one. This is correct, since signal transit on this input gets dispersed in exact antiphase by inverse feedback, halving the input resistance to 5 kΩ. In this way both inputs offer the same input resistance as close as matters.

The 2.2 nF capacitors together with the mixer's internal resistance and the 100 Ω series resistors form simple low-pass filters with a limiting frequency of over 100 kHz, so as to keep remnants of RF well away from the audio frequency stages. The limiting frequency lies far above the transfer frequency range, meaning that capacitor tolerances do not produce any discernible phase errors. You can use even ceramic disc capacitors here. Tolerances between 10 and 20 % are not a problem with any of the capacitors in the signal path acting as high-pass elements with a limiting frequency of around 300 Hz.

The final stage has a tenfold gain (20 dB), which can, however, be reduced to unity gain by the analogue switches. A total of three attenuation steps are provided: 0 dB, –10 dB und –20 dB. To avoid it being driven too hard, the gain can be reduced in software. As the receiver's input displays high resistance to being overdriven the attenuator is placed in the final stage, so as to prevent overdriving of the output. This corresponds to gain control in an IF amplifier.

Construction

The printed circuit board shown in **Figure 2** uses standard wire-ended components as far as possible, with the exception of the LSI (large scale integration) chips FT232RL and CY27EE16, which unfortunately are available only in SSOP case format with a pin spacing of 0.65 mm. **Figure 3** shows the laboratory prototype PCB with components fitted.

The best way to begin is by soldering the two surface-mount device (SMD) chips in place. It pays to start first at the four corners, before soldering all the other pins generously. Superfluous solder can be removed with desolder braid, followed by thorough checking with a magnifying glass to avoid unwelcome surprises later on.

The components with wire leads will present no difficulty. The circuit does not call for any special RF components or test points. Capacitors C12 and C13 should not be fitted initially. The CY27EE16 has presettable internal capacitors that should enable you to achieve a frequency of exactly 10 MHz without difficulty. C12 and C13 will be needed only if the crystal used requires greater loading capacity.

Once all construction is complete you need to make a quick round-up with a multimeter checking for any short circuits around the USB connections, as you certainly don't want to damage the PC.

Hook-up and alignment

Before connecting the receiver to the computer's USB port for the first time you will need to install the driver software for the FT232R. You can find this on the manufacturer's website (www.ftdichip.com/FTDrivers.htm) or alternatively in the software download for this article. Installation using CDM_Setup.exe automatically removes any traces of older FTDI drivers on your computer. After this has been done Windows will find the correct driver automatically as soon as the receiver is connected. The same process provides the PC automatically with an additional virtual COM-port interface. For this you do not even need to know which COM number is allocated to the device, as it effectively sets up its own direct connection to the FT232R. FTD2XX.dll controls the eight data lines of the chip as for a parallel port, eliminating at the same time all timing problems. To save time the multiple level changes involved in controlling the I2C bus are loaded conveniently into a buffer and then fed out to the data lines in short order. The program ElektorSDR.exe enables you to control all functions of the receiver (**Figure 4**) and can be found in the download archive as an executable file together with the Delphi source code. Also available for download is a supplementary .pdf document that describes initialisation and commissioning.

Decoder software

Nearly all significant characteristics of the receiver are determined by settings in the decoder software on your PC. As the survey in [1] indicates, there are a number of different programs to choose from. You could perform your first test with SDRadio [2] for example. After this you will discover additional possibilities in DREAM [3] or G8JCFSDR [4]. Whichever program you select, it's vital to set up the sound card correctly (this is described in the supplementary document). Information on the programs can be found on the relevant Web pages and in the Elektor Electronics articles listed below. Further advice may be found on the author's homepage (www.b-kainka.de) and will appear also in due course on the project page at www.elektor-electronics.co.uk and, if necessary, in the Forum on the same website.

(070039-1)

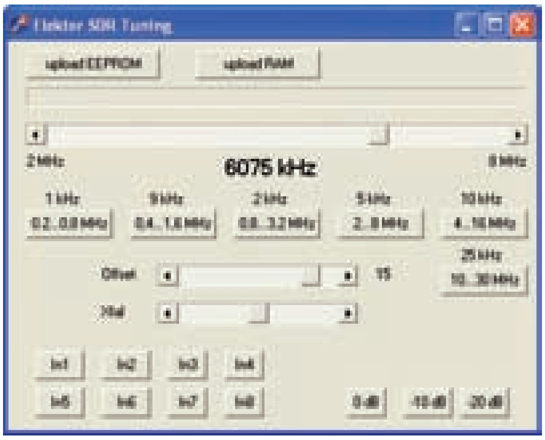


Figure 4. Elektor Electronics SDR Tuning control program.

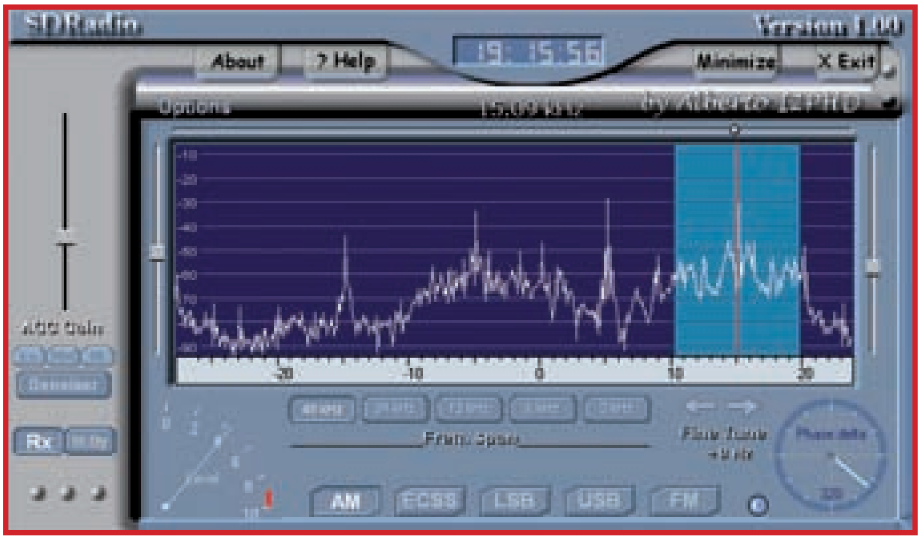


Figure 5. Four AM stations in tuning range spectrum, as displayed by the SDRadio program.

Web links:

[1] www.nti-online.de/diraboxsdr.htm

[2] www.sdradio.org/

[3] http://sourceforge.net/projects/drm

[4] www.g8jcf.dyndns.org/

Literature:

Burkhard Kainka: DREAM Team –Software for DRM reception, Elektor Electronics 4/2004, pp. 20 ff.

Wolfgang Hartmann and Burkhard Kainka: 'Radio listening with Matlab—Diorama software DRM receiver', Elektor Electronics 4/2006, pp. 76 ff.

Burkhard Kainka: I-Q: a highly intelligent approach to quality radio, Elektor Electronics 12/2006, pp. 38 ff.

Thank you for

Brendan Hughes

Over the years, there have been a fair number of designs published enabling a radio-control (RC) transmitter to interface with a personal computer. Having this interface enables prospective model aircraft pilots to hone their skills using a simulation program rather than aviating their pride and joy nose-down into the nearby landscape.

Arguably, many RC modelling enthusiasts would rather see a PC ‘crash’ than the latest model built with blood sweat and tears, not forgetting lots of time and money. In this respect, the follow a buzzword in modern electronics: *simulation*. Simulating flights, landings and takeoffs for a given model is a great way of familiarising yourself with its response to your actions (and errors) on the RC transmitter. Excellent flight simulators are available these days that give very realistic results — to the extent of users actually starting to sweat and exhaust themselves trying to keep the model where it should be — up in the air!

The circuit described in this article is the ‘glue’ between the ‘buddy’ (or ‘trainer’) connection on your RC model transmitter and the virtual model aircraft, car, boat or even helicopter gracefully finding its way across the PC screen in response to your operating the joystick(s) and pressing buttons. No model will be lost to unforgiving rocks, trees, church steeples or Farmer Jim’s cowherd. If you crash, simply start the simulator again and *do better*.

flying USB-FliteSim

An RC transmitter-to-USB interface

Goodbye gameport, welcome USB

Most designs interface to the PC via the gameport which is now becoming less common on newer PCs and has disappeared completely from laptops and notebooks. The design discussed in this article utilises the USB port which offers greater accuracy. Some commercial designs offer similar capabilities but most only have 6-bit precision on the linear axis, so small trim changes may not be effective.

Capabilities and limitations

As published here, four linear controls and four switched controls are catered for as would be used in a typical 8-channel transmitter, i.e., two 2-axis joysticks and four switched inputs. The linear inputs are measured with 12-bit accuracy although in reality just over 11-bit accuracy is achieved with this software on a typical RC set. With this level of resolution, poor joystick centring is easily measured using the joystick calibration program in Windows (Select 'Display raw data'). More channels could be easily added but it was felt that eight would be adequate for most users.

Super simple hardware

The hardware is simplicity itself, see **Figure 1**. At the heart of the circuit is a PIC18F2550 clocked at 8 MHz, with a simple transistor buffer/inverter on the input. Eight jumpers have been included although only four are presently used to select between different options. The remainder are to enable possible future enhancements.
When plugged into an USB connection on the PC, the HID firmware in the F2550 enables the circuit to be enumerated as a 4-axis with 4-button joystick, so no additional drivers are required.
Note that due to the PIC software used, the circuit is a low-speed USB device and Chapter 6.4.4 of the USB1.1 specification states that USB cables should be hardwired to the peripheral and not use the USB 'B' connector. However, considering that the circuit will typically be for personal use only, the 'B' connector was elected.

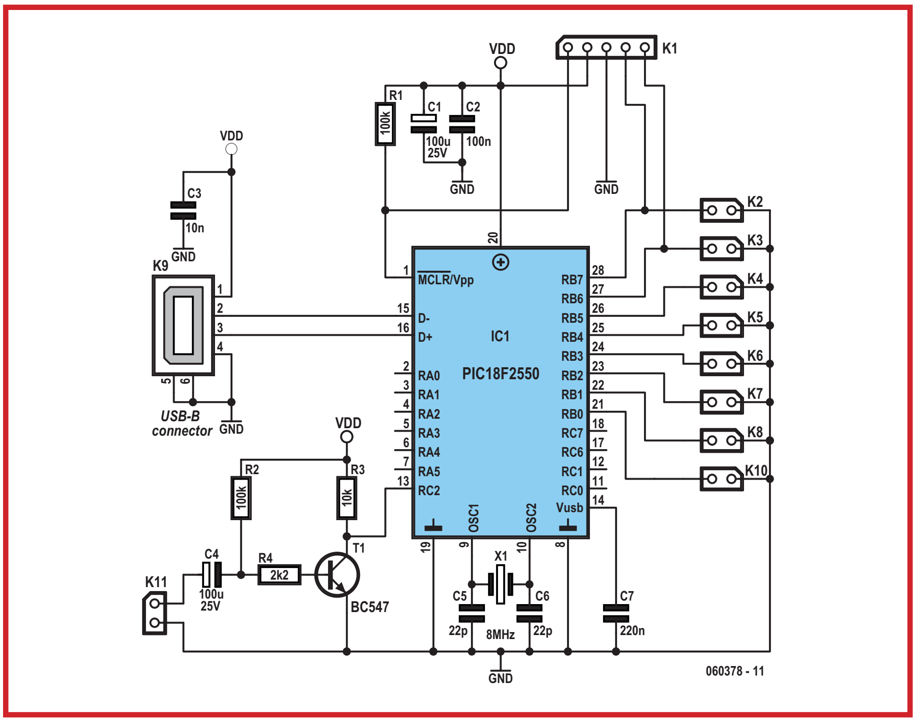


Figure 1. Circuit diagram of the RC TX to USB interface. Hardware, what hardware?

Software

The following description of the software is pertinent to the PIC 16C745. See the heading 'Project History' for a brief overview of the differences to the current 18F2550 software.
All the USB dedicated software is available from the Microchip website and is included with the source files supplied free of charge through the Elektor website as file no. **060378-11.zip** (see month of publication). A snippet of the extremely well-commented source code listing is shown in **Listing 1** — very useful for the jumper descriptions!
Of the Microchip supplied files, both *DESCRIPT.ASM* and *USB_CH9.ASM* need to be modified. *USB_CH9.ASM* needs the following compiler directive commenting out (or removing) so that port B is available for our use:

```
#define SHOW_ENUM_STATUS
```

DESCRIPT.ASM needs some more serious editing of the various descriptors to allow for proper enumeration and operation of the USB functions. Seven bytes are sent to the PC every 10 ms. The arrangement of the data within these seven bytes is laid out in the report descriptor. Essentially, four blocks of 12 bits representing the four joystick axes followed by four bits representing the four switches are sent. That makes a total of 52 bits, which falls short of the 56 bits available in seven bytes,

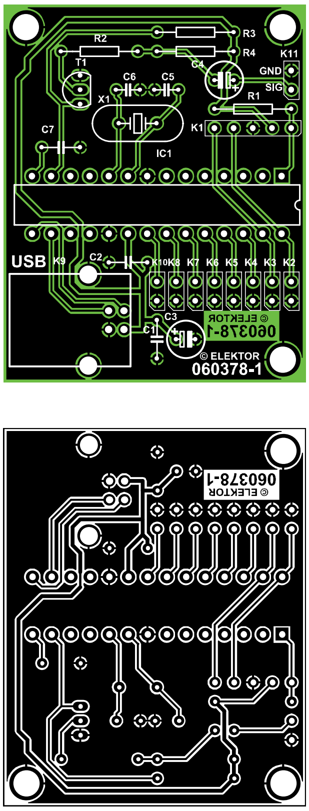


Figure 2. Copper track layout and component mounting plan of the miniature PCB designed for the interface.

COMPONENTS LIST

Resistors
R1,R2 = 100kΩ
R3 = 10kΩ
R4 = 2kΩ2

Capacitors
C1,C4 = 100µF 25V radial
C2 = 100nF
C3 = 10nF
C5,C6 = 22pF

Semiconductors
IC1 = PIC18F2550-I/S, programmed, order code **060378-41**
T1 = BC547

Miscellaneous
K1 = 5-way SIL pinheader
K2-K10 = 2-way SIL pinheader with jumper
K11 = 2-way SIL pinheader
K9 = USB-B connector, PCB mount
X1 = 8MHz quartz crystal
PCB no. **060378-1** from The PCBShop
PIC source code files, free download no. **060378-11** from www.elektor-electronics.co.uk

therefore a further four bits of padding are sent.

The *RC_USB.ASM* source file has a good number of comments so should be fairly easy to follow. Because the USB functions make unpredictable use of the interrupts, these are not used for pulsewidth measurements. Therefore, the only user of the interrupt facility is the USB routine.

Pulsewidth measurements are made using the Capture/Compare/PWM module. Capture register CCPR1 is a 16-bit register configured to capture the contents of Timer1 on either the High-to-Low or the Low-to-High transitions on the input (as selected by jumper K10 on RB0). Timer1 runs continuously with a ÷2 prescaler at 3 MHz and therefore increments every 333 ns. Pulsewidth can therefore be detected to an accuracy within 666 ns.

Due to the way servos are controlled, pulsewidths vary from 1-2 ms for each channel, therefore we have a range of approximately 0 to 3000.

When the program starts, *InitRC_USB* is called that configures the ports, sets up the CCPR to capture on a rising edge and starts Timer1. Next, InitUSB is called and the device is enumerated. The firmware waits until enumeration is complete.

LOOP is the main body of the program. If a pulse is detected (CCP1IF bit set), we check if it is a synchronisation pulse (>2.7 ms) or one of the channel pulses, which vary between 1 and 2 ms pulsewidth. The last value of CCPR1 (Tmr1Lo and Tmr1Hi) is subtracted from CCPR1 to give pulsewidth in units of 333 ns. If it is a sync pulse, we send the data in the *BUFFER* to the USB routines for transmission to the PC. Else, if a normal channel pulse is detected, we subtract 4500 (4500 counts of 333 ns = 1.5 ms) to centralise the pulse on 1.5 ms so that positive numbers indicate a positive swing from neutral on the joystick and negative numbers indicate a negative swing. Next, the pulse width information is stored at the appropriate place in *BUFFER* as pointed to by the *Pulse_Count* variable. *Temp_Count* is a working copy of *Pulse_Count* that can be manipulated without losing track of the channel number.

Jumpers for unusual cases

Left-handed modellers may wish to have the aileron/elevator joystick on the left. To this end, jumper K8 on port line RB1 adjusts the value of *Temp_Count* so that the data is stored in the correct part of *BUFFER*.

Certain RC transmitters use a non-standard sync pulse. This may affect the operation of the device. Installing the jumper on RB0 causes *CCPR1* to capture on the falling edge of the pulse train. Unfortunately we did not have access to any of these non-standard RC radios so we cannot guarantee that this will help.

Construction

The interface is built on a small printed circuit board of which the true-size artwork is reproduced in Figure 2. This board is available from Elektor's business partner The PCBShop who reside at www.thepcbshop.com.

With so few parts on the circuit board, — and all of the 'leaded' variety as opposed to SMDs — there should be no problems building the interface if you exercise normal care in fitting the parts to match the component overlay, and of course the soldering. We recommend fitting the PIC micro (IC1) is a 28-way narrow DIL socket.

We reckon there's much to be learned, enjoyed and economised upon if the project is undertaken as a joint undertaking by RC modelling club members. Subtasks can be assigned like component/PCB purchasing, soldering, programming and software tinkering to those with the relevant skills or their arm twisted.

Calibration

When the interface is plugged into a USB port on a PC, it should enumerate with a message stating that a 'RC/USB Interface' has been found. Open up the Control Panel and select 'Game Controllers'. Listed in the dialogue box should be 'RC/U' or 'RC/USB Interface'. Select the controller and click on Properties. Movement of the joysticks should produce the required movement on the screen. If no movement is observed, then toggle jumper K10. Huh, "toggle"? If the jumper is Fitted then Remove it and vice versa. Similarly, toggling jumper K8 will cause the two joysticks to be swapped. When it is working as required, the system will need to be calibrated. Select 'Settings' and in the new dialogue box select 'Calibrate'. Follow the instructions onscreen. This completes the installation.

Wrong enumeration

For some reason the device may be referred to as 'RC/U' even though Windows retrieves the full name of 'RC/USB Interface' during enumeration. If this bothers you, simply edit the registry setting at

```
HKEY_LOCAL_MACHINE\SYSTEM\
  ControlSet\Control\MediaProper-
  ties\PrivateProperties\
  Joystick\OEM\VID_04D8&PID_FE70
```

Each USB device manufacturer is allocated a unique Vendor ID code (VID) and each device model that the manufacturer produces is allocated a Product ID code (PID). We have obtained a sub-licence from Microchip to use the Microchip VID (04D8) with a PID code of FE70. This should ensure that this device will not conflict with any other commercial USB device.

Interlude — odds & ends

Note that the interface will only decode Pulse Position Modulation (PPM) pulses and not Pulse Code Modulation (PCM), and therefore the transmitter will need to be in PPM mode.

A list of the buddy-lead pinouts for various RC transmitter manufacturers can be found at [1] and [2].
A good tutorial on the on the principles of PPM can be found at [3] and [4].

Project History

Originally the software was written for the PIC16C745, and later modified to work on a 18F2550. Microchip did not (yet) release USB framework code for the 18F2550 in assembler format. Fortunately, Brad Minch of Olin College has generated an assembler framework that is freely available [5]. This code was adapted and mated to the file *rc_usb.asm* that was tweaked for 18F2550 code to produce the file *RC_USB_18F2550.asm* which needs to be compiled with the included *ENGR2210.inc* and *usb_defs.inc* files. The code should also run on the 18F2455 without any further adjustments.

The advantage of the 18F devices is that they are flash-programmable and faster to erase. K1 is a 5-pin header that allows in-circuit programming of the device with an appropriate programmer, like the Microchip PICkit2 (pin 1 of PiCkit podule not used).

Listing 1. Source code snippet

```
;*******************************************************************
; filename: RC_USB_18F2550.ASM   Ver 1.0 - 01 Dec 2006
;
; This file implements the conversion of a PPM mo-
   dulated output from a radio
; control transmitter to a 3 axis plus throt-
   tle and 4 button USB joystick.
; PORTB,0 pin header selects inverted in-
   put i.e. pulses are active low
; PORTB,1 pin header selects joystick swapping
; PORTB,2 pin header selects the Airtronics option
; PORTB,3 pin header selects the JR option
; PORTB,4..7 not used
; The code is written for a Futaba transmit-
   ter but by installing EITHER PortB,2 or 3
;   pin header, then it can be configu-
   red for an Airtronics or JR radio
; The USB port is configured to interrupt eve-
   ry 10mS and sends 7 bytes of data
;  (maximum is 8).  The 4 joystick chan-
   nels are sent as 12 bit values and the 4
;  switches as boolean values.  Therefore, 52
   bits are required to be sent and the
;  7th byte is filled with 4 bits of 'padding'
; The following shows how the bits are saved
   in the Buffer prior to being sent
;  to the USB port
;  Throttle=T  Rudder=R  Aileron=A  Elevator=E
   Switches=S  Padding=P
;              MSB                           LSB
; Buffer0      A7   A6   A5   A4   A3   A2   A1   A0
; Buffer1      E3   E2   E1   E0   A11  A10  A9   A8
; Buffer2      E11  E10  E9   E8   E7   E6   E5   E4
; Buffer3      T7   T6   T5   T4   T3   T2   T1   T0
; Buffer4      R3   R2   R1   R0   T11  T10  T9   T8
; Buffer5      R11  R10  R9   R8   R7   R6   R5   R4
; Buffer6      P    P    P    P    S4   S3   S2   S1
;
;**********************************************
   **********************************
; All USB routines kindly provided by Brad-
   ley A. Minch of the Franklin W. Olin
;  College of Engineering and the origi-
   nal source can be obtained from
;       http://pe.ece.olin.edu/ece/projects.html.
; The source was the Lab2 project that was
   then modified by myself with
;  permission from the author to distribu-
   te as required.  The main areas of
;  change are the descriptors up to line 265
   and all code after line 1178 is
;  new.  There are a few small changes in between.
;
; Revision History:
;       2006-12-01             Versi-
   on 1.0                      Brendan Hughes
;*******************************************************************

#include <p18F2550.inc>
#include <usb_defs.inc>
#include <ENGR2210.inc>
```

Those interested in learning more about USB are advised to have a look at websites [6] through [9].

A full set of source files for both the 16C745 and 18F2550 processors is supplied through Elektor's website. It should be noted though that hardware changes are required in the circuit if the C745 is used: change the quartz crsystal to 6 MHz and fit a 1kΩ5 resistor between Vusb and the USB D-line.

(060378-I)

Web links

[1] http://users.belgacom.net/TX2TX/tx2tx/english/tx2txgb3.htm

[2] www.rc-circuits.com/Transmitter%20Connector%20Pinout.htm

[3] www.mh.ttu.ee/risto/rc/electronics/radio/signal.htm

[4[http://rc-circuits.com/PPM%20signal.htm

5] http://pe.ece.olin.edu/ece/projects.html

[6] www.usb.org

[7] www.lvr.com/

[8] www.beyondlogic.org/usbnutshell/usb1.htm

[9] http://pe.ece.olin.edu/ece/projects.html

Seismograph

Loudspeaker as vibration sensor

Gert Baars

Big earthquakes are rare events, but every now and then we are startled by small shocks that (luckily!) do not usually have any serious consequences. With the circuit described here and a PC you can very easily keep an eye on all earthquakes.

Natural phenomena such as earthquakes, volcanic eruptions, landslides and meteorite impacts generate seismic tremors that can propagate over (through) the earth's surface. With violent events such as a large earthquake on the other side of the world these tremors can travel several times around the earth before they completely die away.

Humans can also cause seismic tremors, examples are extracting natural gas or nuclear tests. These are generally not audible or noticeable from a large distance, but they can be detected with a sensitive vibration sensor. The seismograph described here makes that possible.

The sensor

Normally a seismograph sensor uses a spring with a weight attached. The weight just stretches the spring a little. Because of the inertia of the mass-spring system, vibrations cause changes in the elongation of the spring, which can be electronically detected and displayed.

This type of sensor is rather expensive to buy and the construction is not that straightforward. There is also the need for a damping mechanism (for example a ring in an oil bath) because the mass-spring system has the tendency to continue to vibrate for a long time.

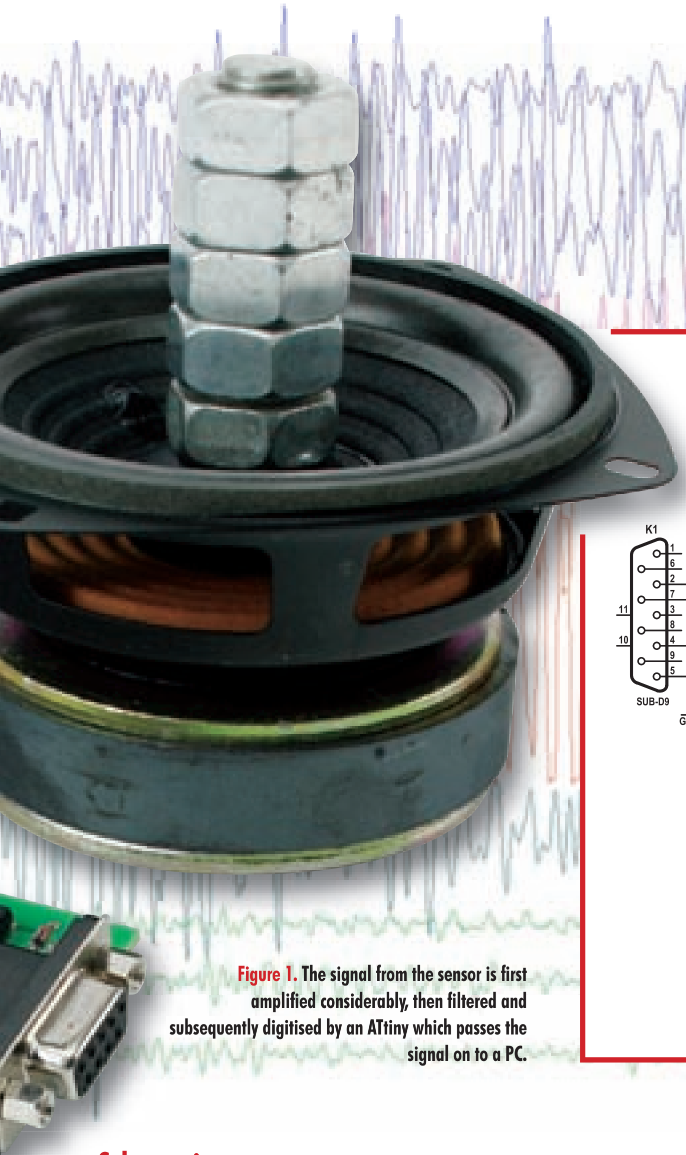
The author thought of a much simpler solution: a loudspeaker. A loudspeaker contains a coil attached to the back of the cone. The coil is centred in the gap of a permanent magnet. A voltage is generated when this coil moves. Placing a weight on the cone of the loudspeaker turns it into a vibration sensor. When the loudspeaker moves up and down because of vibrations in the underlying surface, the mass, because of its inertia (Newton's first law) will stay in the same place and exerts a force on the cone. In this way a voltage is generated across the coil.

The loudspeaker that is used is a small type of 0.5 W/8 Ω, with a diameter of about 8 to 12 cm, preferably with a flexible suspension. A mass in the shape of a steel, M10x25 bolt is used to weigh down the cone. A few additional nuts on the bolt give a good result without jamming the cone against the magnet. This lowers the resonant frequency of the loudspeaker and the amount of damping is not too large. These are very useful properties that make it suitable for it to be used as a seismic vibration sensor.

Principle

The signal from the loudspeaker is first amplified and then followed by a filter to eliminate hum and to reduce noise. The signal is then presented to the ADC-input of an ATtiny-microcontroller. Once the conversion is completed, the microcontroller sends the signal to the computer via the serial link. A program running on the computer or laptop converts this data into a graphical representation, which allows the user to read the time and strength of the seismic activity. In two smaller windows you can see in real-time the amplitude and the frequency spectrum of the signal.

When designing the hardware, one of the requirements was that it should be powered from the serial port of the PC (or laptop). This does away with the need for a battery or external power supply. This does mean however that the current consumption cannot be all that much. This is mainly achieved by running the microcontroller at a slow clock frequency and selecting low-current devices for the voltage regulators.



Specifications

- **0.5 to 25 Hz bandwidth (50 S/s)**
- **Sensitivity from a few µm**
- **Sensor circuitry is powered from the PC**
- **Serial port: 2400 baud, 8 bits data transmission**

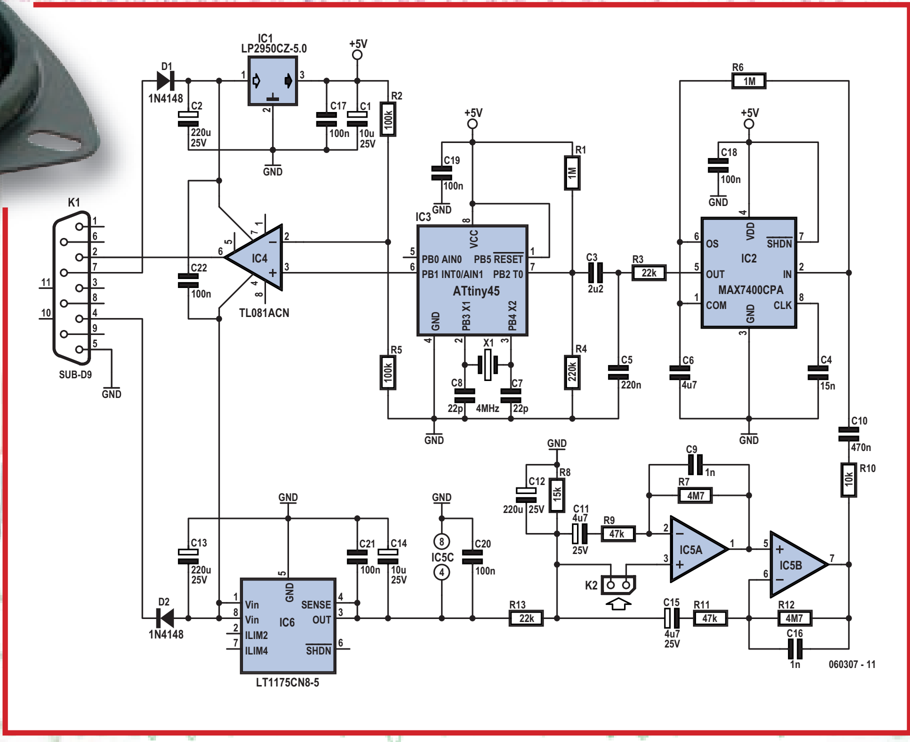


Figure 1. The signal from the sensor is first amplified considerably, then filtered and subsequently digitised by an ATtiny which passes the signal on to a PC.

Schematic

The schematic for the electronics is shown in **Figure 1**. A dual opamp of the type TL082 was selected for the preamp. The total gain of about 10,000 times (80 dB) is divided across two opamps. This is to prevent the effect of the input offset voltage of the opamps of having too great an influence. For the same reason, the total DC gain is set to 1x by C11 and C15. The signal from the preamp is subsequently filtered by and eighth order low-pass filter to remove hum and reduce noise. This filter is an IC from Maxim; the MAX7400 (a so-called switched capacitor filter, SCF). With capacitor C4 connected to pin 8 of this IC the corner frequency is set to a fixed value of about 25 Hz. This results in a total frequency range from about 0.5 to 25 Hz, which is suitable for seismic recording. The ADC in the microcontroller, an ATtiny45 from Atmel, converts this signal into an 8-bit result, sufficient for this application.

A single, low-power opamp, type TL081 (IC4) is then used as a level shifter, converting the data that the ATtiny transmits from TTL to RS232-level.

The power supply is derived from the RS232 lines with the aid of D1 and D2. Two thrifty, low-drop voltage regulators (an LP2950 for the positive voltage an an LT1175 for the negative voltage) subsequently provide regulated voltages of plus and minus 5 V. In an attempt to spread the load roughly equally between the positive and negative rails, the filter and microcontroller are powered from the positive side, while the two opamps in IC5 are powered from -5 V. A voltage divider R8/R13 has also been added for the DC adjustment of the opamps.

A printed circuit board has been designed for the circuit, which is shown in **Figure 2**. There is nothing special that we need to say about the construction, in this case this is just a very straightforward job.

Programming of the controller.

If you program your own micro for this project, the following fuses need to be selected:

- Crystal oscillator fuse: ext crystal osc 3-8 MHz
- Clock divider fuse, divide by 8: CKDIV8

Software

The assembler-written software in the microcontroller has the simple task of transmitting the ADC-result when requested. Because this particular controller does not have a UART, this is done with additional software.

The PC-application is programmed in the Delphi programming language. A disadvantage of Windows is that it is not a real-time operating system. Commands from the user interface such as the mouse and keyboard and also system tasks that need to be done are not immediately carried out, but are placed in a type of queue; depending on the priority they will have to wait until Windows can deal with them. From the perspective of the user this goes so fast that you will hardly notice this. When reading or sending data, the exact timing is however difficult for the programmer to control.

For this type of measurement a spectrum from about 0.5 to 25 Hz is very appropriate. This means that the measurements have to be done at 50 samples/s (Nyquist theorem). In this case

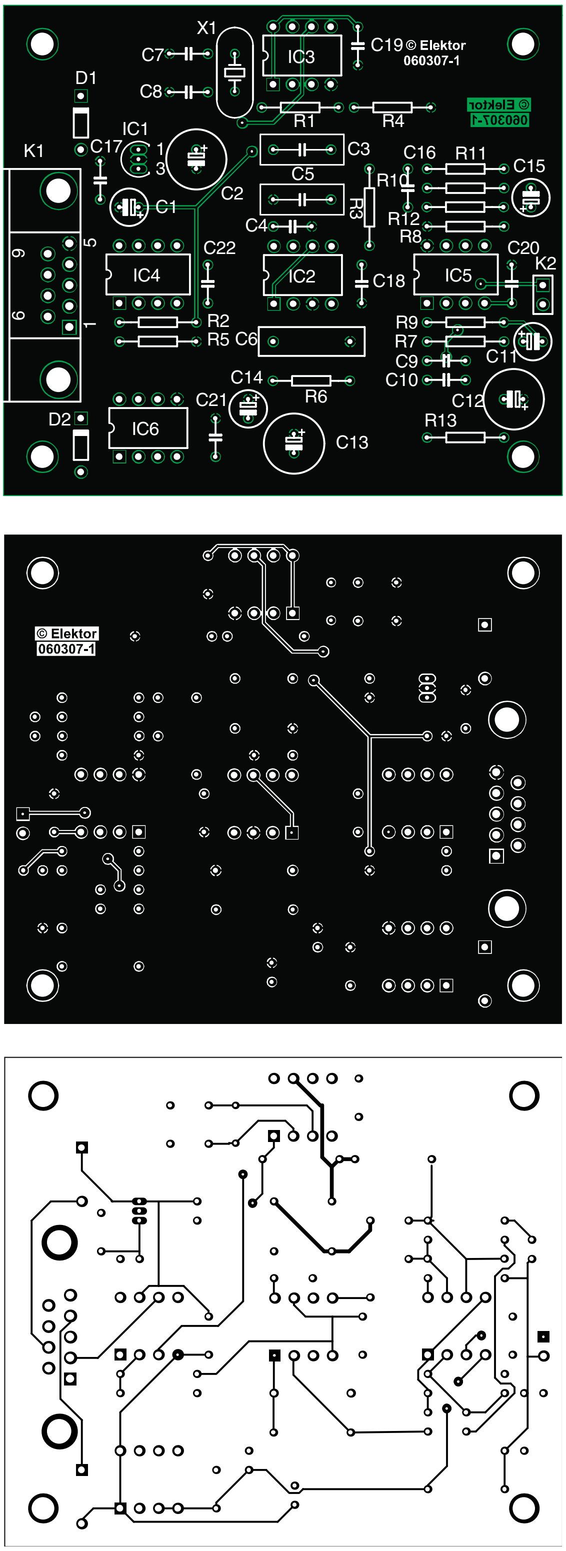


Figure 2. If you would like to make a PCB yourself you can get going with this layout.

the timing can be done by the hardware so that the software timing of the PC does not need to be that accurate. The samples that can be read sufficiently fast by the program are displayed in three windows, each containing a different type of graph. These are a ‘real-time' oscilloscope to show the details of the amplitude history of the seismic vibration, a spectrum display for the frequency components and a large graphical display for the long-term record. On the latter, the number of lines per window and the duration of each line can be adjusted. An obvious setting is to select 24 lines of 1 hour each for one 24-hour period per window. The user is however free to change this.

Working with the seismograph program

When the Windows application is started (**Figure 3**), the serial port is initialised with RTS high and DTR low. This is how the hardware is provided with its power supply. At the top right of the window are two graphs. These display the present state of the sensor. The left window shows the amplitude of the sensor over a time period of 3 seconds. The window on the right shows the frequency analysis of the signal that is shown in the left window (DFT), with a bandwidth from about 0 to 25 Hz.

The actual recording starts after clicking the ‘Start' button. There then appears a large recording window that shows the amplitude history of the sensor on multiple lines, the number of lines per window and the duration of each line can be adjusted.

By default there are 24 lines of 1 hour each, but the user can change this by entering other values. This must be done before the start button is clicked. If the recording is already in progress it has to be stopped first by clicking the start button again.

The recorder can also be started at a specific time with a timer by ticking the box ‘Start at' and filling in the time below it. The format for this is HH:MM:SS AM/PM. To start at 10 o'clock in the morning this becomes 10:00:00 AM (AM in capital letters).

Once the recorder has been started, measuring will continue indefinitely and the window is automatically refreshed whenever it is full.

Using the File-menu this window can be saved as a bitmap (picture).

In the Settings-menu the COM-port, magnification, automatic data saving and the audio settings can be adjusted. The magnification setting (Magnify) allows 1, 2 or 4 times vertical magnification.

Via the Analyze-menu data can be read back in that was saved with the Autosave-setting, for each line or for each window. The format of the data is simply in bytes. The file name of each part of the recorded data is ‘DDMMYYYYHHMMSS.dta'.

Looking up a recording via the Load-data option is therefore just a case of finding the required date and time in the list of file names. When this file is selected with 'Open' it is displayed in graphical form on the screen. This data can then be saved as a picture or printed via the File-menu. The number of lines is the value shown underneath the text 'Lines' that is shown on the screen. The same data can be displayed with a different number by simply changing the value and clicking on the text 'Lines'.
The value of the Magnify-setting is also applied when clicking 'Lines', so that can be changed as well.
A good way of recording is to select a 'Line time' of 1 hour with 24 lines and with a 'Per line' setting for the Autosave setting.
Each data save action is now one hour apart; when reading this data back at a later time, this one hour can be stretched across 24 lines so that each line now displays 2.5 minutes which results in a very good display of the details.
In the Analyze-menu there is also the option 'Listen'. This allows the data that has been loaded with 'Load data' to be made audible. The Audio-option in the Settings-menu allows the volume and sample rate to be adjusted. This window disappears when 'Audio' is clicked again.
Since the recording is at 50 samples/s, at a sample rate of 5000 S/s the audio is played back 100x faster. Listening to a recording of one hour duration therefore takes only 36 seconds. Remarkable is that when listening to the recording, the sound has a resemblance to listening to a VLF-receiver in the audio range.
Post processing of the data can simply be done with the 'Paint' program in Windows. To do this, a previously recorded data file has to be read in with the Load-data option and then saved as an image with the Save-BMP option. The picture can then be opened with Paint and you can, for example, add text to certain 'events'.

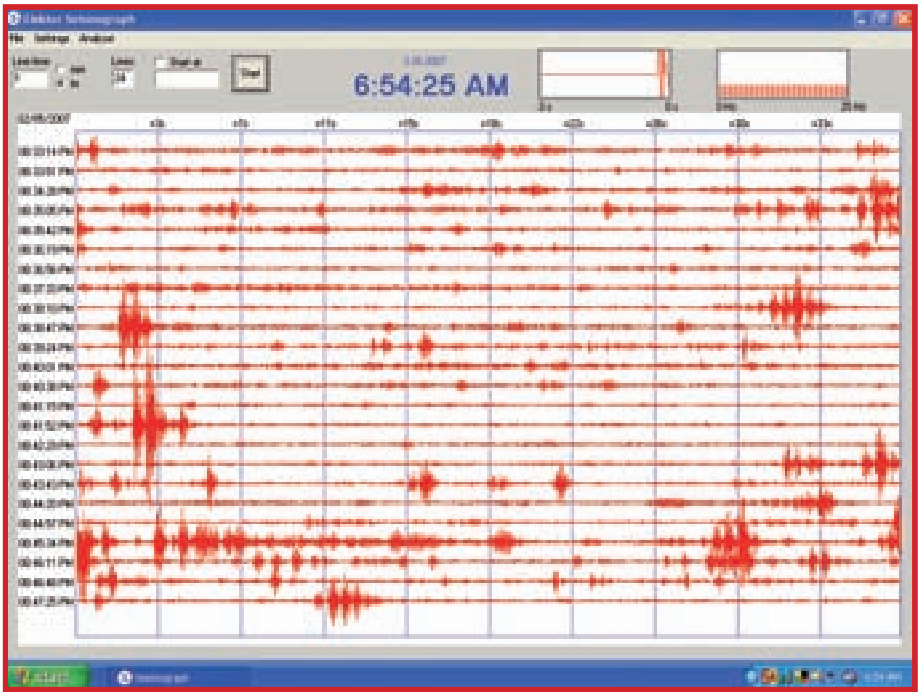


Figure 3. Screen dump of the accompanying PC program that makes the measured signal visible.

In use

The foundation is important when positioning a seismograph sensor. Soft, swampy soil damps the seismic tremors while, on the other hand, hard rocky ground ensures a very good transmission of these signals, even across large distances. Soft soil really requires a stake to be driven into the ground, but in many situations this has effectively already been done in the form of piles under the foundation of a building. Because the concrete that is often used for the floors and walls is also a good transmitter of seismic vibrations, the seismograph sensor can also be used indoors in these situations. On the floor it is best when this is uncovered, such as in the garage or on a balcony. But perhaps hanging the sensor from a concrete wall is the simplest solution. In many cases the sensor can be placed on the wall behind the PC. The sensor has the be fixed rigidly to the wall to prevent additional damping.
It is, however, ideal to measure in the open field on a hard surface, far from urban areas to avoid the seismic vibrations resulting from human activity and machines.

(060307-I)

COMPONENTS LIST

Resistors
R1,R6 = 1MΩ
R2,R5 = 100kΩ
R3,R13 = 22kΩ
R4 = 220kΩ
R7,R12 = 4MΩ7
R8 = 15kΩ
R9,R11 = 47kΩ
R10 = 10kΩ

Capacitors
C1,C14 = 10µF 25V radial
C2,C12,C13 = 220 µF 25V radial
C3 = 2µF2
C4 = 15nF
C5 = 220nF
C6 = 4µF7
C7,C8 = 22pF
C9,C16 = 1nF
C10 = 470nF
C11,C15 = 4µF7 25V radial
C17-C21 = 100nF

Semiconductors
D1,D2 = 1N4148
IC1 = LP2950CZ-5.0
IC2 = MAX7400CPA
IC3 = ATtiny45 (programmed, order code 060307-41)
IC4 = TL081ACN
IC5 = TL082CN
IC6 = LT1175CN8-5

Miscellaneous
K1 = 9-way sub-D socket (female), PCB mount
X1 = 4MHz quartz crystal
PCB, ref. 060307-1 from www.thePCBShop.com

ELF Reception

Signal hunting below 150 kHz

Rolf Hähle

Mobile phones, Wi-Fi and satellite communications are increasingly making use of ever higher frequencies stretching up into the Gigahertz bands. That doesn't mean that there is nothing interesting going on at the other end of the radio spectrum. We build a simple receiver and tune into some of the more bizarre signals in the extremely low frequency (ELF) domain.

A quick check on the tuner scale of any old analogue radio is all that is required to find out that the lowest frequency used for commercial broadcasting is 150 kHz on the long wave scale. That doesn't mean to say that if you were able to tune the radio below this frequency you would hear nothing but radio silence or maybe the odd crackle of static. Some of the bands below 150 kHz are used for scientific purposes and also for military applications. Communications with submerged submarines for example are carried out in the band between 70 and 80 Hz.

As the transmission wavelength gets longer so the expenditure on transmitting and receiving equipment gets higher and higher. Submarine communication requires a kilometre long antenna and a very high power transmitter, however the advantage of this band is that the signal can penetrate almost everything and can be received anywhere, even under the sea. Some applications of the low frequency bands are shown in the table.

In addition to these man-made signals there are some naturally occurring sources of radio signals below 150 kHz. The propagation of these signals is intimately related with the properties of the ionosphere and many radio amateurs have become experts in the study of these phenomena. Below 16 kHz in the VLF (Very Low Frequency) band it is possible to detect atmospherics or 'sferics'. These signals are produced where an electromagnetic pulse from a lightning stroke bounces around between the earths surface and the ionosphere producing signals that can be categorised as 'tweeks' while others are 'whistlers' and another type is the 'dawn chorus'. The 'dawn chorus' occurs at daybreak and sounds like birds calling to one another. The electrical properties of the ionosphere are affected by radiation from the sun so signal paths are constantly changing.

Frequency bands

	ELF	SLF	ULF	VLF	LF
	Extremely Low Frequency	Super Low Frequency	Ultra Low Frequency	Very Low Frequency	Low Frequency
Frequency	3 Hz to 30 Hz	30 Hz to 300 Hz	300 Hz to 3 kHz	3 kHz to 30 kHz	30 kHz to 300 kHz
Application	Technical maintenance: PIGs = Pipeline Inspection Gauges (20 Hz) Military: Submarine communications Signals of unknown origin	Military: Submarine communications: ZEVS Russia (82 Hz) Saguine USA (76 Hz)	Earthquake: Pre-quake sensing. Communications below ground: Bunkers, caves	Worldwide broadcast for various applications (Between 10 and 30 kHz) Omega navigation system: 10 to 14 kHz (up to 1997) Sferics: Signals from natural events: 'Whistlers', 'Tweeks', 'Dawn Chorus'	Standard Time signals: DCF 77 Frankfurt (77.5 kHz) MSF Rugby UK (60 kHz) HBG Switzerland (75 kHz) Military: Submarine communications (below 50 kHz) Amateur radio: 137 kHz band in some countries

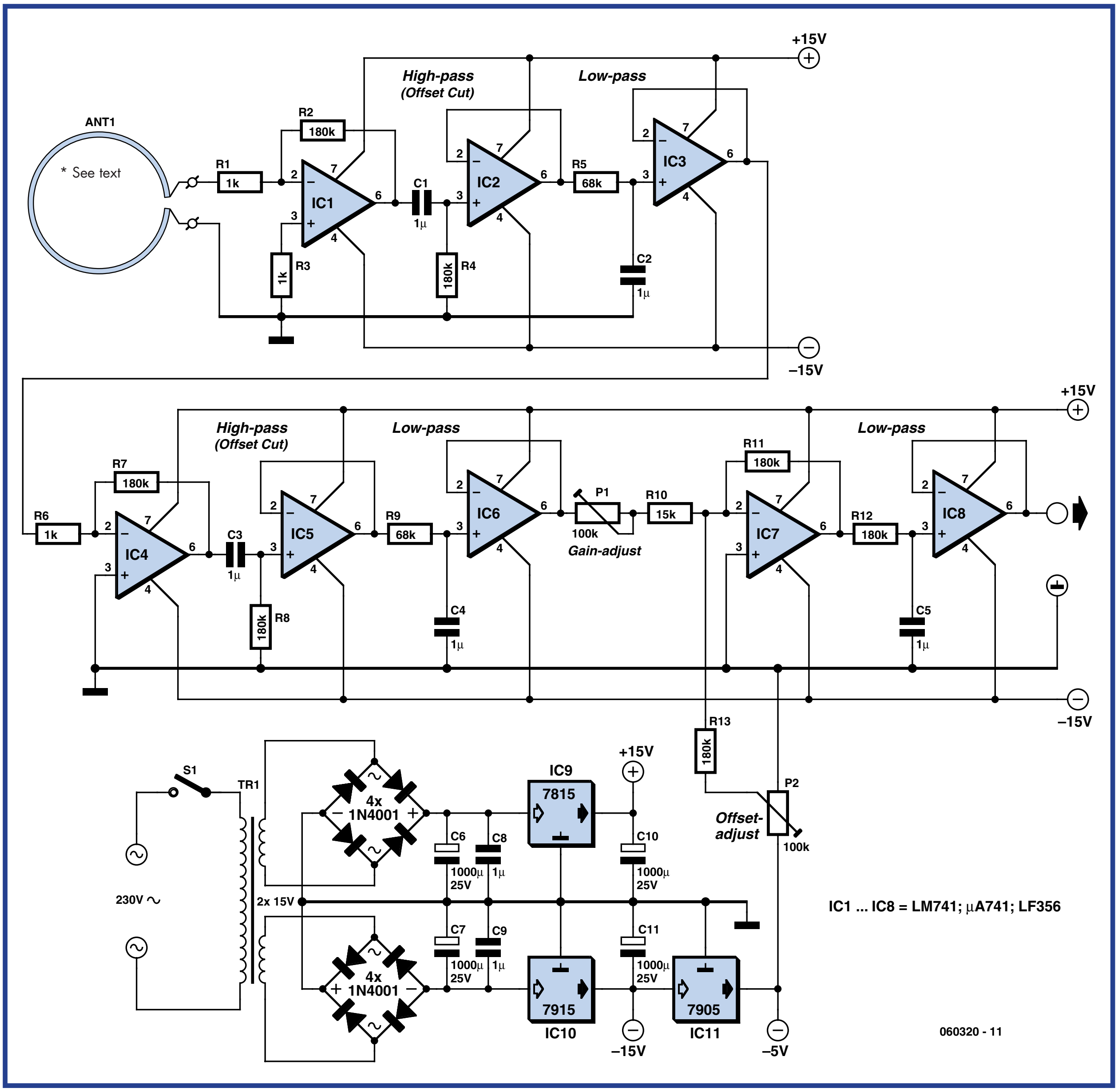


Figure 1. The ELF receiver circuit. The mains power supply can be replaced by batteries.

At these low frequencies there is no need to apply any demodulation to the signal, it is only necessary to convert the electromagnetic waves into audio waves.

There are a number of Internet sites suggesting designs of receivers capable of picking up the types of signals mentioned above. Many of the designs stand little chance of picking up more than a mains hum signal if they are operated in a normal domestic environment. The 50 Hz or 60 Hz mains signal pervades most populated regions of the world and it is difficult to filter out even with a steep high-pass filter. The mains signal is ideally a pure sine wave but in practice it contains many higher order harmonics that extend into ultrasonic frequencies and these can block the signals of interest.

VLF reception can only be successfully attempted once the receiver is situated far enough away from towns, villages, high voltage cables and factories. It goes without saying that a VLF receiver cannot be powered from the mains.

Reception of ELF signals below 50 Hz does not present so many problems as the mains frequency (50 or 60 Hz) does not contain any lower order harmonics so it is relatively easy to remove its effect with a simple low-pass filter. A receiver for these ELF frequencies can be built using just a highly sensitive audio amplifier together with a low-pass filter with a cut off frequency of around 20 Hz and a coil of wire to pick up the electromagnetic components of the signals (See the **inset** for details of coil construction).

A low-pass filter does the trick

There are several different design suggestions for ELF receivers posted on the Internet but none of them are universally suitable for the application. One contributor suggests connecting a pick-up coil directly to the sound card input and relying on the software spectrum analyser program to recover the ELF signals. Interference from the mains frequency is however so much higher in the average environment that the really interesting ELF signals are completely swamped when this approach is used.

Even with the addition of a low-pass filter the 50 Hz signal is still too large.

In principle the signal induced in the coil need only be amplified by a factor of 100,000 (minimum) but it is important to ensure that the interfering 50 Hz signal is sufficiently suppressed before the signal is amplified too

Figure 2. The receiver and power supply mounted in a small plastic housing. The connections go to the pick-up coil (in the black box) and to the laptop soundcard. The laptop is running CoolEdit.

much otherwise the amplifier will be driven into saturation by the mains signal. The receiver circuit suggested here amplifies the signal picked up by the coil before some of the 50 Hz content is removed by the first low-pass filter. The next stage provides the same amount of gain together with another low-pass filter. After the final filter the 50 Hz hum is barely perceptible on an oscilloscope display. The wanted ELF signals are however still present and can be further amplified or analysed.

The Receiver Circuit

The circuit shown in **Figure 1** should be quite easy to follow for anyone with some experience in analogue design. Amplifier A1 is configured as an inverting amplifier and boosts the signal picked up in the coil by a factor of 180 and presents a low impedance match to the coil. This is followed by a high pass filter formed by C1 and R4 which has a corner frequency 1 Hz. This filter is not strictly necessary for the frequency response of the circuit but C1 ensures that the signal is AC coupled to the next stage so that any DC offset on the output of A1 is not amplified by successive stages. The high pass filters can be omitted if more expensive offset-free op-amps are substituted here. A2 is simply a unity buffer amp while R5 and C2 form a low-pass filter, attenuating frequencies of 23 Hz and above. A3 is again a unity-gain buffer. The overall effect of these three opamps is to provide band pass filtering between 1 and 23 Hz together with some gain.
The following three amplifiers are a repeat of the first three and provide more gain and further attenuation of the 50 Hz signal. The unwanted mains hum signal becomes weaker after each stage while the signals of interest are amplified.
The resulting receiver is so sensitive that it can detect the movement of a small magnet (salvaged from an old loudspeaker) at a distance of 5 m. Waving the magnet up and down produces a corresponding sinewave on an oscilloscope connected to the amplifier output. The 50 Hz mains signal is barely perceptible on the oscilloscope trace.

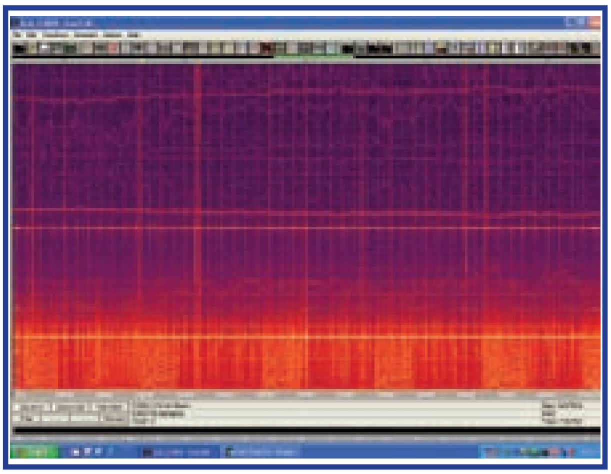


Figure 3. Spectral content of the 'cow' signal. This is just one of over 20 different signals that the author has recorded.

Not all plain sailing

The signals picked up by the circuit are of such low frequency that they are subsonic and by definition cannot be heard. There is also little point in displaying them on a standard oscilloscope because the signals are seen as a mixture of different frequencies and it is difficult to extract any meaningful information.
For this reason it is more useful to make a recording of the signals over a long period (15 minutes minimum) and then display them using a spectrum analyser. Both of these features are available in the audio editing program Cool Edit which is shown here in **Figure 2** running on a laptop PC.
This program is however designed to show the entire audio spectrum so the subsonic ELF signals are cramped up in the corner of the display which makes it difficult see what is going on at these frequencies.
The simplest way to expand the displayed ELF region is to fool the spectrum analyser into thinking that the received signal lies in the audio range (i.e. from around 50 Hz up to 20 kHz). This can be achieved by sampling the signal during recording at a one rate and then playing it back using a faster sample rate. It is basically the same technique as time lapse photography where slowly occurring events are played back much faster. For example a plant may take 100 days to develop from a seed to a flower. Growth is so slow that it is difficult to notice any difference from one day to the next but if you were to take a snapshot every four hours of the plant's life and then view the pictures at 25 frames per second the entire growth period would be shown in just 24 seconds.
The same basic technique is used to capture, display and hear the ELF signals:
1. Connect the VLF receiver output to a PC sound card input and use a PC recorder program to store the received signal. Note that a standard PC sound card provides sharp attenuation to signals below 16 Hz.
2. The sample rate must not be higher than 200 Hz. If the recorder software does not allow selection of this low rate then it is necessary to write a program that effectively reduces the sampling down to this rate by just taking say every hundredth sample in the record file and discarding all the others in between. The effective sample rate is now one hundredth of the original.
3. The resultant sound file can now be used in the analyser program with the sampling rate set to 32 kHz which has the effect of multiplying the signal by 160 (assuming an original sample rate of 200 Hz) and making the signal

audible. The time lapse effect on the signals makes it possible immediately to see structures and patterns in some of these slowly changing received signals which are not obvious when the signals are observed in real time. The time and frequency markers displayed on the analyser program must of course be divided be the difference in sample rates to obtain their true values.

Curious results

The strange nature of the signals that the author has picked up in this frequency band over the past six years really has justified the effort invested to build the ELF receiver. To start with the more banal signals that you are likely to tune into there is a weak 50 Hz line shown on the spectrogram produced by the ubiquitous mains power distribution network and also another signal peak at 16.66 Hz emanating from the railway network power distribution (in Germany) which can even be detected up to 6 km from the railway line! These two frequencies are not at all interesting but can be used as markers for testing the receiver. The majority of train networks outside the UK distribute power using overhead cabling; in Germany this generates a strong 16.66 Hz alternating electromagnetic field which swamps the input to the ELF receiver if it is operated within 1 km of the railway. These are probably the least interesting signals that you are likely to hear with this receiver. After many years of investigation into ELF phenomena the author has been able to identify locations on the earth's surface (in his locale) from where specific signals in the range from 0.8 to 20 Hz seem to emanate. The source of the signals is a mystery; some of the more interesting transmissions have particular characteristics and are strongest in certain areas.
Examples of processed ELF signals can be downloaded from our website at www.elektor-electronics.co.uk. The signal pitch of these sound files has been multiplied by 160 using the 'time lapse' technique described earlier to make them audible.
Figure 3 shows the spectrum (against time) of a particular type of signal which has come to be known as the 'cow' signal. No prizes are on offer if you can guess what it sounds like once it has been transposed into an audible signal. In real time each transmission lasts for around five minutes and has been detected over a number of years, it occurs at random intervals, day or night and seems to be strongest along the main approach road around the northern edge of the village of Eifel in Germany.
The 'goose signal' sounds a bit like a quack when it is transposed but each sequence actually lasts for around one hour. There is a recognisable structure to the signal starting with what looks like a message 'header' and a (variable) series of mark/space pulses at about 16 Hz where each mark lasts for four periods. The complete sequence is repeated after 24 hours. Again this signal is quite localised to the Eifel region of Germany but has been detected up to 40 km away.
The 'heartbeat' signal sounds like the continuous emergency tone emitted by a heatbeat monitor. A look at the spectrum of this signal shows a fundamental frequency of less than 1 Hz with peaks at odd harmonics of the fundamental i.e. 3 and 5 times and so on. This characteristic indicates that the signal is actually a square wave. The signal begins at apparently random times and is interrupted at minute intervals; the entire broadcast can last for several hours and has been detected throughout Germany. Listeners to this particular transmission have reported an increase in activity over the last three years. The signals are quite localised so it is unlikely that they have some connection with submarine communications or are of cosmic origin. One possible explanation is that they are generated by currents in the earth produced by the switching and operation of powerful electrical machines but if that were the case you would expect the signal structures to be similar each time they appeared and that is not the case. Maybe one day the mystery will be solved but until then it certainly makes interesting listening!

(060320-1)

The pick-up coil

The receiver antenna consists of a coil of about 1000 turns of fine enamel coated wire wound on a 40 cm diameter former. The wire can be salvaged from the primary windings of several old mains transformers (solder, then insulate the joints), alternatively a large spool of suitable wire can be purchased (the internet offers a good source of suppliers).

For coil winding a quick and simple former can be constructing by hammering in 8 nails evenly spaced around the circumference of a 40 cm circle drawn on a block of wood (don't hammer them in too far). A little patience and a notepad (you don't want to lose count half way through) is all that is necessary to wind the 1000 turns around the former. Insulating tape should now be wound around the finished winding to give some protection from the elements. The nails can now be carefully withdrawn to release the coil.

The finished coil is quite rigid and self-supporting but it helps to protect the fine wire from damage if it is fitted into a flat wooden box. A quarter inch mono jack socket can be fitted to the box to provide electrical connection to the coil.

NB: Ensure that the coil assembly is fixed firmly and not subject to vibration or any other type of movement during use, even a small movement interacts with the earth's magnetic field and induces a signal in the coil which can overload the input stage.

The coil can also be used for direction finding; the received signal will be strongest when the magnetic field lines are at 90° to the coil plane. The signals have a long period and the recording process is rather slow so it takes a great deal of patience to make the measurements necessary to identify the location of the signal source.

Web links

Example sound files at www.elektor-electronics.co.uk; click on Magazine → May 2007 → ELF Reception.
www.vlf.it

ATtiny

Use a miniature m

Martin Ossmann

These days many radios are capable of receiving and decoding RDS signals, displaying the broadcaster's name and much more besides. Traffic announcements are also triggered via RDS. The very simple transmitter described here will let you test receivers and investigate faults, and could be used as the basis for your own projects. By using advanced techniques we have made it possible to write all the code for the ATtiny2313 microcontroller in C and compile it using the free WINAVR compiler.

Most car radios available today support RDS, usually providing an eight-character display to show the broadcaster's name. Nevertheless, some broadcasters manage to make the display show more than just their name, for example to include music track titles or stock market indices. This is done by using the PS ('program service') data field in creative ways so that variable data can replace the broadcaster name. It would be more elegant to use the RT ('radio text') function for this purpose, which provides for up to 64 characters of information, but this is of little use if the radio does not support the feature. The TP/TA ('traffic programme'/'traffic announcement') feature is widely supported, however.

Our test transmitter transmits the bits to control the TP/TA function along with an example text ('ELEKTOR') for the PS field. The C program code can be used as a basis for more advanced projects. For example, a parameter could be measured and sent via RDS for display on an FM radio. If a threshold value is exceeded this can be flagged as a pseudo-traffic announcement, causing the radio to turn up the volume.

Surprisingly enough the whole transmitter consists of just two digital ICs, together costing just a couple of pounds. One is an Atmel ATtiny2313 microcontroller, and the other is a standard CMOS 74HC00 quad NAND gate. The FM signal is generated as a harmonic of the clock frequency, meaning that its frequency is crystal-controlled and that no RF adjustments are required to the circuit. There are a few clever ideas in the design of the transmitter which make the circuit astonishingly simple.

Fractional PWM

The first step to generating an RDS signal is to create a 57 kHz subcarrier, accurate in frequency to a few Hertz. We need to be able to generate this frequency without using a special crystal. The now standard frequency of 11.0592 MHz is not a simple integer multiple of 57 kHz:

11.0592 MHz/57 kHz=194.0210526....

It is therefore not possible to use a simple divider. However, if we switch a divider between ratios of M=194 and M+1=195 in the right proportions we

as RDS Signal Generator

icrocontroller to send characters to an FM radio display

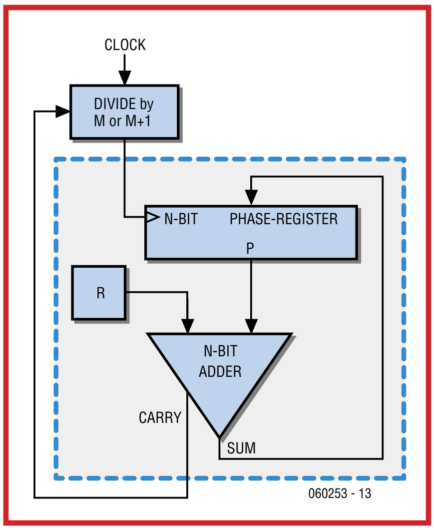


Figure 1. Fractional divider using PWM.

Listing

Interrupt routine

```
// 10 MHz to 77.5 kHz DDS PWM generator
// 10MHz/77.5kHz=129.032258065.. ; 0.032258065*2^16= 2114.0639..
.equ M      = 129
.equ R      = 2114
TIM1_OVF:                       // interrupt
     in     SREGsav,SREG        // save status
     subi   DDS0,low(R)         // 16 Bit subtract
     sbci   DDS1,high(R)
     ldi    temp,M              // preset PWM period
     brcs   no1                 // check carry
     dec    temp                // decrement PWM period
no1: out    ICR1L,temp          // set new PWM period
     out    SREG,SREGsav        // restore status
     reti                       // return from PWM interrupt
```

Technically, no problem

Several interesting applications can be imagined if you (1) adapt the microcontroller source code, (2) burn the object code into a larger, more powerful micro and (3) add a small RF output amplifier (say, one transistor and a filter). For example, you could make the inside and outside temperature, or the oil temperature, appear on the RDS display on your car radio. In principle, any sensor signal lends itself to this application, provided you add the necessary interfacing and software extensions.

The more communicative among you may just play with the idea of 'narrowcasting' RDS text messages to other people, for example, fellow drivers stuck in yet another traffic jam on the M25. You need to be sure, though, of the radio station they are tuned to (best guess: Radio Kent).

Technically speaking, a lot is possible, but not from a legal point of view as in most countries the use as well as the ownership of non-approved transmitter gear is prohibited by solid legislation.

can obtain an average division ratio between these two integer values. In the ATtiny microcontroller a suitable switchable divider can be found in the form of the PWM unit. We simply need a software module which sets the PWM period to $M+1=195$ for an overall fraction of its cycles given by $r = 0.0210526...$ and to M=194 for the remaining fraction $1–r$ of its cycles. The average division ratio is then exactly

$$r(M+1)+(1–r)M=M+r=194.0210526....$$

A suitable module to control the switching of ratios is a device known as a DDS signal generator: **Figure 1** shows a block diagram of the concept. The system is based around an N-bit accumulator, which can hold values up to 2^N-1. Each clock output from the $M/M+1$ divider adds a fixed value R to the value P in the accumulator. The

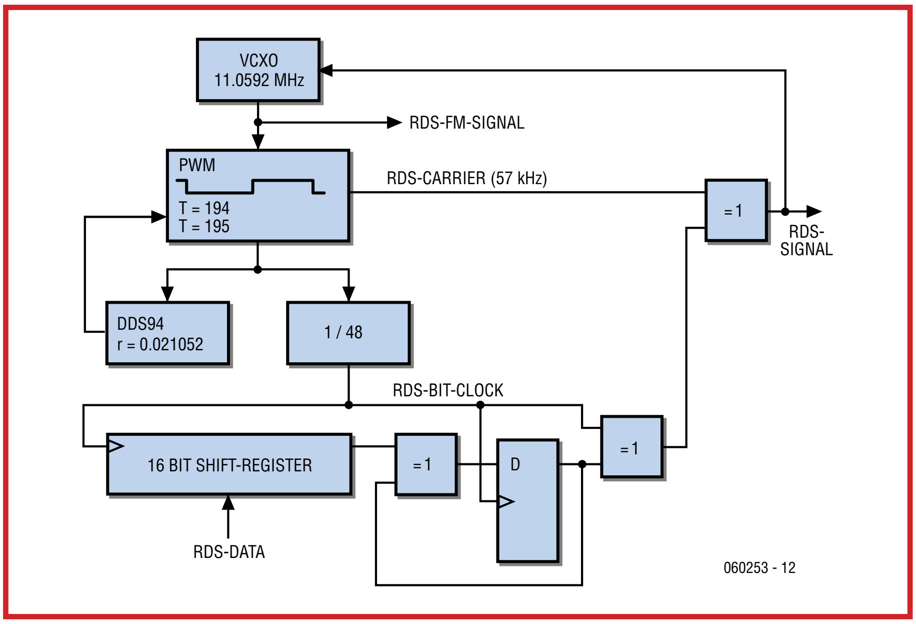


Figure 2. Signal generator block diagram.

fraction of divider cycles for which the carry output of the adder is set is then $r = R/2^N$. If the master clock frequency is f_{CLOCK}, the PWM module (when controlled in this way) will have an output frequency given by

$$f_{OUT} = f_{CLOCK} / (M + R/2^N).$$

A disadvantage of this technique is that the output signal exhibits jitter, which corresponds to phase noise in the output spectrum.
Once suitably initialised, the interrupt routine for the ATtiny2313 is very simple, as can be seen in the **Listing**. The values given generate an output frequency of 77.5 kHz from a clock frequency of 10 MHz.
It is also straightforward to use the method described above to generate the RDS clock frequency from an 11.0592 MHz master clock. The method is so efficient that the whole thing can be written using the C programming language, with the result that the project is considerably easier for the non-specialist to modify. In our case we use a 15-bit phase accumulator. A schematic diagram of the whole system is shown in **Figure 2**.

Modulating the bitstream

The RDS bit clock of 1.1875 kHz can readily be obtained from the 57 kHz clock by division by 48. The bit clock is used to shift data bits from a shift register into a differential encoder, as well as in modulating the 57 kHz subcarrier. It is used to apply a phase shift of 180 degrees to the subcarrier, performed by an exclusive-OR gate in Figure 2; in software we can invert the polarity of the PWM generator output by simply changing a configuration bit. The phase shift is determined by the output of an exclusive-OR gate which combines the RDS bit clock with the output of the differential encoder. The differential encoder changes the modulation polarity from bit to bit when the bit to be transmitted (obtained from the shift register) is a logic one. The data payload has the necessary error correction bits added before being loaded into the shift register.
The whole of the above process is implemented in software, with the RDS signal being present at the output of the PWM module as a square wave (being therefore spectrally rather impure). This signal is used to frequency modulate the master clock generator. Since the biphase-modulated PWM signal has zero overall offset, this modulation does not affect the centre frequency of the oscillator. The bit timing is also essentially unaffected by this frequency modulation.

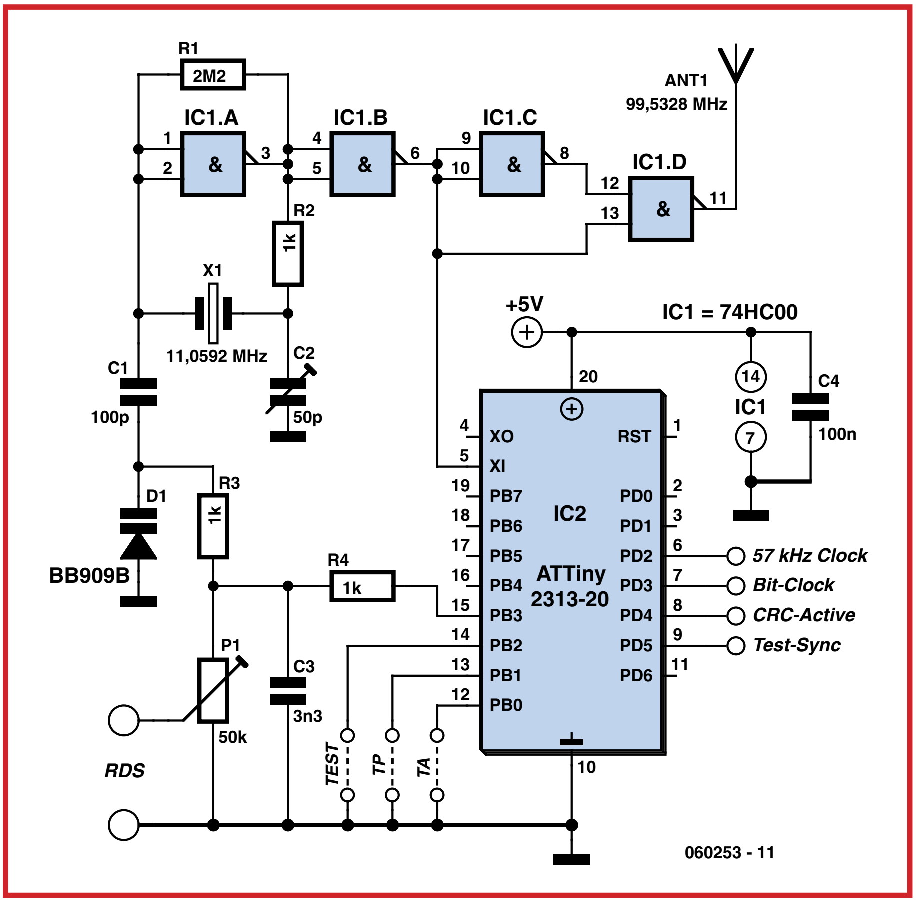


Figure 3. Circuit of the RDS test transmitter.

Construction

The frequency-modulated clock generator is built around a simple CMOS oscillator using a varicap diode. The overall circuit diagram is shown in **Figure 3**. Two NAND gates produce

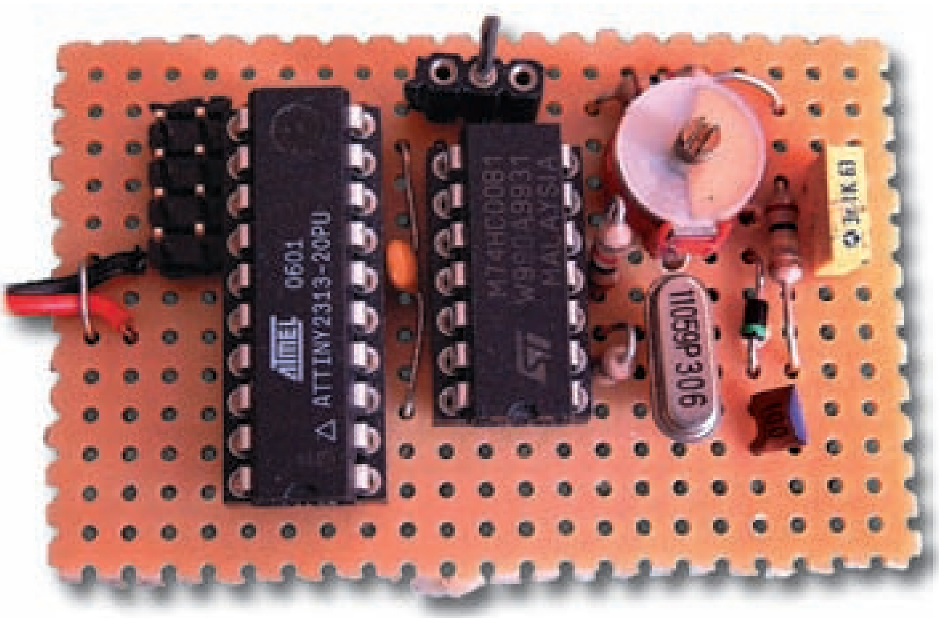


Figure 4. Construction on prototyping board.

narrow spikes at the output, rich in harmonics. A short length of wire makes an adequate antenna for initial testing. The ninth harmonic is at nine times 11.0592 MHz, or 99.5328 MHz, comfortably in the middle of the FM frequency band. The photograph at the head of this article shows a portable receiver with RDS receiving the test signal and displaying the broadcaster's name ('ELEKTOR', naturally enough).

Wire links or switches connected to pins 12 to 14 of the microcontroller activate the TA (traffic announcement) and TP (traffic programme) bits, and a test mode where a 16-bit test pattern is repeatedly transmitted instead of the RDS packets. Pins 6 to 9 carry the most important signals needed for test purposes. Trimmer C2 should be adjusted so that the frequency on pin 6 (PD2) is 57 kHz.

The RDS output provides the baseband RDS signal, which can be used for direct testing of RDS demodulators. Alternatively, the signal can be used to drive another FM transmitter.

The total component count is remarkably small and so construction on a piece of prototyping board (see **Figure 4**) is entirely practical. The ATtiny2313 microcontroller software (hex file and C source file) is available for free download from the *Elektor Electronics* website. Ready-programmed microcontrollers are also available from the *Elektor* SHOP.

You can modify the source code to implement various special functions. You will need a copy of the RDS standard to understand how the information is encoded, and this standard is available on the Internet (see links below).

Because the test transmitter only outputs a tiniest amount of RF power in the VHF FM band, it is possible to connect its output directly to the input of an RDS radio using a length of coaxial cable to minimise the stray emissions.

It should be noted that the transmitter's output signal covers a wide band of frequencies so the suggested method of connecting is recommended to comply with relevant legislation.

(060253-I)

Weblinks

http://en.wikipedia.org/wiki/Radio_Data_System

www.g.laroche.free.fr/english/rds/rds.html

References

RDS: FM with text and data, Elektor Electronics, April 1989.

Martin Ossmann: RDS Decoder, Elektor Electronics, February 1991.

Asynchronous Mot
Atmel Evaluation

With AT90PWM3 microcontroller and Fairchild Smart Power Module

Paul Goossens

Controlling the speed of an asynchronous motor requires a three-phase frequency inverter. The ATAVRMC200 evaluation kit from Atmel is based around a flexible motor control board which uses a special AVR microcontroller, along with a Fairchild SPM for the output driver stage. A special feature of the system is that it can control asynchronous motors without using a sensor.

Engineers usually refer to asynchronous motors as 'AC induction motors' [1], especially when powered from a three-phase supply. The stator in a three-phase induction motor uses the three supply phases, called U, V and W, to create a rotating magnetic field. The simplest way to drive such a motor is to use a sinusoidal voltage on each of three windings, with phase shifts of 120 degrees between each. Normally a three-phase supply will deliver these three voltages at a frequency of 50 Hz and with an amplitude of 400 V between phases.

Since the rotor in an asynchronous motor follows the rotating magnetic field with just a small lag, the speed of the motor is strictly limited by the frequency of the three-phase supply. With a 50 Hz supply the range of available speeds is relatively narrow and independent of the load on the motor. It is really only practical to change the speed of the motor by adjusting the driving frequency. A frequency inverter solves this problem: from the rectified mains power it generates a three-phase sinusoidal output signal with adjustable frequency and (usually) adjustable amplitude, allowing control over both speed and torque.

The frequency inverter

The three-phase frequency inverter essentially consists of three variable frequency sine wave inverters. As with the more familiar single-phase inverters (which convert 12 V DC to 230 V AC) linear power output stages are eschewed because of their poor efficiency when generating sine wave signals. It is better to use power transistors as switches (see **Figure 1**), minimising power losses. If switch S_{a+} is driven by a PWM signal and switch S_{a-} is driven by the inverse of that PWM signal, the result is a voltage that (on average) can be set at will between 0 V and the supply voltage of the circuit by controlling the width of the PWM pulses.

The Smart Power Modules (SPMs) allow the power switches to be controlled using TTL-compatible (5 V) logic inputs. When driving the power switch elements (IGBTs or FETs) it is essential to ensure that the two parts of one half-bridge (such as S_{a+} and S_{a-} in Figure 1) are never on simultaneously. The result would be a short circuit across the supply and an undesirably high current would flow. Since the power transistors do not switch instantly, it is necessary to introduce a small delay in the control circuit between switching one transistor off and the other on. This ensures that a transistor only starts to conduct when its partner is off, and vice versa.

tor Control using Board

Constant voltage-to-frequency ratio

The simplest way to control the speed of the motor is via the frequency of the rotating magnetic field. To maintain the performance of the asynchronous motor, in particular its torque, it is necessary to keep the ratio between voltage and frequency constant. As the speed increases we must therefore also increase the amplitude of the sinusoidal signals we produce. This can of course only go as far as the point where the maximum permissible voltage for the motor is produced at the frequency inverter's output. If we wish to increase the frequency further we must limit the voltage and so the torque produced will no longer be constant; indeed, it will fall. Torque can also fall off at very low speeds.

Maintaining the voltage-frequency ratio constant implies the use of low voltages, which in turn means that the resistance of the windings becomes a consideration. This is compensated for by setting a lower frequency limit (called the boost frequency) below which the amplitude is kept constant rather than reduced. As a rule of thumb this limit can be set to 5 % of the frequency at which the motor's maximum voltage is attained.

To change the direction of rotation of an asynchronous motor it is sufficient to swap the connections to two of the three windings, for example, V and W. This exchange is straightforward to implement in the frequency inverter's control software.

More than just a sine wave

When an asynchronous motor is controlled electronically we have the ability to increase the motor power by using a drive waveform that is not sinusoidal, in particular by using a sine wave plus a component at its third harmonic. If the amplitude of the third harmonic is one sixth that of the fundamental we have a signal that approximates a

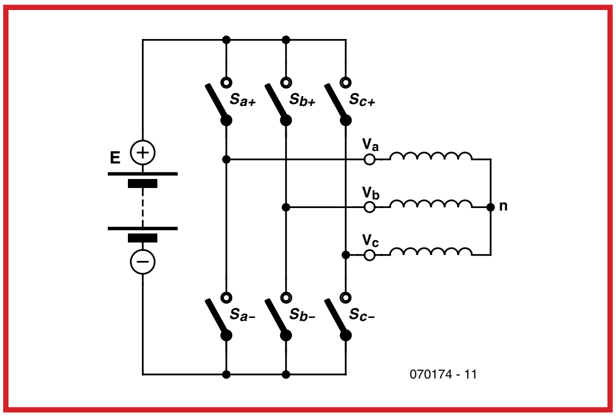


Figure 1. Principle of the inverter controller for asynchronous motors.

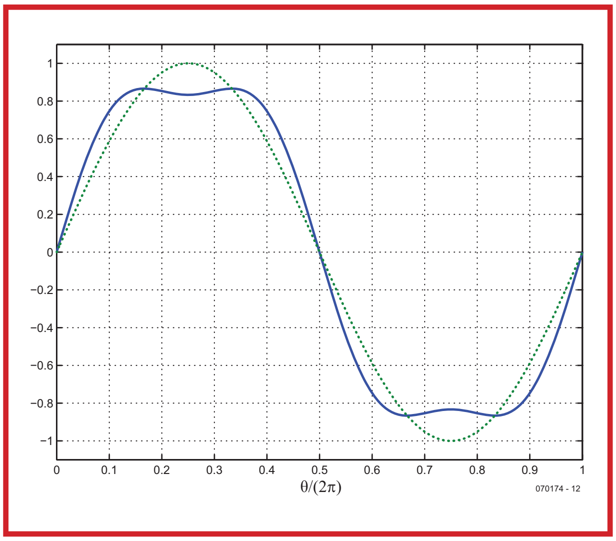


Figure 2. A non-sinusoidal waveform allows a higher RMS voltage to be achieved for a given peak voltage, giving greater power.

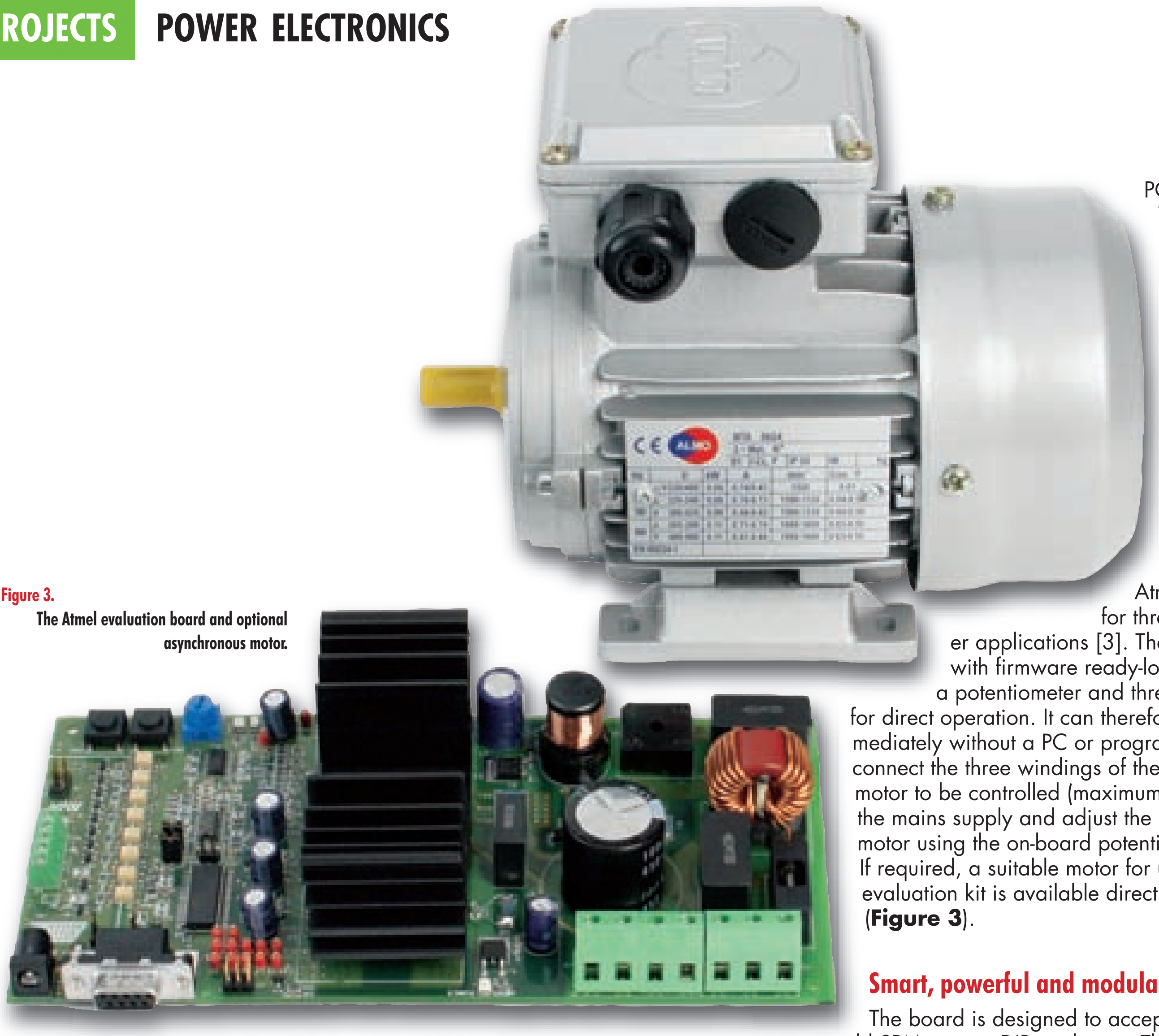


Figure 3.
The Atmel evaluation board and optional asynchronous motor.

square wave (**Figure 2**). The advantage is that the RMS value of this signal is higher relative to its peak voltage than is the case for a simple sine wave. This enables the motor to produce more power for a given peak winding voltage.

Dum volvo, video disco

Theory is all very well, and data sheets and application notes can provide large amounts of information, but these are no substitute for actual practical experience. Semiconductor manufacturers such as Fairchild and Atmel are of course aware of this and so it is no coincidence that they have produced a useful development board as an aid to applications developers, featuring an AVR microcontroller for control and a Smart Power Module as power output stage. The board forms the heart of the Atmel ATA-VRMC200 evaluation kit [2].
The development board is delivered with software and detailed diagram showing which connections should be made where in order to connect mains supply, motor and PC together.
The evaluation board can be used with mains voltages from 110 V to 230 V and frequencies from 50 Hz to 60 Hz. The drive is controlled by an AT90PWM3 microcontroller, developed by Atmel specifically for three-phase inverter applications [3]. The board comes with firmware ready-loaded and with a potentiometer and three push-buttons for direct operation. It can therefore be used immediately without a PC or programming: simply connect the three windings of the asynchronous motor to be controlled (maximum 370 W) and the mains supply and adjust the speed of the motor using the on-board potentiometer.
If required, a suitable motor for use with the evaluation kit is available directly from Atmel (**Figure 3**).

Smart, powerful and modular

The board is designed to accept Fairchild SPM units in DIP packages. The board is shipped with a type FSAM10SH60 10 A module, with a maximum output power of 370 W. In principle any other pin-compatible SPM in a DIP package could be used, for example to obtain a higher output power. The **Table** shows four types differing in maximum current (and hence output power) rating. They are otherwise identical, all having a built-in NTC thermistor, the same package type, the same pinout and the same SPM frequency. This means that the board can easily be adapted for use with different-sized motors. If desired a (free) sample SPM can be ordered directly from the Fairchild website.

Development platform

As well as offering the opportunity for modifications to suit different-sized motors, the hardware and software of the evaluation board provides a well-equipped platform for your own projects. **Figure 4** shows an overview of the hardware. On-board regulators provide the voltages of 5 V and 15 V required for the microcontroller and for the Smart Power Module. The safety circuits built into the

Table. This table shows pin- and function-compatible SPMs for various output power levels

Smart Power Modul (SPM)	SPM frequency [kHz]	I_C at T_C = 100 °C [A]	Maximum motor power [kW]	Motor voltage [V]
FSAM10SH60A	15	10	0,4	220
FSAM15SH60A	15	15	0,75	220
FSAM20SH60A	15	20	1,5	220
FSAM30SH60A	15	30	2,2	220

No mains isolation!

Power electronics operating at 230 V is rarely isolated from the mains, and the Atmel motor control evaluation board is no exception to this rule. When in operation and during testing you must always be conscious of the fact that the majority of the circuit is connected directly to the mains and therefore that any conductive part may be carrying mains voltages! This remark applies equally to the digital parts of the circuit, including the microcontroller.

If the board is in the open and accessible, while taking measurements, testing or experimenting, you should power it via an isolating transformer. In any case you must ensure that no-one can come into contact with mains voltages.

Fairchild module can be monitored using the microcontroller. These include a thermistor for temperature monitoring, a short circuit or overcurrent detector and a monitor for the supply voltage to the gate drivers inside the SPM. Should a fault occur a signal generated by the module is sent to the microcontroller.

The board can be connected directly to a PC via an optically isolated interface. The three sensor inputs and the ISP interface are also optically isolated.

Fairchild celebrates tenth and fiftieth anniversaries

Join in the celebrations and win a complete frequency inverter board plus asynchronous motor!

The year two thousand and seven marks a double anniversary for Fairchild Semiconductor. In 1957, fifty years ago, the 'Traitorous Eight' left the team of transistor co-inventor William Shockley to found their own company in what is now known as Silicon Valley, to manufacture better transistors based on silicon. The name, and the money, for the company came from inventor and legendary entrepreneur Sherman Fairchild. In 1958 the planar transistor was invented at the company, forming the basis for a new industry. There followed a series of firsts: the first silicon IC (1960); the first static flip-flop IC, and, with the μA702, the first operational amplifier IC (both in 1964). The μA709 (1965) and the μA741 (1968) can still be bought today.

Ten years after being taken over by National Semiconductor (itself founded by ex-Fairchild employees), Fairchild became independent once again in 1997. In 2007, therefore, we mark the tenth birthday of the new Fairchild. Making a fresh start in logic, memory and discrete devices, Fairchild has become 'The Power Franchise'. According to its own figures, it is the biggest provider of components worldwide for system power optimisation. The Smart Power Modules (SPMs) described in this issue of Elektor Electronics are a part of the widest range of integrated motor control products in the industry, with devices rated from 50 VA to 10 kVA.

Anniversary Quiz

Answer these three questions correctly, and you could win a prize!

a) Who developed the planar transistor at Fairchild in 1958? (Hint: he was Swiss by birth.)

b) How many integrated components comprise an IGBT?

c) What is the phase angle between any two of the three-phase outputs of a frequency inverter?

As prizes we are giving away ***ten ATAVRMC200 asynchronous motor controller evaluation kits***, ***including asynchronous motors*** (see photographs), ***each worth well over £ 200!***

Send your answers, ***by 21 May 2007***, by e-mail to editor@elektor-electronics.co.uk or by post to Elektor Electronics, Regus Brentford, 1000 Great West Road, Brentford TW8 9HH, England, marking your envelope 'Fairchild'. The editors' decision is final.

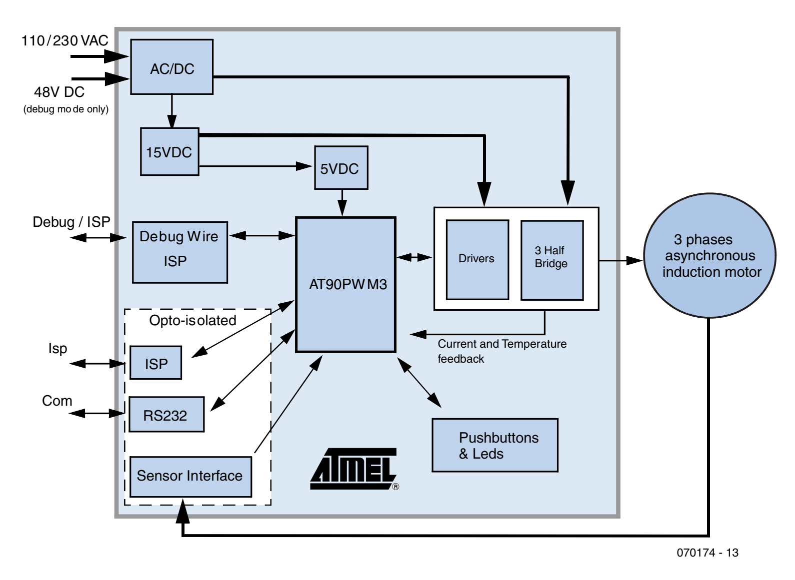


Figure 4. Block diagram of the evaluation board, which can be used directly for motor control.

The AT90PWM3

The AT90PWM3 is an AVR-series microcontroller developed by Atmel specifically for applications in fluorescent lamp ballast and motor control. A special feature of the device is its three high speed PSCs (power stage controllers).

Each PSC has two PWM modules and so can create two PWM signals. In software it is very easy to control these outputs so that they are complementary to one another. It is also easy in software to add a 'dead time' to avoid the problem of a brief short-circuit between the power rails in the output stage when both transistors in one half-bridge conduct simultaneously.

The PSCs can also react, without software intervention, to fault signals, zero-crossing detection and the like. It is also possible to update the settings for the three PSCs simultaneously.

Software

Software tools for developers are provided on the CD delivered with the hardware, and the most recent versions are also available for download from the Atmel website. Code for your own projects can be written in the C programming language and compiled. Two firmware examples for the AT90PWM3 can also be freely downloaded from Atmel [4]. The source code is thoroughly commented and a detailed description is given in two application notes (also available for download [4]). A small but important part of the code, determining the U/f characteristic, is shown in the **Listing**.

In-system programming (ISP) makes it easy to adapt the microcontroller for new applications. Neither of the recommended programmers (AVR ISP or JTAGICE Mk II) is provided with the evaluation kit.

(070014-1)

Weblinks:

[1] http://en.wikipedia.org/wiki/Electric_motor#Three-phase_AC_induction_motors

[2] www.atmel.com/dyn/resources/prod_documents/doc4096.pdf

[3] www.atmel.com/dyn/products/product_card.asp?part_id=3615

[4] www.atmel.com/dyn/products/tools_card.asp?tool_id=3901

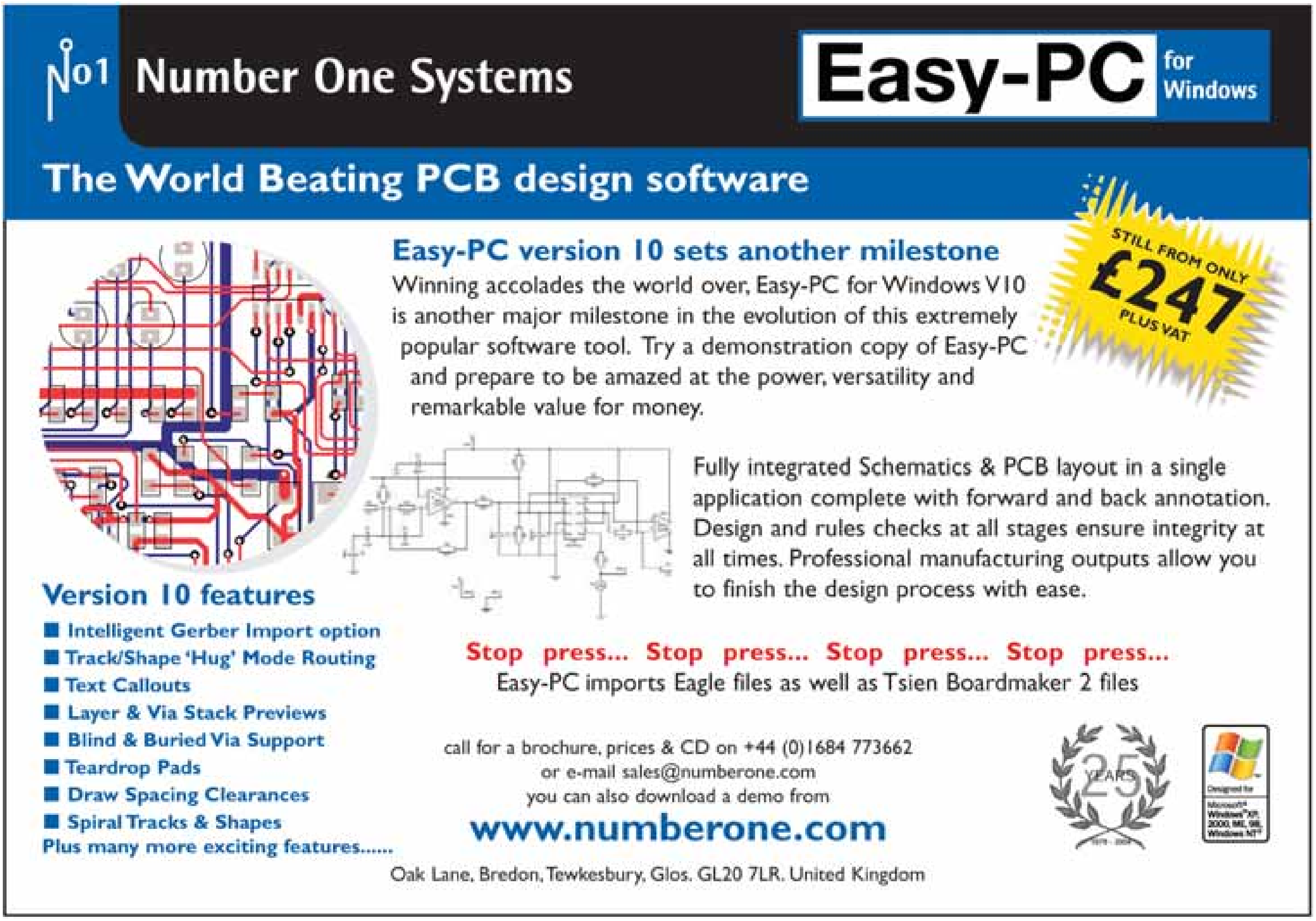
U/f characteristic in software

This listing shows the implementation of a constant U/f ratio, taking into account the boost frequency and maximum permissible voltage.

```
U16 controlVF(U16 wTs) {

    U16  amp ;

    if (wTs <= OMEGA_TS_MIN )         // boost frequency
    {
         amp = (Vf_SLOPE * OMEGA_TS_MIN) / 10;        // boost voltage
    }
    else
         if ( (wTs > OMEGA_TS_MIN) & (wTs < OMEGA_TS_MAX) )
          amp = (Vf_SLOPE * wTs)/10 ;   // V/f law
         else
          amp = (Vf_SLOPE * OMEGA_TS_MAX)/10;       // rated value
    return amp ;
}
```


No1 Number One Systems
Easy-PC for Windows
The World Beating PCB design software
Easy-PC version 10 sets another milestone
Winning accolades the world over, Easy-PC for Windows V10 is another major milestone in the evolution of this extremely popular software tool. Try a demonstration copy of Easy-PC and prepare to be amazed at the power, versatility and remarkable value for money.
STILL FROM ONLY £247 PLUS VAT
Fully integrated Schematics & PCB layout in a single application complete with forward and back annotation. Design and rules checks at all stages ensure integrity at all times. Professional manufacturing outputs allow you to finish the design process with ease.
Version 10 features
■ Intelligent Gerber Import option
■ Track/Shape 'Hug' Mode Routing
■ Text Callouts
■ Layer & Via Stack Previews
■ Blind & Buried Via Support
■ Teardrop Pads
■ Draw Spacing Clearances
■ Spiral Tracks & Shapes
Plus many more exciting features......
Stop press... Stop press... Stop press... Stop press...
Easy-PC imports Eagle files as well as Tsien Boardmaker 2 files
call for a brochure, prices & CD on +44 (0)1684 773662
or e-mail sales@numberone.com
you can also download a demo from
www.numberone.com
Oak Lane, Bredon, Tewkesbury, Glos. GL20 7LR. United Kingdom
25 YEARS
Designed for Microsoft Windows XP, 2000, ME, 98, Windows NT


No Compromise Oscilloscope
pico Technology
Other oscilloscopes in this price range force you to compromise on one of the key specifications:
sampling rate, memory depth or bandwidth.
The PicoScope 5000 series is a no compromise PC oscilloscope at a price every engineer can afford.
1GS/s sampling rate
250MHz bandwidth
128M sample buffer memory
125MS/s 12 bit AWG built in
PicoScope 5203
32M buffer £1195
PicoScope 5204
128M buffer £1795
www.picotech.com/scope408
01480 396395

Smart Power Modules

Power output stages with integrated drivers for motor control

With a contribution by Ralf Keggenhoff (Fairchild Semiconductor)

The energy consumption of household appliances and industrial machines is determined to a large extent by (asynchronous) motors. Motor controllers should produce little interference and have high efficiency in order to economise on energy, and Smart Power Modules help developers meet these requirements. The modules include not only the necessary half-bridges but also a driver stage, enabling direct connection to a 5 V microcontroller.

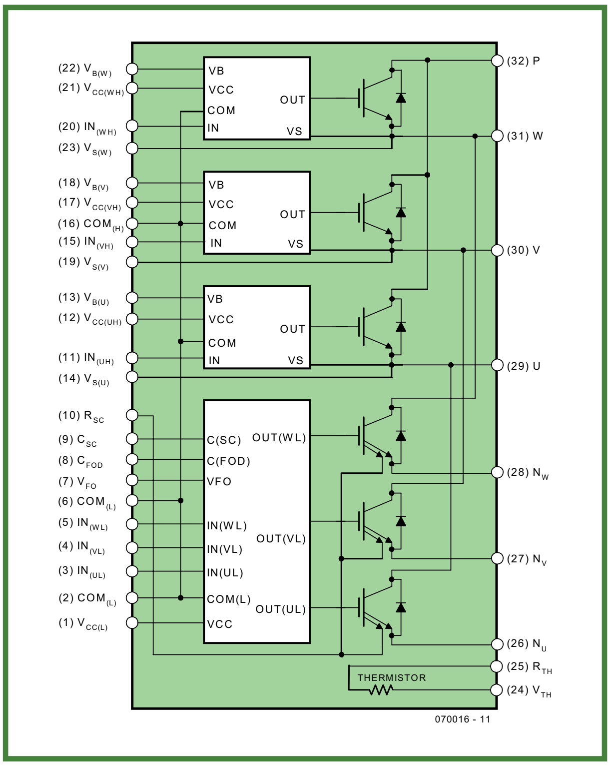


Figure 1. Block diagram of a Mini-DIP module.

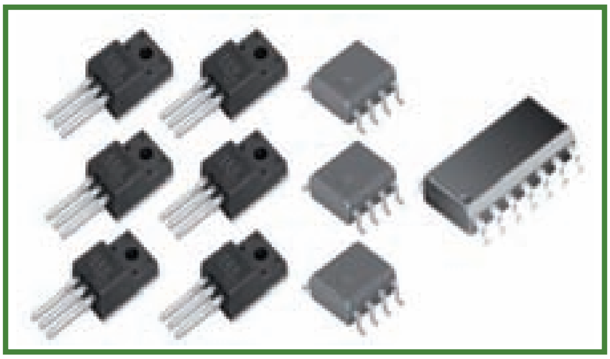


Figure 2. A single module replaces these ten components.

The main industrial applications for motor control are in fans, pumps, cranes, conveyor belts and in automation generally. In the household we find motors in (among other things) air conditioning units, refrigerators, washing machines and extraction hoods. In all these applications there is continuous demand for improved efficiency, power factor (a near-sinusoidal input current), electromagnetic compatibility and compactness. Reliability is also an important criterion.

Requirements

A power control module must satisfy many requirements: small dimensions, easy installation during assembly, high reliability, low power losses, good heat dissipation, simple design and low cost. The most significant requirement on the manufacturer of power control modules is to match these properties to market needs by combining carefully-selected individual components. An example of this is the series of Smart Power Modules (SPM™) from Fairchild which use a well-matched combination of innovative packaging technology and robust semiconductors that dissipate very little waste power.

Convenient power

A three-phase motor controller needs six power semiconductors and the same number of driver stages. The Fairchild SPM family includes devices employing IGBTs as well as short-circuit proof MOSFET-based devices [1]. A feature of all the modules is that they include not only the power components but also drivers optimally matched to them. This is especially important with regard to meeting ever more stringent EMC requirements.

Figure 1 shows an example block diagram, in this case of an FSAM10SH60A Mini-DIP module [2] which features six IGBTs. To obtain the same functionality we would otherwise need ten components: six IGBTs and four driver ICs (**Figure 2**). The 'discrete' solution increases development and manufacturing costs and increases the chances of failure. It is also more bulky and less EMC-friendly.

The example application circuit shown in **Figure 3** illustrates how simple it is to construct an asynchronous motor controller using a Smart Power Module. Besides a microcontroller (CPU) and the module from Figure 1 there are just a few discrete components. The module used here includes an NTC thermistor for temperature monitoring.

The SPM family

Members of the SPM family come in the following packages:
- Tiny-DIP module (**Figure 4a**);
- Smart Power Module in SMD package (**Figure 4b**);
- Mini-DIP module (**Figure 4c**);
- DIP module (**Figure 4d**).

There are two different versions of the Mini-DIP and DIP Modules. The main difference between them is in the thermal connection to the heatsink. For lower-power devices this is done using a ceramic, while for higher power devices DBC (direct bonded copper) is used. Both variants offer a specified isolation voltage of 2500 V.

Mechanical construction

Figure 5 illustrates the construction of the ceramic and DBC SPM module variants.
In the ceramic version the semiconductor die is first bonded to its leadframe. The leadframe is then attached to the ceramic using a thermally-conductive adhesive. Bond wires are added to make the remaining electrical connections. The whole assembly is then potted in a plastic. The connection pins are formed and a final electrical test completes the module.
Many of the manufacturing steps are the same in the case of the DBC module. The main difference compared to the ceramic-based version is that the connections inside the module are made not via the leadframe but rather using a DBC structure similar to a printed circuit board. The DBC structure consists of a ceramic with a full copper plane on the underside which provides the thermal connection to the heatsink, and printed conductors on the top side. The power semiconductors are bonded to this structure and the remaining electrical connections (for example to the leadframe proper) made using bond wires. Again the assembly is potted, the pins are formed and the device is given a final electrical test.

(070016)

Weblinks

[1] http://www.fairchildsemi.com/power

[2] http://www.fairchildsemi.com/pf/FS/FSAM10SH60A.html

Availability

SPM devices are available from Fairchild themselves (http://www.fairchildsemi.com) and their authorised distributors.

Free samples can be requested directly from Fairchild's website.

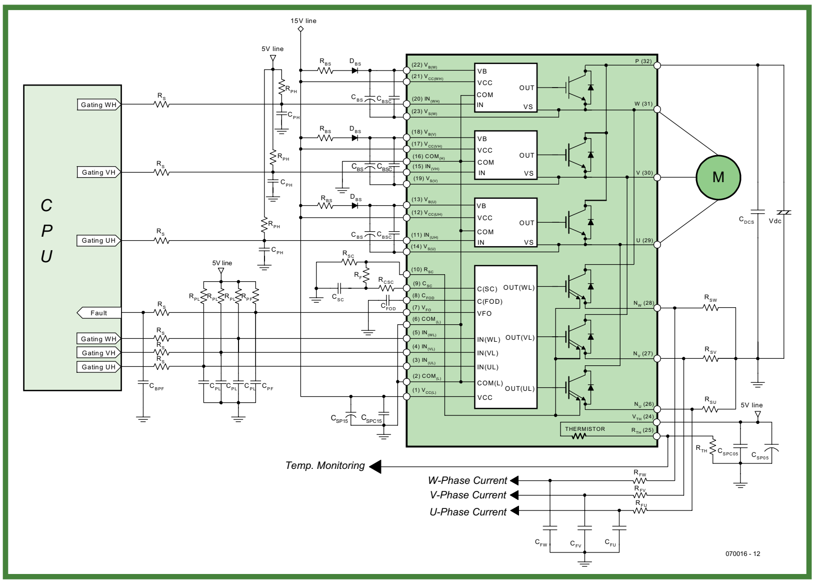


Figure 3. Typical application: driving an asynchronous motor using a Smart Power Module.

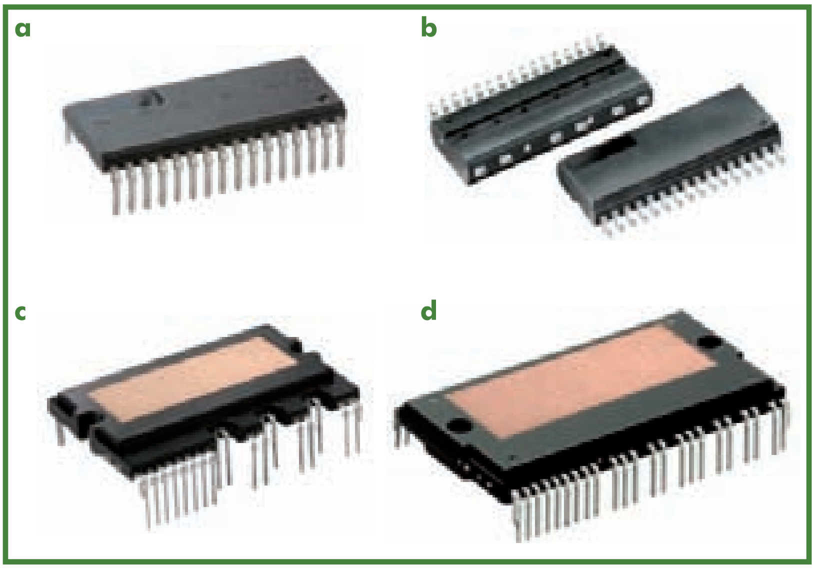


Figure 4. a. Tiny-DIP module b. A Smart Power Module in an SMD package c. Mini-DIP module d. DIP module.

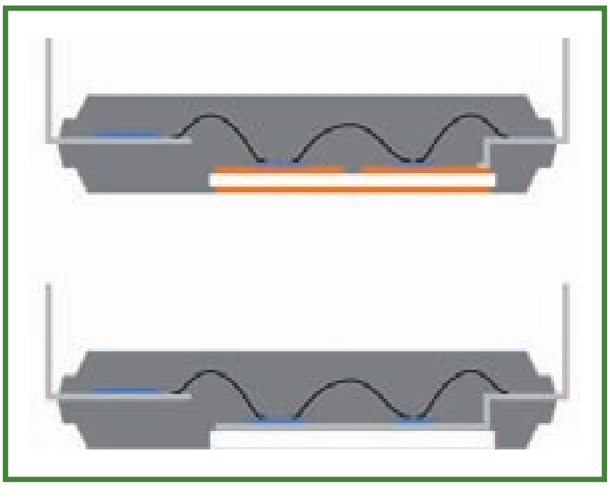


Figure 5. Construction using direct bonded copper (above) and ceramic (below).

Power to the LEDs

Driver circuits for high-power LEDs

Eberhard Haug

LEDs have started living up to their name in recent years: 'Advanced Power TopLEDs' from Osram are used as daytime running lights in the new Audi R8 (photo: Audi AG).

Although the acronym 'LED' has stood for 'light-emitting diode' since the 1960's, LEDs have only recently started to emit significant amounts of light. High-power LEDs need suitable drivers to enable them to emit light under a wide variety of conditions. Here we present a summary of driver designs ranging from simple to sophisticated.

We can't say it too often: LEDs are essentially current-driven devices. This is simply due to the fact that they have non-linear current versus voltage characteristics with a distinct 'corner', which depends on the colour or the technology-dependent forward voltage. To make things even worse, the 'corner' or threshold voltage is temperature dependent and varies from one device to the next. **Figure 1** shows the measured current versus voltage characteristics of three high-power white LEDs (also called high-brightness LEDs or HB LEDs) from different manufacturers. However, these characteristic curves could just as easily be measured with three different examples of the same type or at three different temperatures. Although even a small change in voltage causes a large change in the LED current and thus the brightness of the LED, a small change in current (in the normal operating range) does not produce any significant change in LED brightness.

Linear LED driver

This means that LEDs must be powered by a stiff current source. The combination of a voltage source and a series resistor that limits the current through the LED to the desired or permitted value can only be used if the supply voltage is more or less constant or an especially inexpensive solution is required.

In many cases, a linear voltage regulator with a suitable load resistance can be regarded as a 'good' LED current source (LED driver). **Figure 2** shows a linear LED driver for powering three HB LEDs with a supply voltage (U_B) of 12 V. In contrast to standard three-pin linear regulators such as the LM317T, the MIC29152 [1] has a supplementary Enable input that can be used to switch the regulator on or off, but it is also quite suitable for PWM dimming at a frequency of several hundred hertz. Pull-up resistor R2 is only necessary if the EN input is driven by a switch contact or an open-collector signal. A TTL or CMOS logic signal can also be used for this purpose. R2 can be omitted in this case, or it can be connected to the logic supply voltage instead of $+U_B$.

The IC can easily source 350 mA with three LEDs and a 12-V supply voltage, and it doesn't need a heat sink. The LED current is determined by the ratio of U1 and R1 ($I_{LED} = U1/R1 = 1.24\ V / 3.9\ \Omega = 318\ mA$). If you want the full 350 mA, you can connect a 39-Ω resistor (E12 series) in parallel with R1. The losses in the linear circuit are dissipated in current sense resistor R1 (approximately 0.5 W) and the low-dropout (LDO) regulator.

Due to the low dropout voltage (the minimum voltage between the input and output of the LDO regulator necessary for reliable operation at a specific current), a single HB LED can also be operated from a supply voltage ($+U_B$) of 5 V. At the other extreme, up to seven LEDs in series can be driven by this circuit if the supply voltage $+U_B$ is raised to the maximum permissible value of 26 V (and the voltage rating of the capacitors is increased accordingly).

Efficiency

The basic prerequisite for using a linear LED driver is that the supply voltage is greater than the forward voltage of the LED(s). The product of the difference voltage and the LED current gives the approximate value of the dissipated power with a linear LED driver (ignoring losses in the driver IC and other components connected in parallel, but including the loss in the current sense resistor, since it is connected in series with the LED). A simple expression for the efficiency can be derived from this: $\eta = U_{LED}/U_B$. This means that a relatively high supply voltage leads to low efficiency.
However, it is possible to achieve even better efficiency than a more sophisticated switch-mode LED driver if the difference voltage is small, although this requires an LDO regulator that does not need much voltage headroom to control the LED current (the dropout voltage is usually well below 1 V) and the lowest possible voltage drop (around 0.5 V to less than 0.1 V) across the current-sense resistor usually present in such a circuit.
As a rule of thumb, you can say that a linear driver is always an attractive option if the voltage headroom (LDO dropout voltage) is less than 10%, since its efficiency will be on the same order as that of a switch-mode LED driver but with distinctly less effort, lower cost, and possibly better performance characteristics. Another aspect worth considering is that linear LED drivers do not produce any electrical or electromagnetic interference (as long as they are not dimmed using a PWM signal).

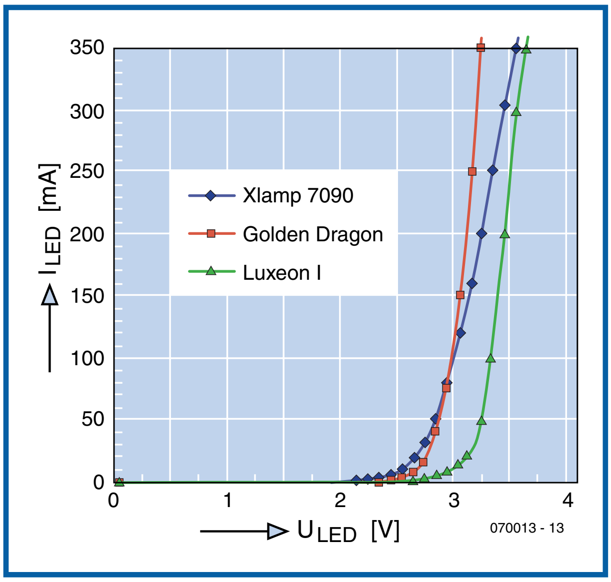


Figure 1. Current versus voltage characteristics of high-power LEDs from different manufacturers. Although even a small change in voltage causes a large change in LED current and thus the brightness of the LED, a small change in current has almost no effect.

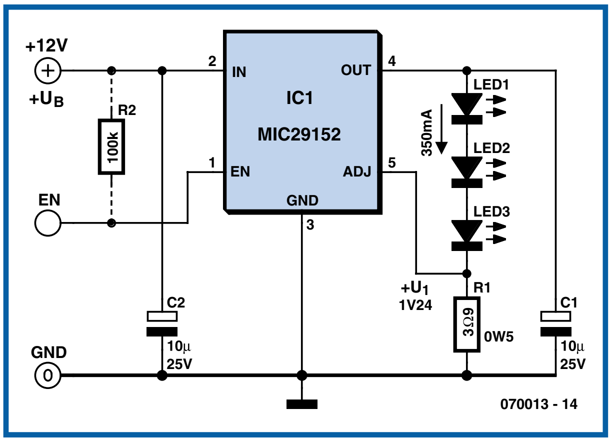


Figure 2. A linear LED driver for powering three high-power LEDs from a 12-V supply (maximum total forward voltage 10.5 V). The Enable input can even be used for PWM dimming at a few hundred hertz.

LED controller

The circuit shown in **Figure 3** is similar to the circuit in Figure 2. The MIC5190 is an LDO controller that does not supply the output current directly, but instead drives the LED via a power MOSFET (T1). This makes it an LED controller. On the one hand, this means the LED current can have almost any desired value with a voltage drop across the MOSFET that can be limited to almost any desired value, while on the other hand the HB LED can be connected to the positive supply rail, which means that RGB LEDs with a common anode can be used if necessary.
Another difference is that here the LED is connected to the drain lead of the MOSFET. This yields sufficient gate-source voltage for the N-channel MOSFET. The LED current sense voltage is only 0.5 V in this circuit. The LED current is thus given by the expression $I_{LED1} = 0.5\ V/R1$. The MOSFET may require a heat sink, depending on the LED current.
This example also indicates how a three-channel LED driver (for example, for a high-power RGB LED) can be implemented. For simplicity, the drive circuitry of the second and third channels using two additional LDO controllers is not shown here. The LED currents can be set individually using R1, R2 and R3, which can be used with an RGB LED to obtain the best white balance.
PWM dimming (or colour adjustment in the case of an RGB LED) is again possible using the Enable inputs. Once again, the pull-up resistor R50 can be omitted if EN1 is driven by a logic-level signal. This LED controller does not need any capacitors in the output circuit, so relatively high PWM dimming frequencies can be used thanks to the short response time.
The circuit shown in Figure 3 can be used to power one LED per channel in a 5-V system. If you want to connect several LEDs in series (in which case it is naturally no longer possible to use common-anode RGB LEDs), you can simply increase the supply voltage to a suitable level and connect the most positive anode to the supply rail.
If you do not have MOSFETs suitable for logic-level drive, you will need a separate power supply for VCC2 (refer to the MIC5190 data sheet [2]).

Switch-mode LED driver

There are two conditions under which it is practically imperative to use a switched-mode LED driver. The first condition is when there is a large difference between the supply voltage and the net forward voltage of the LED(s), combined with a high LED current. The second condition is when the total LED forward voltage is larger than the

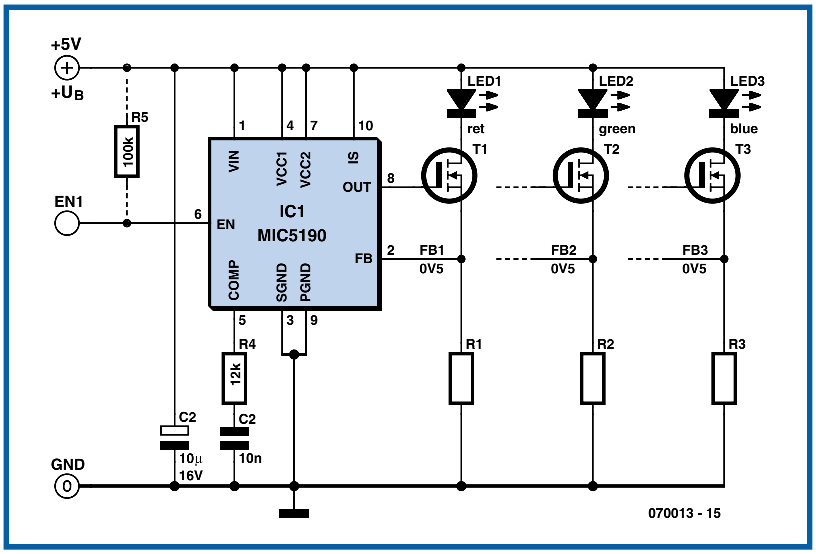


Figure 3. The IC used here is a LDO controller that does not supply the output current directly, but instead drives an LED via a power MOSFET.

available supply voltage. The first case involves a 'step-down' LED driver, while the second case involves a 'step-up' LED driver (all pretty logical, isn't it?). However, even more complicated solutions are possible.

In contrast to a step-down voltage converter (also called a 'buck regulator'), a step-down LED driver is a switch-mode current source instead of a switch-mode voltage source. In the same way as a linear voltage regulator can be used to make a linear LED driver, a switch-mode voltage source can be converted into a current source relatively easily by using a current-sense resistor (R_S) in combination with the reference voltage U_{REF} (typically 1.2 V) to generate the desired LED current. The LED current is then given by the expression

$I_{LED} = U_{REF}$ / RS

The drawback of this approach is the relatively high reference voltage, which degrades the overall efficiency despite the use of a switch-mode current source. This can be remedied by amplifying a significantly smaller current-sense voltage to the level of the available reference voltage or starting with a small reference voltage. As more and more step-down voltage converters for output voltages below 1 V are becoming available, it should be relatively easy to find a suitable candidate among modern ICs.

The especially simple and tiny MIC4628 HB LED driver (**Figure 4**) can power up to three HB LEDs in series with a 24-V supply voltage (typically available in industrial systems). The Enable input can be driven by a 24-V signal or a contact if necessary, but it can also be driven by a logic signal. In this case, R5 can be omitted or connected to the logic supply voltage instead of $+U_B$.

The value of C1 must be selected according to whether PWM dimming is to be used. The suggest value of 220 µF can be used for the least possible LED current ripple if dimming is not necessary. If PWM dimming is necessary, use a value of 10 µF for C1 (tantalum or aluminium electrolytic) so it can discharge faster. The circuit remains stable despite the smaller value of C1, although the ripple current (as measured with a 100% PWM dimming ratio) is somewhat larger.

With the given component values, the voltage divider at the output (R3/R4) limits the output voltage to approximately 14 V if the LED string is open (be careful with connecting the LEDs if the circuit is already switched on!). R1 sets the LED current. Its value is taken from a diagram on the MIC5682 data sheet [3]. A value of 22 kΩ for R1 yields a LED current of approximately 700 mA.

One criterion for selecting a suitable switch-mode LED driver is its switching frequency (the available range is a few dozen hertz to several megahertz). This essentially determines the size of the coil, and it inversely affects the level of LED current ripple that can be achieved. However, dynamic losses can increase strongly at high frequencies, depending on the design, thus decreasing the achievable efficiency.

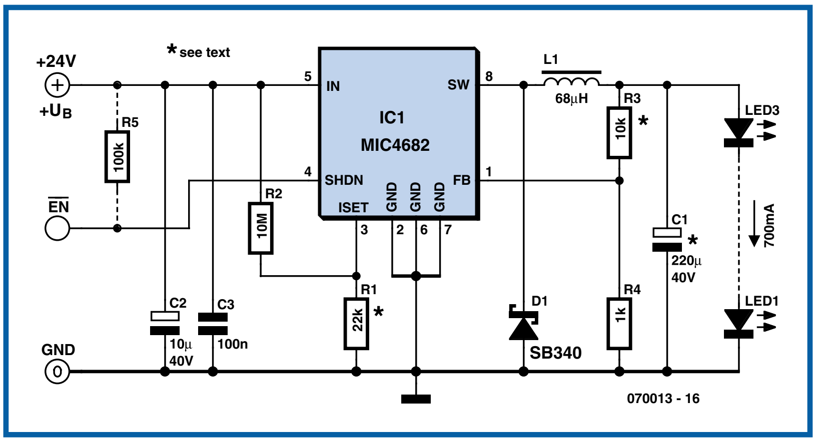


Figure 4. This simple step-down LED driver can power up to three series-connected high-power LEDs when used with a supply voltage of 24 V.

LEDs on the mains

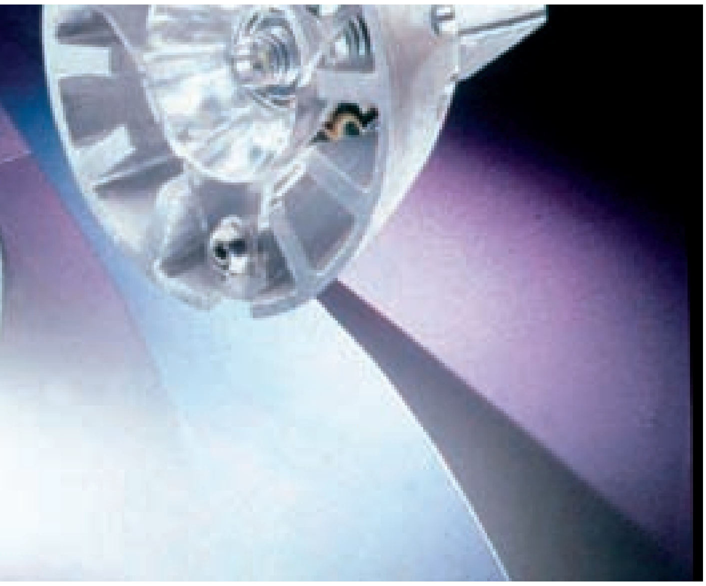
An extreme case of a step-down LED driver is powering LEDs directly from the mains voltage. Here the objective is to obtain a relatively high LED current, usually at a very low LED voltage, from a very high and highly variable voltage. The main challenge here is the extremely low PWM duty cycle resulting from the ratio of the LED forward voltage and the actual supply voltage (usually the rectified AC mains voltage).

With a single white LED and a 230-V mains voltage plus a 15% overvoltage allowance, the worst-case duty cycle would be approximately 1%. The number of suitable converter ICs that can meet such requirements is rather small.

An example of a possible implementation of a step-down LED driver for operation from the AC mains has already been published in *Elektor Electronics* under the title 'HV9901 – a novel LED driver' [4].

A completely new approach is provided by LEDs that can be operated directly from the AC mains without a driver. In any case, the Acriche LED modules displayed by Seoul Semiconductor at the Electronica 2006 trade fair (**Figure 5**) certainly drew attention. A few other companies, such as Lynk Labs, are also active in this area.

Figure 5. The Acriche LED modules from Seoul Semiconductor can be operated directly from the AC mains without a transformer. This is a 2-watt single-LED module. The manufacturer plans to boost the light yield from the current 48 lumen/W to 80 lumen/W in Q4 2007 and 120 lumen/W in 2008.



Step-up LED driver

The other end of the supply-voltage spectrum is found with very low supply voltages, usually provided by batteries. A step-up LED driver (also called a boost regulator) is essential in such cases. The number of LEDs to be driven varies, and it can be as much as ten or more LEDs in series, which yields a total LED forward voltage of more than 30 V.

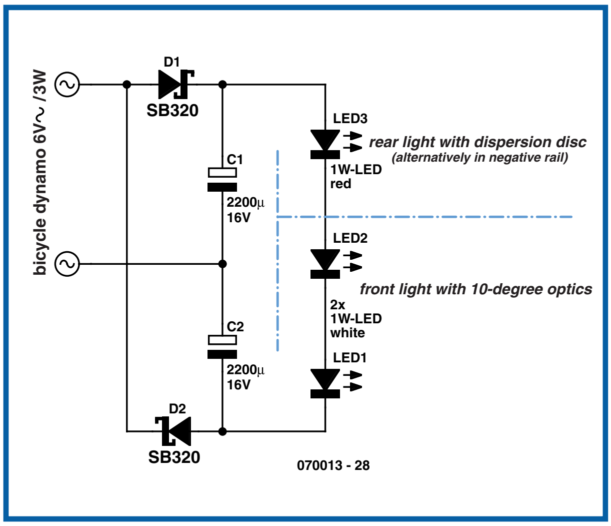
A step-up LED driver of this sort using a MIC2196 boost controller [5] with an N-channel MOSFET can easily drive a six-chip Ostar LED with a rated power of 24 W. Here you have to bear in mind that with this type of boost topology, the input voltage must be lie below the LED forward voltage. This versatile circuit is described in detail in the documentation of an evaluation board available from Micrel [6].

Here the challenge to the designer is not so much the voltage ratio as amount of power that must be supplied to the LED, since especially with a relatively low battery voltage the required peak currents in MOSFET switch and the converter coil can be correspondingly high. For this reason, such converters usually require a minimum supply voltage of more than 2 V so they can continue to provide satisfactory operation with two nearly discharged batteries. Although step-up LED drivers for high-power LEDs that can operate from a single cell (nominal voltage

Manufacturers

Manufacturers of LED drivers (list not necessarily complete)

www.allegromicro.com	www.monolithicpower.com
www.analog.com	www.national.com
www.austriamicrosystems.com	www.nxp.com
www.catsemi.com/	www.onsemi.com
www.fairchildsemi.com	www.ricoh.com/LSI/
www.infineon.com	www.rohm.com
www.intersil.com	www.semtech.com
www.ixys.com	www.sipex.com
www.linear.com	www.st.com
www.maxim-ic.com	www.supertex.com
www.melexis.com	www.ti.com
www.micrel.com	www.zetex.com
www.microchip.com	



The triumphal march of high-power LEDs is imminent. This is the author's suggestion for a dynamo-driven LED lighting system for bicycles [7].

1.2–1.5 V) are technically feasible, they are not necessarily economically feasible.

Another tricky issue with step-up drivers is PWM dimming. Entire essays can be written about the advantages and disadvantages of PWM dimming, so here we limit ourselves to the remark that if you want to have a large dimming range (0–100% if possible), you need a step-up LED driver with a relatively high switching frequency and a relatively small control-loop time constant.

One of the critical situations that must be mastered with a step-up converter is operation with an open load circuit. A failed LED normally leads to an open circuit, and only rarely to a short circuit. There are several possible approaches to open-circuit protection. The simplest solution is a Zener diode with a breakdown voltage greater than the maximum total LED forward voltage. The disadvantage of this is that the Zener diode must conduct the LED current in case of an open circuit, and the resulting power dissipation ($U_Z \times I_{LED}$) is always greater than the total power dissipation of the LEDs. A much more elegant solution is to use a voltage limiter such as with a voltage regulator, but this usually requires a supplementary input pin on the IC.

Alternatively, the Zener diode can be connected directly to the current-sense feedback input and the current-sense voltage ca be provided via a resistor that normally does not carry any current. In this case, a situation in which the setpoint value of the control loop is exceeded can be simulated if the LED chain is open. This avoids unnecessary output power dissipation in case of an open-circuit condition and eliminates the need for an additional pin. These tricks are incorporated in the circuit diagram shown in **Figure 6**, which is a step-up LED driver based on an MIC2196.

Mixed-mode operation

Besides the previous described step-down and step-up LED drivers, there are implementations that support mixed-mode operation. LED drivers of this sort are necessary in situations where the battery voltage is higher than the LED forward voltage when the battery is fully charged but drops below the LED forward voltage during operation. LED drivers of this sort are usually based on Sepic, CUK, buck/boost, or inverting buck/boost topologies.

These LED driver topologies are also used when the supply voltage is fixed (such as in a car) but the number of LEDs can vary. A combined step-up/step-down solution can be used as a versatile but complicated 'general-purpose' LED driver in such situations.

Another type of step-up circuit is the charge-pump LED driver, which is based on capacitors instead of the coils used by the previously described types of switch-mode LED drivers. In simplified terms, a charge pump uses MOSFET switches operated in a suitable switching arrangement to generate an output voltage by 'stacking' the charges stored in the capacitors. It is usually only possible to obtain a multiple of the input voltage, which is the main drawback of these compact circuits. In most cases, the LED forward voltage is not an exact multiple of the input voltage, so the charge pump is usually followed by a linear LED driver to regulate the current. This means that the efficiency depends indirectly on the input voltage, but it is relatively good if the LED forward voltage is just below an integer multiple of the input voltage. Modern charge-pump LED drivers can even adjust the multiplication factor automatically, which can be seen from their step-shaped efficiency characteristic curves.

(070013-I)

Weblinks

[1] www.micrel.com/_PDF/mic29150.pdf

[2] www.micrel.com/_PDF/mic5190.pdf

[3] www.micrel.com/_PDF/mic4682.pdf

[4] Elektor Electronics, January 2004

[5] www.micrel.com/_PDF/mic2196.pdf

[6] www.micrel.com/_PDF/Eval-Board/mic2196_led_eb.pdf

[7] www.led-treiber.de

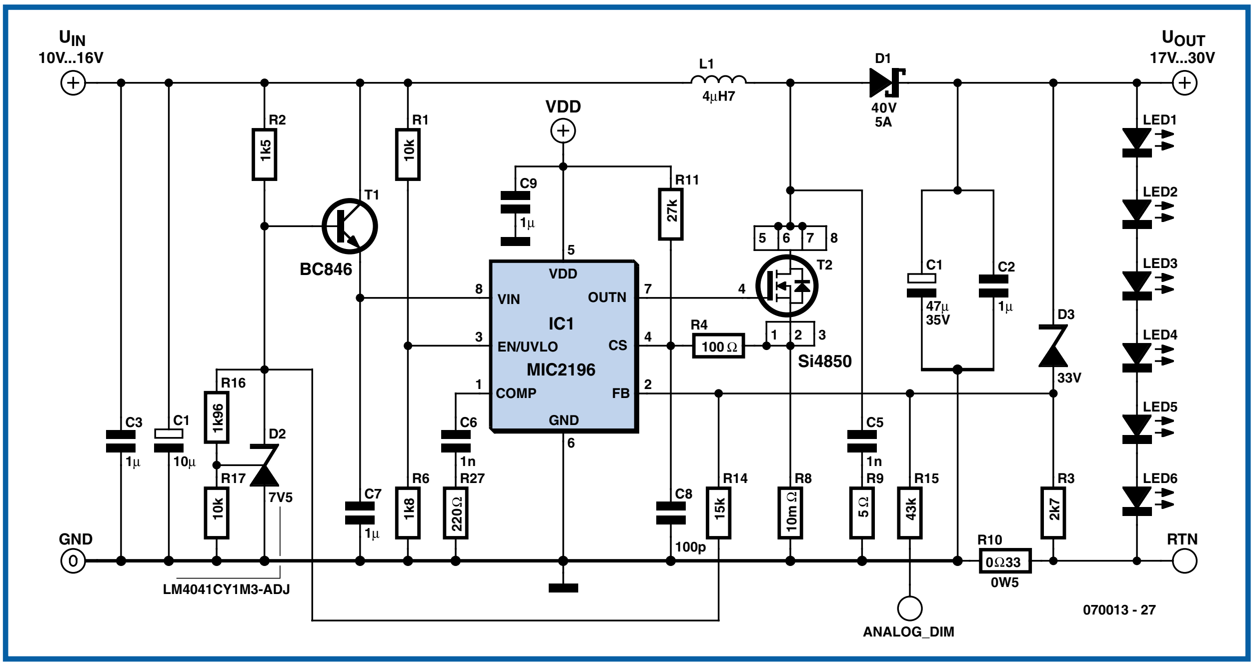


Figure 6. Circuit diagram of a step-up LED driver. Zener diode D3 provides open-circuit protection (see text).

40 Layers
EzPCB, Easy Way To PCB
Features:
UL Proved High Quality
ISO 9000 Certificated
Accept Orders From 3pcs to 1M Pcs
Capabilities:
Up to 40 Layers
2. 5mil Track/Space
0. 1mm Hole Size
Blind And Buried Vias
RoHs, WEEE Compliant
Prices:
Only $50 For 5pcs 4″ x 4″ 2L
Only $188 For 3pcs 4″ x 4″ 4L
Only $288 For 3pcs 4″ x 4″ 6L
Free Solder Mask & Silkscreen
Very Competitive Price For Bulk Orders
Http://www.ezpcb.com
sales@ezpcb.com

PCBs in
24 hours
from £30.00
www.PCBTrain.com
Tel: 01635 40347
Newbury Electronics Ltd

ANDRE LAMOTHE'S
XGAMESTATION
LEARN STEP-BY-STEP HOW TO BUILD
AND DESIGN YOUR OWN VIDEO GAME CONSOLE!
Design inspired by the
Atari 800/2600, Sinclair ZX Spectrum,
Apple II & Commodore 64!
Parallax SX-Key Compatible!
eBook Included!
Development Kit
Complete Kit
INCLUDES:
• Tools, Demos & Utilities!
• Great for Hobbyists AND Students!
• The Fun Way to Learn Embedded Systems!
• Fully Assembled XGS Micro Edition Unit!
• Complete Software Development Kit!
• eBook on Designing the XGS Console!
• Cables and Power Supply Included!
WWW.XGAMESTATION.COM
PH: 925.736-2098
SUPPORT@NURVE.NET

Schaeffer AG
FRONT PANELS & HOUSINGS
Cost-effective single units and small production runs
Customized front panels can be designed effortlessly with the Front Panel Designer.
The Front Panel Designer is available free on the Internet or on CD.
· automatic price calculation
· delivery in 5–8 days
· 24-Hour-Service if required
Sample price: 30,42 €
plus VAT/shipping
Schaeffer AG · Hohentwielsteig 6a · D–14163 Berlin · Tel +49 (0)30 8058695-0
Fax +49 (0)30 8058695-33 · Web info@schaeffer-ag.de · www.schaeffer-ag.de

Speedmaster

The winning circuit in 3D

Markus Simon

Here is the circuit voted winner of the International R8C Design Competition by *Elektor Electronics* readers: an intelligent 3D accelerometer that not only measures acceleration on all three spatial axes, but also calculates the total distance moved. And, as promised, a ready-assembled printed circuit board!

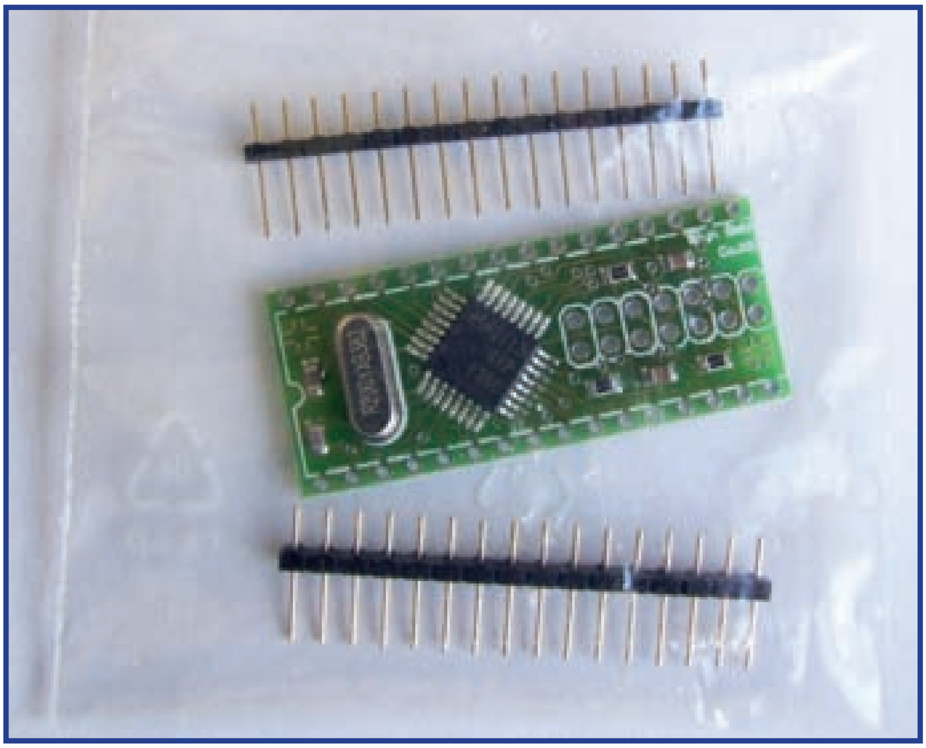


Figure 1. The R8C/13 daughter board described in the February 2006 issue.

It all began in February 2006 with the 'Tom Thumb' R8C starter kit special offer: an ultra low-cost R8C/13 processor on a carrier board to which you could solder two SIL headers (see **Figure 1**). The response from our readers showed that this tiny 16-bit microcontroller had inspired many people to develop their own projects. As a result, we announced in the May 2006 issue of *Elektor Electronics* our international R8C design competition. An expert jury was assembled to judge the excellent response, and the winners were published in the November 2006 issue — with the exception of the first prize, which we asked our readers to decide. An essential part of the first prize was that we would see the winning design go into production.
Our readers have now reached their decision.

From the concept...

Ten years ago, on a skiing holiday, Markus Simon was wondering (as any self-respecting engineer would) what would be the best way to measure his speed on the slopes. It rapidly became apparent that suitable acceleration sensors were far too expensive and that small microcontrollers were not powerful enough. Ten years on, we have the economical MMA7260Q sensor from Freescale as well as the *Elektor Electronics* R8C board. When he heard of our competition, Markus went back to his idea with renewed ambition.
The first thing was to plan the kind of functions that the completed design might offer. The author imagined a device that could calculate speed from two- or three-dimensional acceleration information, and, from that, calculate distance travelled from a given start point. That all sounded rather complicated; however, pilots were already accustomed to using accelerometers in addition to GPS for navigation.
The device could also be used in cars to measure acceleration and the effectiveness of the brakes, along with instantaneous speed and distance travelled. Another application would be to measure how smoothly a lift is controlled or how exciting a fairground ride is. And we can estimate how many horsepower a car would need to provide a g-force comparable to that experienced in an aircraft on take-off.
The particular charm of this project is that so little hardware is required: just the sensor, R8C board, and an LCD panel. And, like practically every microcontroller-based project, the real cleverness lies in the software.

About the author:

Markus Simon studied Electronic Engineering at the Koblenz University of Applied Sciences, specialising in instrumentation and process control technology. Since graduation in 1996 he has been working on software development for embedded systems. In his spare time he works on digital electronics.

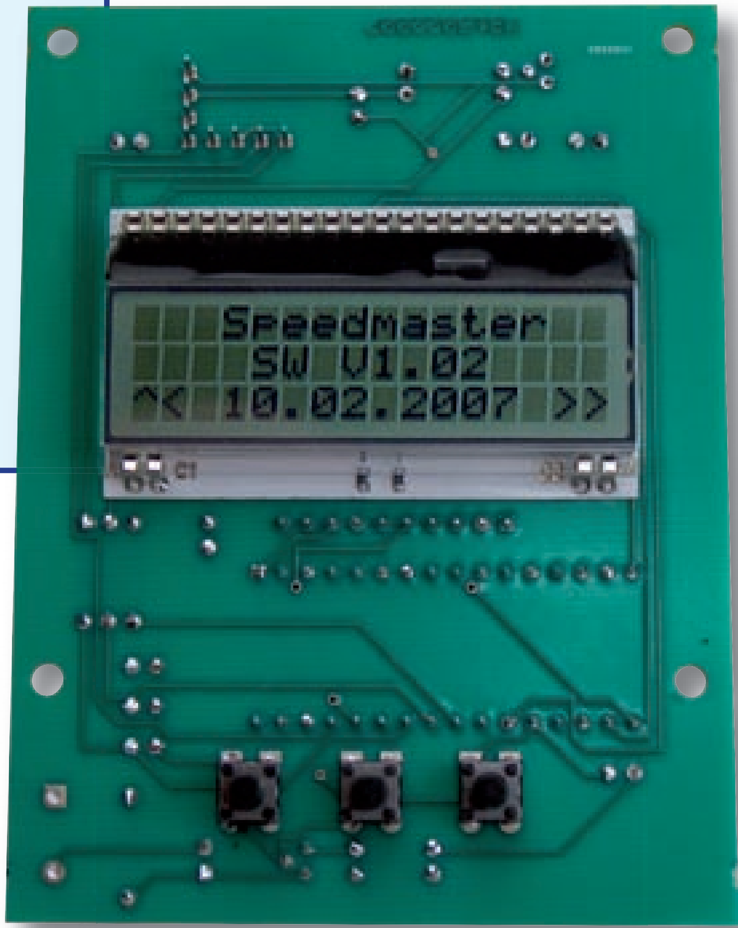
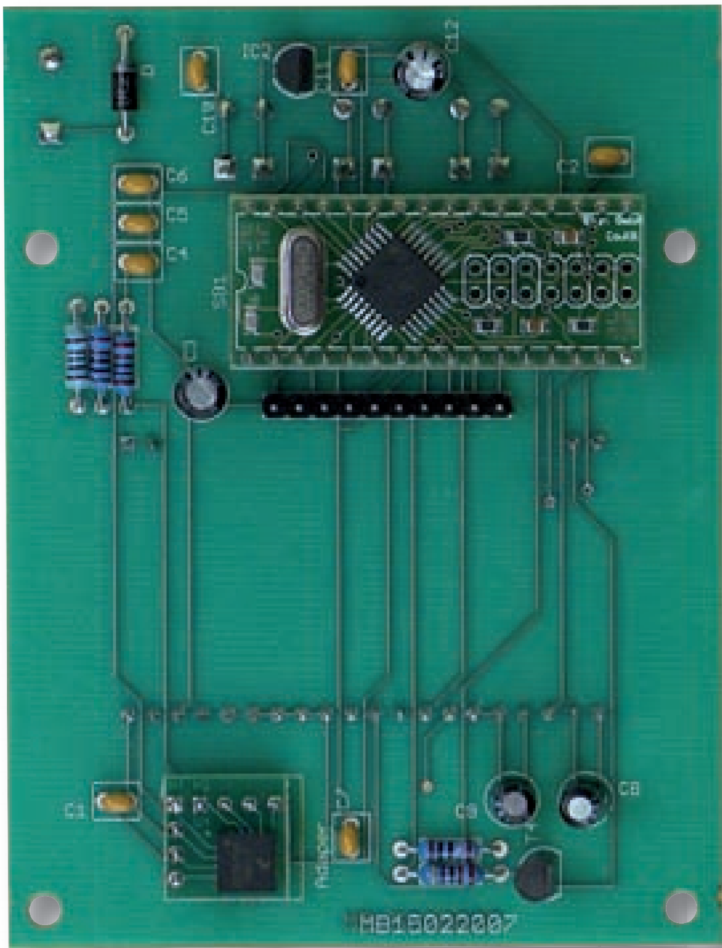


Figure 2: Front and back of the populated Speedmaster printed circuit board, fitted with LCD and R8C module.



... via the printed circuit board...

The hardware consists of the R8C module, a three-axis acceleration sensor, and a three-line LCD module. Two of the lines of the display can be used together to produce large, easy-to-read characters. Besides these components there are also three buttons to operate the unit, some simple power supply electronics, and a couple of capacitors and resistors.

Just a few small changes from the prototype design have been made to the printed circuit board for production. **Figure 2** shows the front and back of the populated board. Hard-core experimenters can of course assemble a Speedmaster unit themselves from the individual components. **Tip:** two free MMA7260Q devices on carrier boards are supplied free of charge with parts/PCB set 060297-71 for the Elektor accelerometer project (‘*g*-Force on LEDs’, April 2007).

However, an easier approach is to use the ready-made printed circuit board from *Elektor Electronics*. This avoids having to work with SMD components and tracking down a supplier for the display and sensor, which come already fitted. All that is left to do is burn the software into the R8C/13 daughter board and then fit this to the main board. Put the whole thing in a suitable enclosure and the job is done.

Figure 3 shows the circuit diagram of the Speedmaster. The unit is operated using the three buttons. The bottom line of the display shows the function of these buttons (either symbolically or as text) to simplify operation. All settings are stored in the R8C’s internal flash memory, and so are retained when the device is reset.

The MMA7260Q acceleration sensor is a capacitive three-axis device whose range can be switched between 1.5 *g*, 2 *g*, 4 *g* and 6 *g* (although we do not recommend that readers experience accelerations of 6 *g* themselves!).

Power is provided by four AA cells, rechargeable if desired. IC2 is a 3.3 V regulator that can withstand higher input voltages, and so it is possible to run the unit from the 12 V supply in a car without problems. D1 provides protection against reversed polarity.

ST1 brings out the R8C’s spare port pins P14 to P17. These could be used to connect to an SD memory card in SPI mode to record sensor readings, given suitable software. The foundations for this modification have been laid in the source code, but are commented out.

The display includes a step-up converter to generate, in conjunction with C8 and C9, the higher voltages it requires internally.

Chiefly to economise on power consumption the R8C is clocked at 10 MHz (divider 2 in ‘system clock control’). In

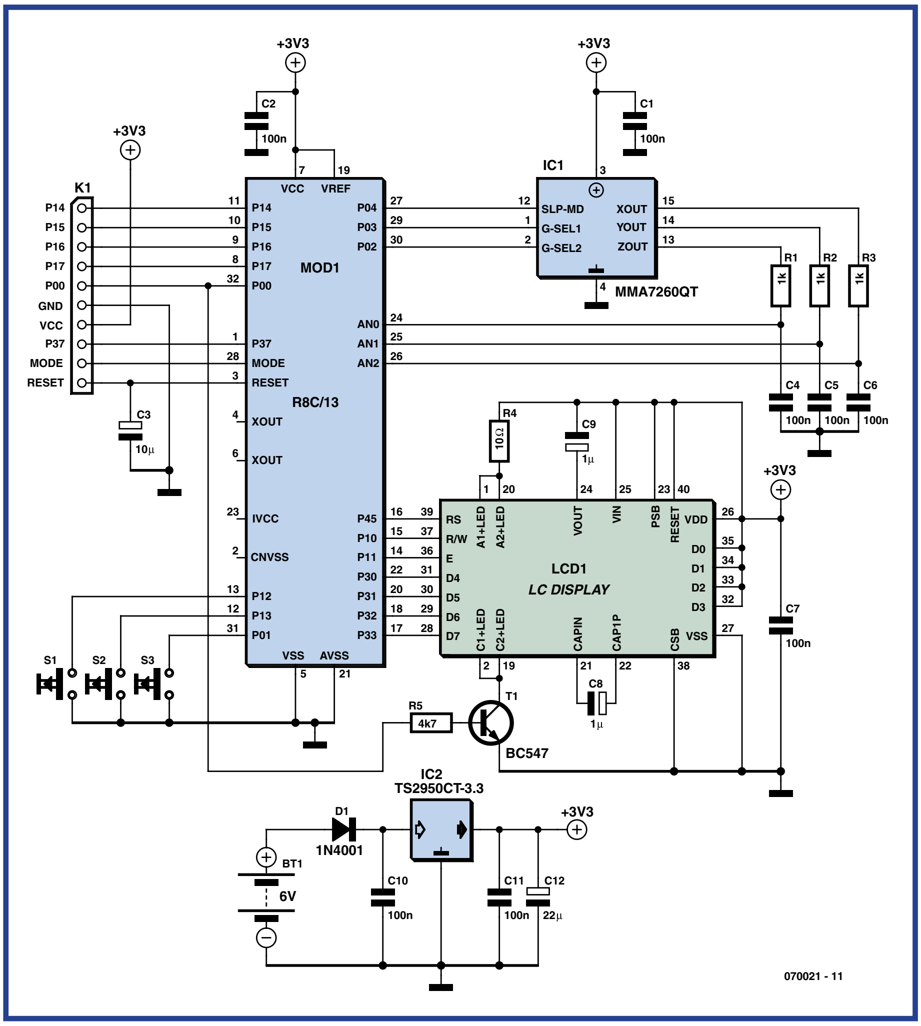


Figure 3. Considering its capabilities the Speedmaster circuit is remarkably simple.

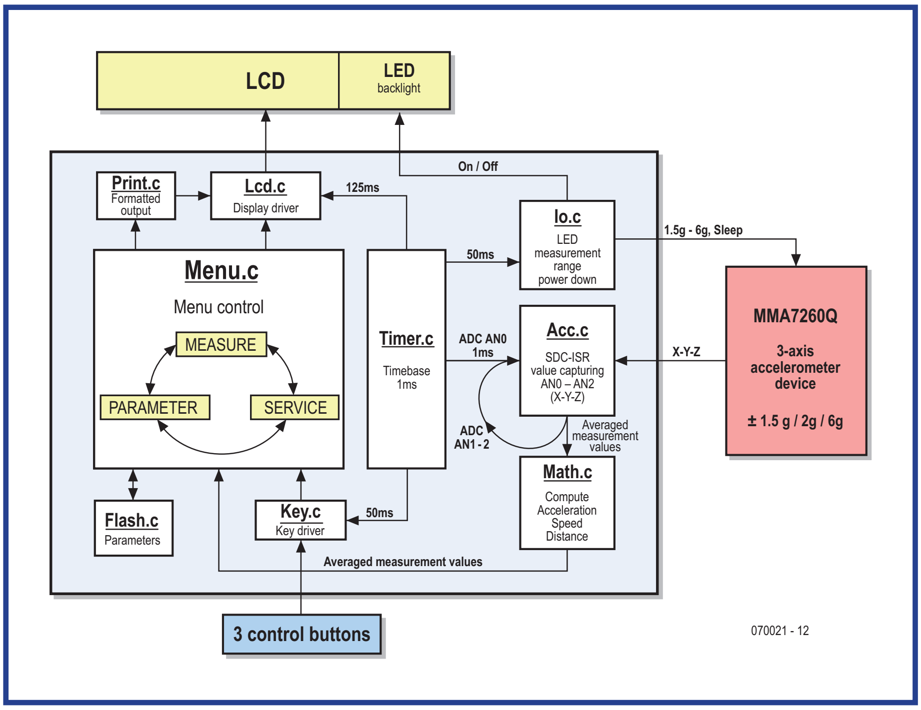


Figure 4. Diagram showing the functions of and interactions between the various software modules.

operation, with the LCD backlight off, the circuit draws only about 6 mA, and in power-down mode just 0.5 mA. To extend battery life the circuit automatically enters power-down mode 60 s after the last button press, as long as no measurement is in progress.

... to the software

The source code to Speedmaster is, of course, too complex to describe in detail (or even list in full) here. Instead the various C source files and the corresponding hex files can be downloaded free of charge from the *Elektor Electronics* website [1]. The firmware is divided into ten modules whose interrelationships are displayed in **Figure 4**. We now look at each module in turn.

Speed.c: This calls the function initHW(void) in the module ncrt0.a30 (the NC30 start-up code). This function initialises the system clock (using function IO_set_clock()), the configuration of the input and output ports (using function IO_init()), and the system timers (using function TimerX_init()). The tick timer is initialised to use a 1 ms timebase.

Timer.c: This is where the 1 ms timebase for the tick timer is generated, using Timer X. TIMER_get_Ticks(void) returns the system tick count, giving the time in milliseconds since the system was initialised. Function TIMER_OVER_ms(x,y) returns TRUE or FALSE depending on whether a specified time has elapsed.
The A/D converter is triggered on each increment of the tick timer.
Thanks to the computing power offered by the R8C it is possible to read in analogue values from three sensors every millisecond and process the results.

Acc.c: Interrupt service routine ACC_ADC_ISR(void) captures results from A/D converter channels AN0 to AN2. The conversion for AN0 (the x-axis) is initiated from Timer.c; when this conversion is complete, the conversion for AN1 (y-axis) is initiated; and when this completes, the conversion for AN2 (z-axis) is initiated. Acquisition and conversion for the three channels takes just a few microseconds.
Sixteen readings are averaged for calibration. In measurement mode the arithmetic means of the readings on each axis are taken in groups of four before further processing in Math.c. Four and sixteen are powers of two

Physics fundamentals

Acceleration a is the first derivative of velocity v(t) with respect to time: a=dv/dt. It is also the second derivative of displacement s(t) with respect to time: $a = d^2s / dt^2$.

We can therefore derive these quantities from acceleration as follows.

Velocity is the integral with respect to time of a:

$v = \int a\ d$

Displacement is the integral with respect to time of velocity v:

$s = \int v\ dt$

For implementation on a microcontroller we have to evaluate these integrals using discrete time steps (replacing dt by Δt).

Then we obtain the expressions

$v = a\Delta t$

and

$s = vt + a\Delta t^2 / 2$

for displacement.

When set to its 1.5 g range and operated from a 3.3 V supply the acceleration sensor produces an output voltage of exactly 1.65 V at 0 g. With a sensitivity of 0.8 V/g it outputs 2.45 V at +1 g and 0.85 V at –1 g. Using the 10-bit resolution of the A/D converters integrated in the R8C we can obtain very precise measurements with low drift. We can also perform a very accurate calibration using the 1 g reference conveniently provided by the Earth.

and so the averaging process can take advantage of fast shift operations.

Math.c: This function performs calibration using the 1 *g* reference acceleration due to the Earth's gravity. In measurement mode the acceleration, speed and distance calculations are carried out every 4 ms. Values shown on the LCD are averaged over periods of 512 ms.

Lcd.c: The display driver operates the display in 4-bit mode. The display is updated cyclically every 125 ms via function LC_TASK() in Speed.c. The information to be displayed is read from the global array ucLCD_Display[48] and passed directly to the LCD.

Menu.c: The menu control code processes button presses and causes relevant text and data to be passed to the LCD module.

Flash.c: This file contains the functions for erasing and storing data in block A of the internal flash memory. All settings made via the menu are stored here. If any change is made the entire block must be erased and rewritten with the new values from tSpeedParam.

Key.c: The keyboard driver is called from the menu control code at Key_get_ID(). The return value is a code corresponding to the key that has been pressed. The key must be released before another press can be registered: auto-repeat is not implemented.

Print.c: Function sprint_f(char*, long int, char) performs the conversion of numbers into formatted strings for display. It writes directly into the display buffer array ucLCD_Display[48]. The sprintf() function from the C standard library is not suitable for use here as its memory footprint is too great.

Io.c: Every 50 ms the 'g-Select' inputs of the acceleration sensor are updated. At the same time the LCD backlight status is updated from the setting in the control menu.

Construction, calibration and operation

As we noted earlier, we recommend using the ready-populated printed circuit board: the parts list is only given for the benefit of more intrepid constructors and the sake of completeness. Construction using the ready-made board is very simple: solder in the LCD as described, program the firmware into the R8C module, fit the

Calculations

To produce our results we need to choose a regular timebase. In the Speedmaster we selected a timebase of 4 ms, which enables us to use the shift instructions of the R8C microcontroller for speed. This in turn gives the advantage of allowing us to use integer variables in all our calculations, which again leads to increased speed.

Every 4 ms the acceleration is calculated from the arithmetic mean of the sensor readings. From this we compute the instantaneous velocity and displacement.

All the following calculations are carried out in source file Math.c.

Velocity:

*v = a * 4 ms*

Using the shift operation:

liSpeed = tMeasure.liAcceleration << 2

Displacement (every 512 ms for positive accelerations): $s = 0.5 * a(512\ ms)^2$

Using the shift operation:

liWay = tMeasure.liAccelerationAverage << 4

*Displacement (every 4 ms for negative accelerations): s = v * 4 ms*

Using the shift operation:

tMeasure.liDeltaWay += tMeasure.liSpeed << 2

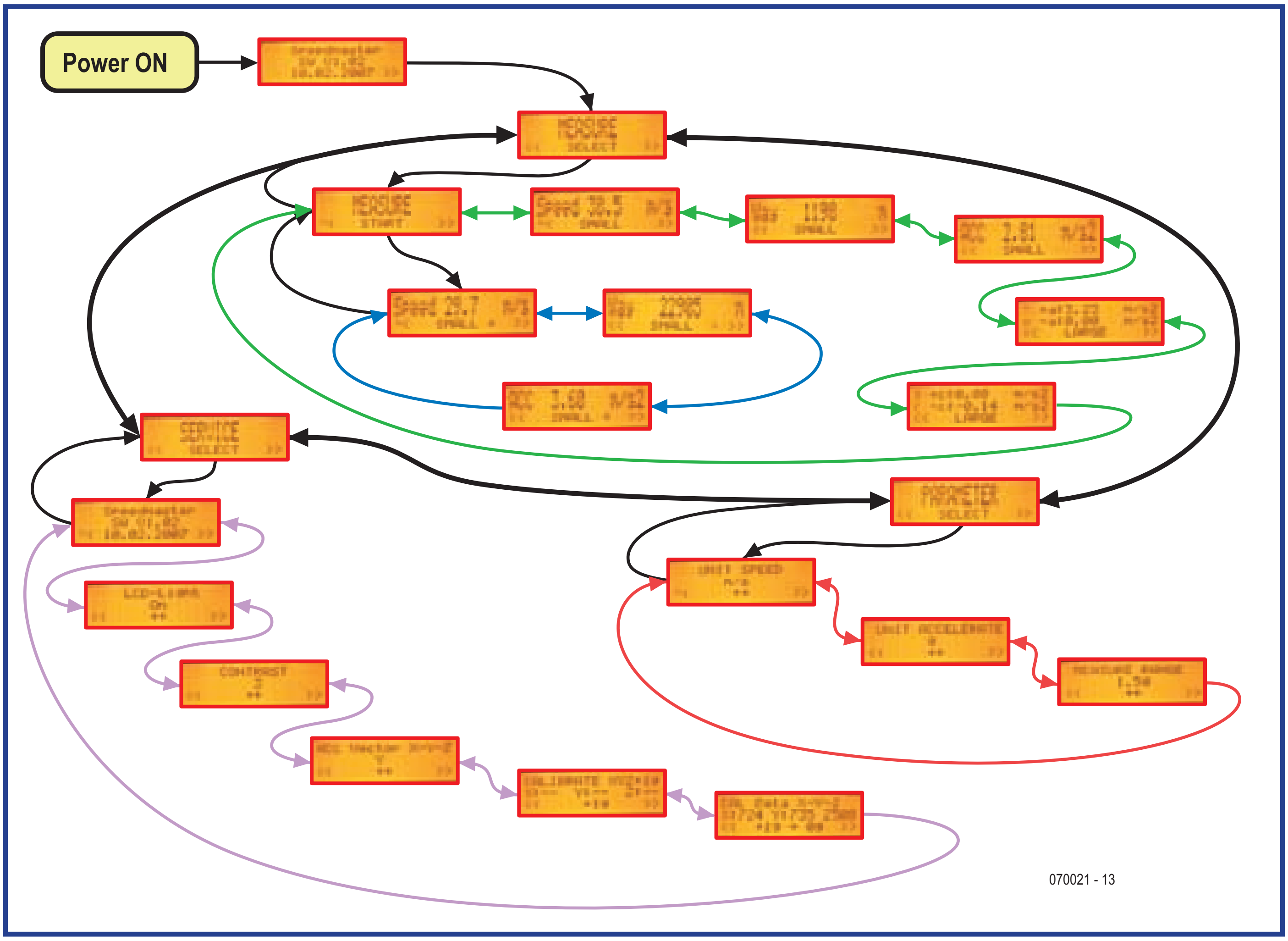


Figure 5. The Speedmaster menu system.

R8C module, test the circuit and fit the whole thing into an enclosure.
Do-it-yourself constructors should beware one thing: before fitting the display the backlight should be soldered to it. The protective films should be removed from the backlight and display (both front and back) first.
Calibration is performed from the menu (see **Figure 5**). Using a spirit level, turn the Speedmaster so that each axis in turn experiences the 1 *g* acceleration due to the Earth's gravity. A correctly calibrated and accurately aligned Speedmaster should indicate 1 *g* on the axis that is vertical and 0 *g* on the other two axes.
Operation of the device is largely self-explanatory: have fun experimenting!

(070021-1)

Web link

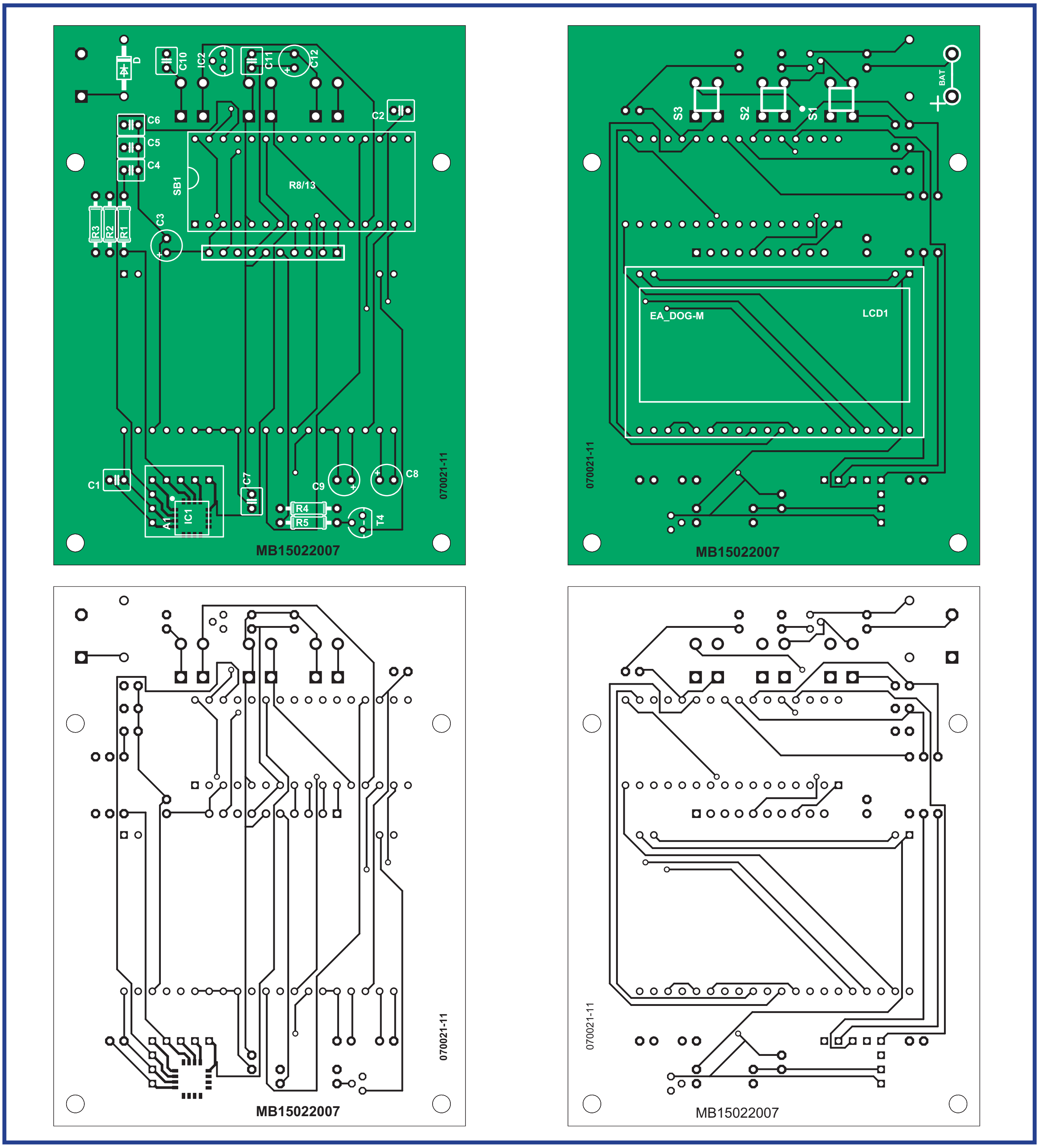
[1] http://www.elektor-electronics.co.uk/Default.aspx?tabid=110

Acceleration due to gravity: the good and the bad

The constant presence of Earth's gravity makes precise calibration of the unit very simple, but unfortunately has a detrimental effect on measurements. This effect is particularly noticeable when the angle that the Speedmaster makes to the horizontal changes during a measurement or between two measurements. The effect is detectable when the orientation of the Speedmaster is different in its initial position from its orientation while a measurement is being carried out.

In the skiing example the orientation of the Speedmaster changes frequently in a hard-to-reproduce way and it is very difficult to remove the effect of the Earth's gravity completely.

Perhaps an ingenious reader can come up with an elegant solution to this problem. Ideally we would measure the orientation of the device, but it is not clear how this can be done.



components list

Resistors
R1,R2,R3 = 1kΩ
R4 = 10Ω
R5 = 4kΩ7

Capacitors
C1,C2,C4-C7,C10,C11 = 100nF
C3 = 10µF
C8,C9 = 1µF 25V
C12 = 22µF 25V

Semiconductors
D1 = 1N4001
T1 = BC547C
IC1 = MMA7260QT (Freescale)
IC2 = TS2950CT-3.3V
MOD1 = R8C/13 carrier board

Miscellaneous
K1 = 10-way SIL pinheader
S1,S2,S3 = pushbutton
LCD1 = LCD type EA DOG-M, 3 lines, with backlight
32-way socket for MOD1

Ready assembled board
070021-91, populated & tested board (except MOD1 and K1)

Universal JTAG Adaptor

Marcel Cremmel

For programming and emulation

This adaptor was originally intended to allow programming of the memory and CPLD of the PSD813 used in the GBECG Gameboy cartridge, which converts this games console into an electrocardioscope (see October 2006 issue). But it's much more universal than that (see box entitled 'In-Circuit JTAG') Our adaptor connects to a PC parallel port and uses the JTAG IEEE 1149.1 protocol.

Informed microelectronics amateurs will of course be aware that other 'In-Circuit' programmable devices use this same port (parallel) and an identical protocol. Unfortunately, the programmer/emulators intended for these devices are not compatible — far from it in fact: so there's no point hoping for a mixed marriage!

However, closer examination of the circuit diagrams of certain programmers suggested by the IC manufacturers shows that the differences are relatively minor and in fact concern the interconnections between the LPT port signals and the JTAG connectors. So a few multiplexing functions is all it takes to produce a 'universal' adaptor.

Had it been achieved using conventional logic components, the circuit of our adaptor would have been quite complex, with different electronics for each of the sections for the different types of processor. Using an EP900 programmable logic circuit (Altera, on free offer from Elektor) makes it possible to offer a very cheap and simple programmer.

Many manufacturers have adopted the JTAG (Join Test Action Group) protocol for programming, debugging, and testing their ICs in situ on the board (IC for In Circuit). Fortunately, you don't need to know all the details of this protocol to be able to use it: the PC software (usually free) and the target components each include a JTAG core that al-

lows them to communicate completely transparently.
The devices involved have special 'JTAG' pins that you merely need to connect to the pins of the same name on the programmer connector. The size (number of contacts) and pinning of this connector differ from one manufacturer to another. This information is given in the various diagrams shown in the boxes of Figures 1–4, concerning respectively Altera CPLDs and EPLDs (Byteblaster II) (**Figure 1**), Xilinx CPLDs and EPLDs (Parallel Download Cable) (**Figure 2**), MSP430 microcontrollers from Texas Instruments (LPT IF 4 wire JTAG Communication) (**Figure 3**) and the PSD, uPSD and DSM families (Flashlink FL101) from ST Microelectronics (**Figure 4**). It should also be noted that there is a certain discrepancy in the naming of the signals between the different JTAG connectors.

ADAPTOR CIRCUIT

The heart of the circuit (**Figure 5**), which with its 44 pins could hardly go unnoticed, is an EP900 PLD. This PLD forms the link between the PC's parallel port, K1, and the four DIL pin headers for the JTAG connections to the four targets, named respectively MSP430 (K2), FLASHLINK (K3), XILINX (K4) and ALTERA (K5). SW, a dual-gang DIP switch comprising contacts JP1 and JP2, allows selection of one of the 4 types of programmer recognized by the JTAG adaptor (see truth table in the circuit diagram, also given on the component overlay on the board). These four options appear in the form of the same number of HE-10 headers in the bottom right-hand part of the circuit. Each option has its own logic structure within the EP900; all these various sub-assemblies using logic gates are shown in **Figure 6**.
Each of these structures is drawn from the manufacturers' programmer circuits. For reasons of efficiency, the EP900's logic structure is described in Altera's AHDL language. The circuit diagram is easier for an electronics technician to read, but the 'AHDL' form is more efficient here. Just for information, the 'source' file (.tdf) for the contents of the EP900 is given in the **inset**.
At the bottom left we find the…

POWER SUPPLY

The EP900 PLD is quite an old IC already! It requires a 5 V supply, but as its consumption is quite high, the pro-

JTAG 'In-Circuit' – some applications

- PSDs, uPSDs and DSMs from ST Microelectronics
- MSP430 microcontrollers from Texas Instruments
- EPLDs and CPLDs from ALTERA
- EPLDs and CPLDs from XILINX

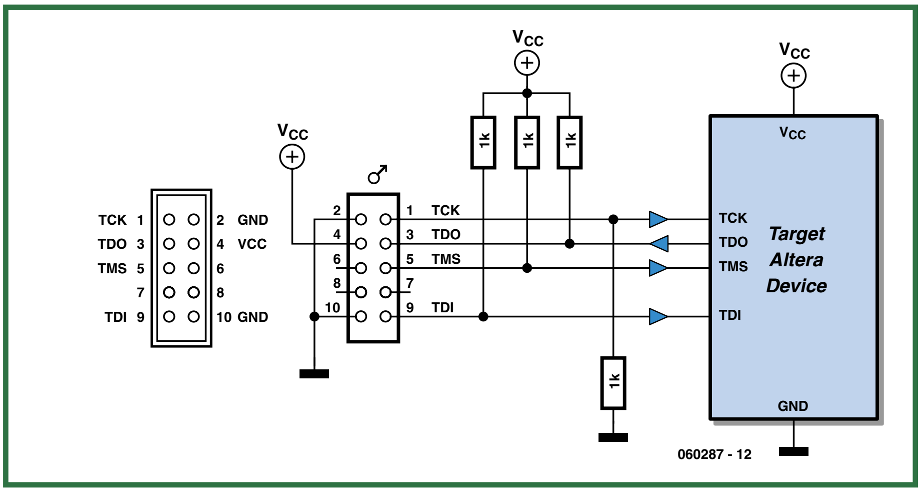


Figure 1. CPLD and EPLD (Byteblaster II) from Altera: 10-pin DIL connector.
Software: Quartus II Web Edition, Quartus II Programmer [1]

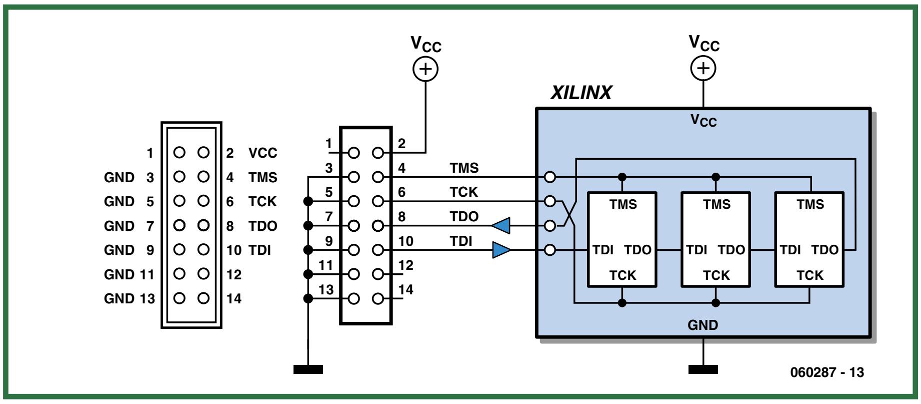


Figure 2. CPLD and EPLD (Parallel Download Cable) from Xilinx: 14-pin DIL connector.
Software: ISE WebPACK [2]

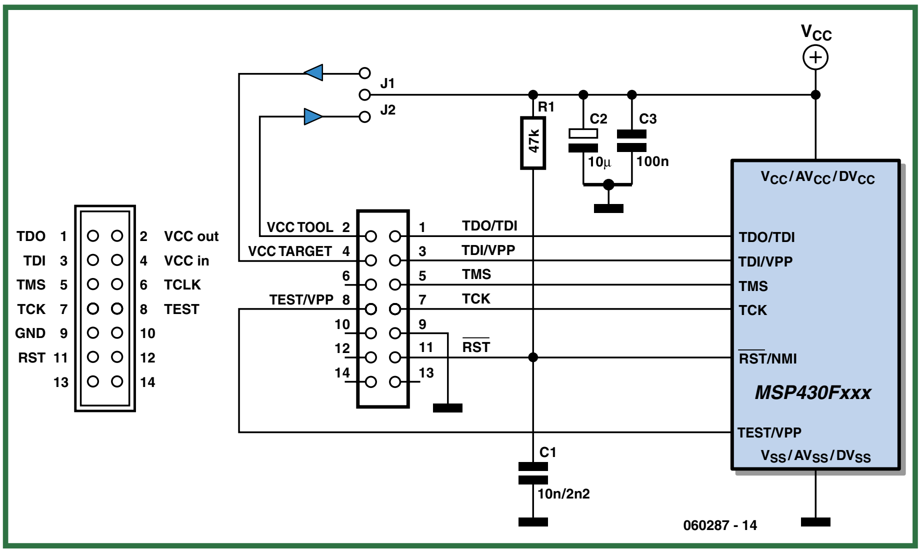


Figure 3. MSP430 microcontrollers (LPT-IF 4-wire JTAG Communication) from Texas Instruments: 14-pin DIL connector. Software: IAR-Kickstart [3]

About the author

Marcel Cremmel, the author, has been a qualified lecturer in Electrical Engineering, electronics option, since 1979 (state certified by the French National Education system).

After completing his first years of teaching in the School of Engineering in Rabat in Morocco, under the Co-operation scheme, in 1982 he was assigned to the Louis Couffignal College in Strasbourg, in the BTS SE section (Higher Technician's Certificate, 'electronics systems').

His job requires him to cover all fields of electronics, though his preference is for telecommunications, video, microcontrollers (MSP430 and PIC) and programmable logic devices (Altera).

Alongside electronics, his other passion is motorbikes in all their forms: touring, competitions, etc. His personal website is at http://electronique.marcel.free.fr/

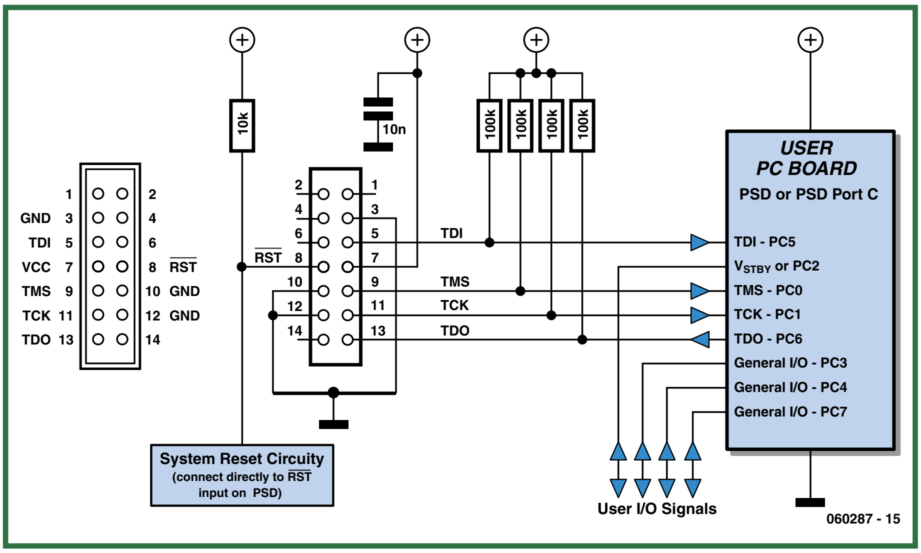


Figure 4. PSD, uPSD and DSM families (Flashlink FL-101) from ST Microelectronics: 14-pin DIL connector.
Software: among others, PSDsoft Express [3] for programming the PSD813 in the ECG cartridge for Game Boy.

gramming adaptor can't be powered directly from the outputs of the PC's LPT port. To simplify implementation and allow us to dispense with a special dedicated power supply, we have decided to power the adaptor from the power rails in the target systems. But these are usually content – especially nowadays! – with 3 V or 3.6 V, which is not enough to power the EP900.

So we've fitted the adaptor with a very flexible switched capacitor voltage converter that supplies a regulated 5 V output from an input voltage anywhere between 2.7 and 5.5 V! Yes, that's right: the converter works just as well with an input voltage either lower or higher than the output voltage, with an efficiency of around 90%! Bravo to the Burr Brown engineers (that company since taken over by Texas Instruments, which explains why the spec. sheet has to be obtained from the TI website). However, the current is limited to 30 mA.

The only awkward point for amateurs is the size of the regulator IC (it's only available in an SM version), making it tricky to solder. But luckily it only has six pins. So its now or never, to try your hand with an SM device. Position IC2 accurately on its pads. Apply a little solder to one of the pad + legs. Once the solder has set, solder the leg diametrically opposite the previous one. If everything is OK, now solder the remaining legs. If you create a solder bridge between two legs, remove it using desoldering wick.

CONSTRUCTION

As shown in **Figure 7**, the board designed for this project is double sided; it uses only a very few SM components, mainly around the EP900. Naturally, these are to be fitted on the track side of the board. So let's get stuck in! For reasons of practicality, we recommend starting with the SM components. Watch out – certain of them, in particular capacitor C1, are tucked away at the centre of the board, right between the legs of the PLCC44 socket (into which the EP900 is going to be plugged, on the other side). Take care to solder the regulator IC2 carefully, as without this, nothing else will work. It's surrounded by capacitors that are bigger than it is. Take care to identify the values of the SM components correctly (resistors often have coded value information: 103 means 10 kΩ, 1203 means 120 kΩ; things are trickier with the capacitors, which are often not identified or identifiable. Once the SM components are fitted, you can fit the row of resistors, the rest of the conventional components, the selector SW, the headers K2 (MSP430) to K5 (ALTERA), the PLCC44 socket, finishing off with the 25-pin sub-D connector K1. Make sure you pick the male version of the printer connector (LPT); the female version won't make for a very good connection! One little note about the dual selector SW: it's not always easy to get hold of a dual DIP switch, so we've left enough room to fit a quad one, but you'll need to cut off the spare legs before you fit it.

If you're making your own board, it's equally possible to make it single-sided – the second side of the double-sided board is in fact only used to avoid the need for the wire links that a single-sided version will require. Construction is the same, but in this case, it's preferable, for reasons of practicality, to start off by fitting various wire links, using tinned copper wire.

Take care to avoid shorts with the wire links positioned between the 'FLASHLINK' and 'XILINX' connectors, which are relatively close together.

All that remains is to plug the EP900 into its socket. Check the quality of your construction one last time (soldering, component values – luckily there's only one value for the conventional resistors), as there is no way of testing the proper operation of this circuit except by trying it out for real!

Note about the EP900 PLD (order code 060287-41): this is available programmed, free of charge (apart from standard postage and packing charges) from the Elektor SHOP. If you order PCB # 060287-1, the programmed IC will be automatically supplied with it.

TARGET CONNECTIONS

Watch out – you must only use one connector at a time! In most cases, a

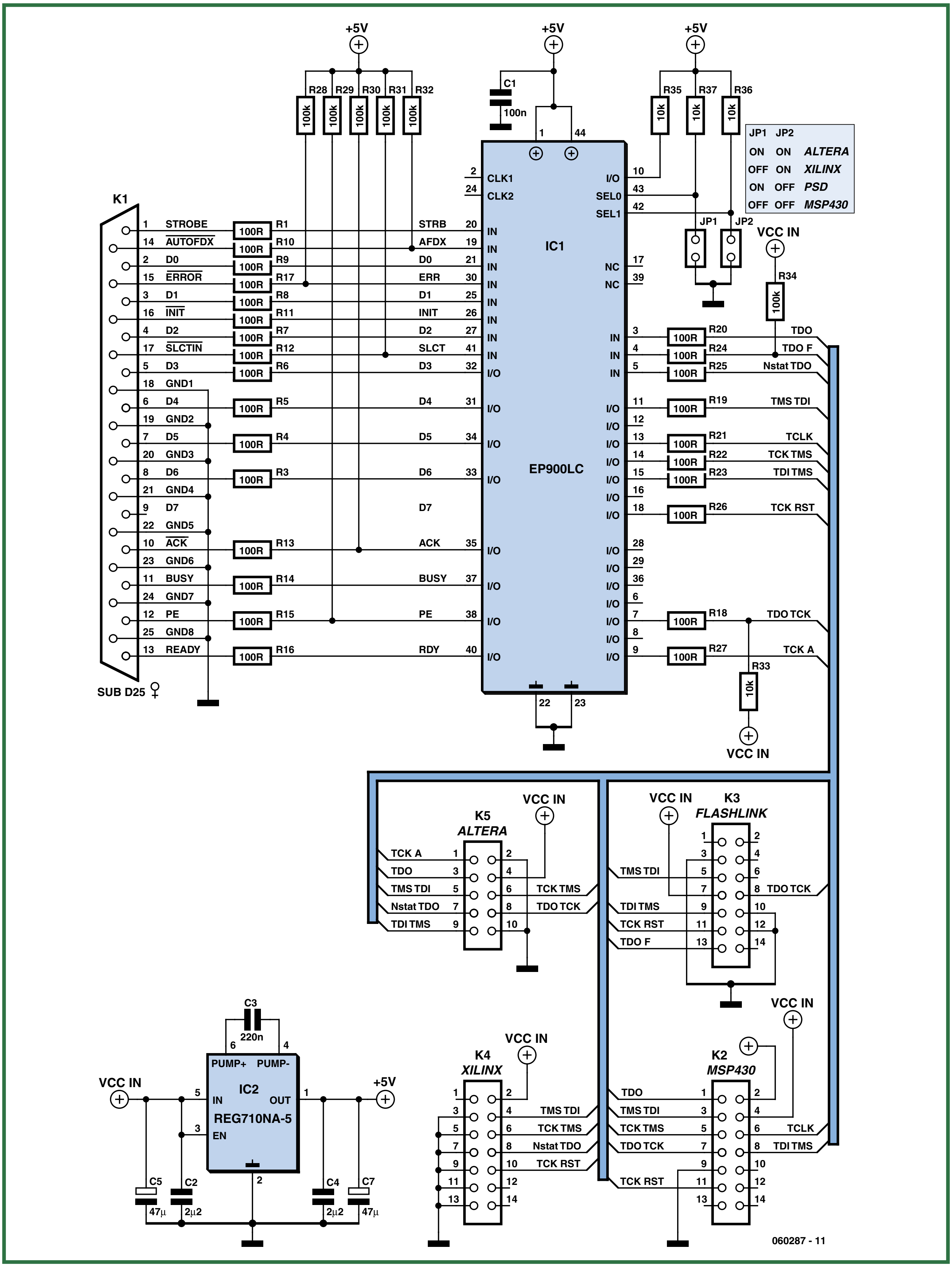


Figure 5. The EP900 takes pride of place in the centre of the circuit for the universal JTAG programmer. It's available ready-programmed, free of charge, when you order the PCB 060287-1.

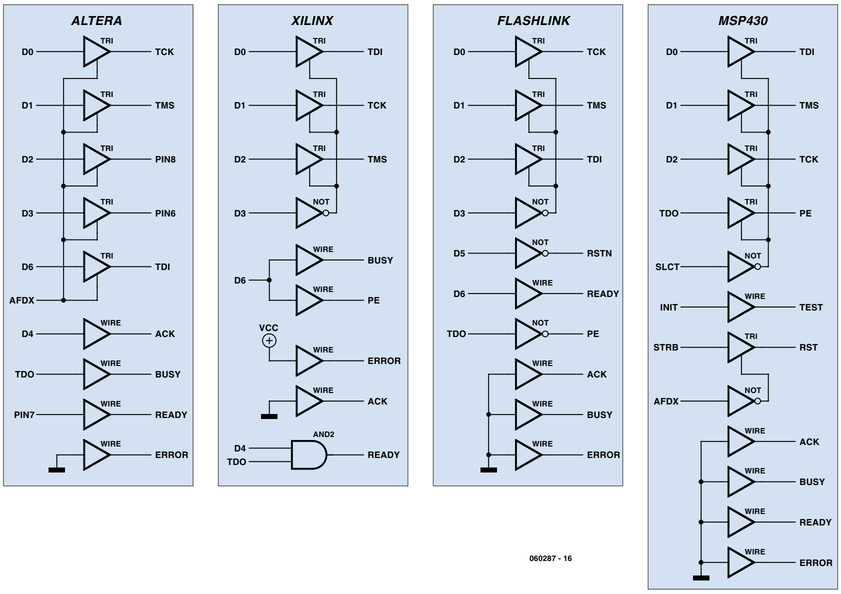


Figure 6. Nothing like it to illustrate the flexibility of a PLD like the EP900! A single device can fulfil several complex logic functions.

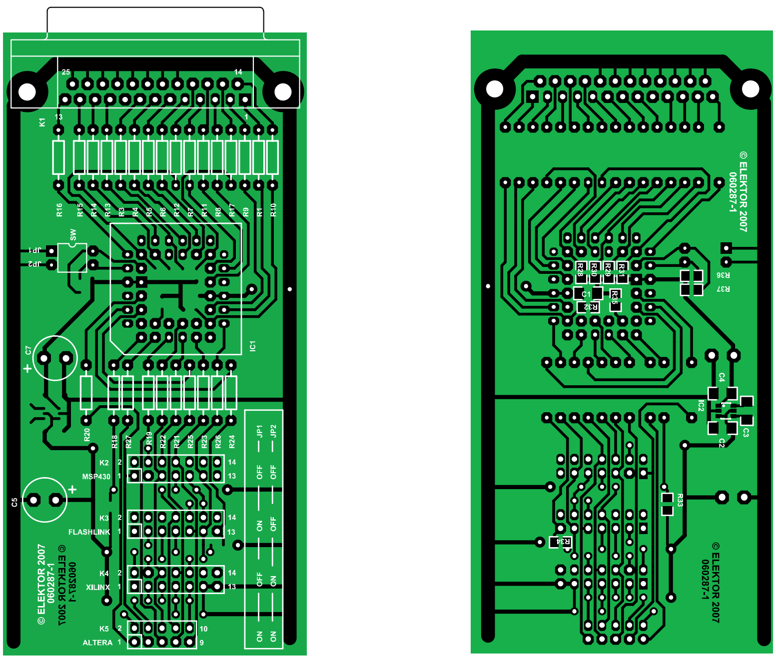


Figure 7. Component overlay for the board designed for this project. The track layout is available for free download.

simple 10- or 14-way ribbon cable, with a crimped connector at each end (watch out for the orientation!) is used to establish the electrical links between the target and the adaptor (see the circuit diagrams of Figures 1 through 4 and the pinning of the relevant connectors).
If you have direct access to the rear of the PC, the adaptor can be inserted directly into the LPT port, without using an extender cable interconnecting the PC and the JTAG adaptor.

USB adaptors

The latest office and notebook PCs no longer have parallel ports (LPT) – a highly regrettable decision, especially for this project! To make up for this, you can find USB/LPT adaptors, but do make sure you check their compatibility with our JTAG programmer; many of them will only accept printers. We can't go into details of the programming procedures for all the possible targets, so we're going to confine ourselves to one example, the…

GameBoy ECG cartridge

The cartridge uses an SMD connector with a pitch of 1.25 mm (K3). To make the cable, we recommend you follow the following procedure.
1. Press a piece of 14-way ribbon cable to a female DIL14 connector;
2. Use the Molex connector and the wires already prepared in the components list (see *Elektor Electronics* October 2006) to make up the appropriate 6-way connector for K3;
3. Solder the four wires TCK, TDI, TDO and TMS and the two power supply wires to both connectors;
4. Check the connections with a continuity tester and then insulate the soldering with heat-shrink sleeving.

And there you go, all ready to program the PSD813s in the GameBoy ECG cartridge.
One last remark: the adaptor is compatible with Byteblaster II (Altera); it does **not** work with the first version of the driver (Byteblaster on its own, without the II). This old driver was used by the MaxPlus II software, and has been replaced by Quartus for two or three years now).

(060287-I)

Bibliography and Internet links

[1] https://www.altera.com/support/software/download/sof-download_center.html

[2] http://www.xilinx.com/ise/logic_design_prod/webpack.htm

[3] http://focus.ti.com/docs/toolsw/folders/print/iar-kickstart.html

[4] http://mcu.st.com/mcu/modules.php?name=Content&pa=showpage&pid=57

REF710-5 data sheet:

http://focus.ti.com/lit/ds/symlink/reg710-5.pdf

Supplementary information, file # 060287-11.zip, free download from: www.elektor-electronics.co.uk

Components list

Resistors
R1,R3-R27 = 100Ω
R28-R32,R34 = 100kΩ (SMD)
R33,R35,R26,R37 = 10kΩ (SMD)
(R2 not fitted)

Capacitors
C1 = 100nF (SMD 1206)
C2,C4 = 2µF2 (SMD 1206)
C3 = 220nF (SMD 1206)
C5,C7 = 47µF 10V radial
(C6 not fitted)

Semiconductors
IC1 = EP900LC (programmed, order code 060287-41) *
IC2 = REG710-NA5

Miscellaneous
K1 (K_LPT) = 25-way sub-D plug, (male), right-angled pins, PCB mount
K2 (FLASHLINK), K3 (MSP430), K4 (XILINX) = 14-way 2-row pinheader
K5 (ALTERA) = 10-way 2-row pinheader
J1,J2 (SW) = 2-way DIP switch
PLCC-44 socket
Project software, file # 060287-11.zip, free download from Elektor website
PCB, order code 060287-1
* Ready-programmed PLD supplied free when ordering PCB # 060287-1 from the Elektor SHOP

Optional
Parts for the cable connection to K3 on the GBECG:
- 14-way (2x7) press-on IDC socket
- Molex socket, 6-way, 1.25mm lead pitch (RS Components # 279-9178)
- 6 wires with crimped contacts for Molex connector (RS Components # 279-9544)

'AHDL' source file for the EP900

Contrary to first impressions, an AHDL file can tell you a lot. Looking at this one a little more closely, it's easy to spot the various options (->).

```
subdesign prog_jtag_univers
(
TDO,Nstat_TDO,TDO_F : input;
STRB,AFDX,INIT,SLCT : input;
D[6..0] : input;
SEL[1..0] : input; -- 0->ALTERA,1->XILINX,
-- 2->FLASHLINK,3->MSP430
ACK,BUSY,READY,ERROR: output;
TCK_A,TMS_TDI,TCK_TMS,TDO_TCK,TDI_TMS,TCK_RST,PE : bidir;
)
variable
TCK_A,TMS_TDI,TCK_TMS,TDO_TCK,TDI_TMS,TCK_RST,PE : tri;
begin
TCK_A.in=D0; TCK_A.oe=AFDX;
case SEL[] is
when 0 -- ALTERA
=> TMS_TDI.in=D1 ; TMS_TDI.oe=AFDX;
TCK_TMS.in=D3 ; TCK_TMS.oe=AFDX;
TDO_TCK.in=D2 ; TDO_TCK.oe=AFDX;
TDI_TMS.in=D6 ; TDI_TMS.oe=AFDX;
TCK_RST.in=GND; TCK_RST.oe=GND;
ACK =D4;
BUSY =TDO;
PE.in=GND; PE.oe=GND;
READY=Nstat_TDO;
ERROR=GND;
when 1 -- XILINX
=> TMS_TDI.in=D2 ; TMS_TDI.oe=!D3;
TCK_TMS.in=D1 ; TCK_TMS.oe=!D3;
TDO_TCK.in=GND; TDO_TCK.oe=GND;
TDI_TMS.in=GND; TDI_TMS.oe=GND;
TCK_RST.in=D0 ; TCK_RST.oe=!D3;
ACK =GND;
BUSY =D6;
PE.in=D6; PE.oe=VCC;
READY=Nstat_TDO & D4;
ERROR=VCC;
when 2 -- FLASHLINK
=> TMS_TDI.in=D2 ; TMS_TDI.oe=!D3;
TCK_TMS.in=GND; TCK_TMS.oe=GND;
TDO_TCK.in=!D5; TDO_TCK.oe=VCC;
TDI_TMS.in=D1 ; TDI_TMS.oe=!D3;
TCK_RST.in=D0 ; TCK_RST.oe=!D3;
ACK =GND;
BUSY =GND;
PE.in=!TDO_F; PE.oe=VCC;
READY=D6;
ERROR=GND;
when 3 -- MSP430
=> TMS_TDI.in=D0 ; TMS_TDI.oe=!SLCT;
TCK_TMS.in=D1 ; TCK_TMS.oe=!SLCT;
TDO_TCK.in=D2 ; TDO_TCK.oe=!SLCT;
TDI_TMS.in=INIT; TDI_TMS.oe=VCC;
TCK_RST.in=STRB; TCK_RST.oe=!AFDX;
ACK =GND;
BUSY =GND;
PE.in=TDO; PE.oe=!SLCT;
READY=GND;
ERROR=GND;
end case;
end;
```

For info: the 'Jedec' programming file (prog_jtag_univers.jed) is available from the Elektor website (www.elektor-electronics.co.uk).

Magnetometer

Detects even the smallest changes

Rev. Thomas Scarborough

The circuit described in this article is incredibly sensitive to changes in the magnetic field. It can be used to detect earthquakes, but it can also function as a car alarm or for theft prevention. The construction is straightforward and only standard components have been used in the design.

The author, who lives in Cape Town, South Africa, originally designed this circuit to detect small earth tremors that could be possible precursors to more violent earthquakes. We know that earthquakes only occur very rarely in Western Europe, but this circuit also lends itself for use in several other applications. The circuit in question is fairly simple and it uses an ordinary mains transformer as a sensor coil. It is capable of picking up minute changes in the magnetic field strength. It is so sensitive that it can detect a passing train at a distance of two kilometres. Before we look at the principle of operation we'll take a look at several possible applications for the circuit:

- Theft prevention: fix a neodymium magnet to your laptop or briefcase and the magnetometer will immediately warn you when it's picked up.
- Car alarm: when the car is moved and changes its angle to the Earth's mag-

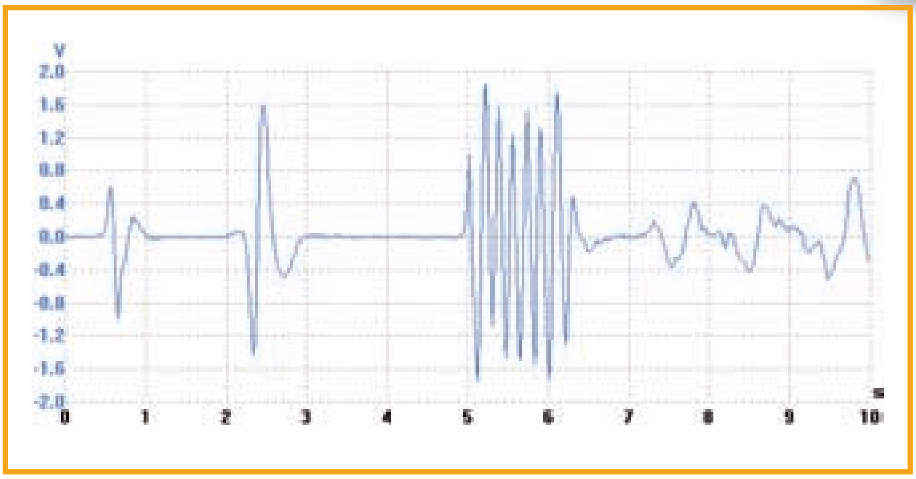


Figure 1. This oscilloscope trace shows the signals generated when a magnet is moved nearby (see text).

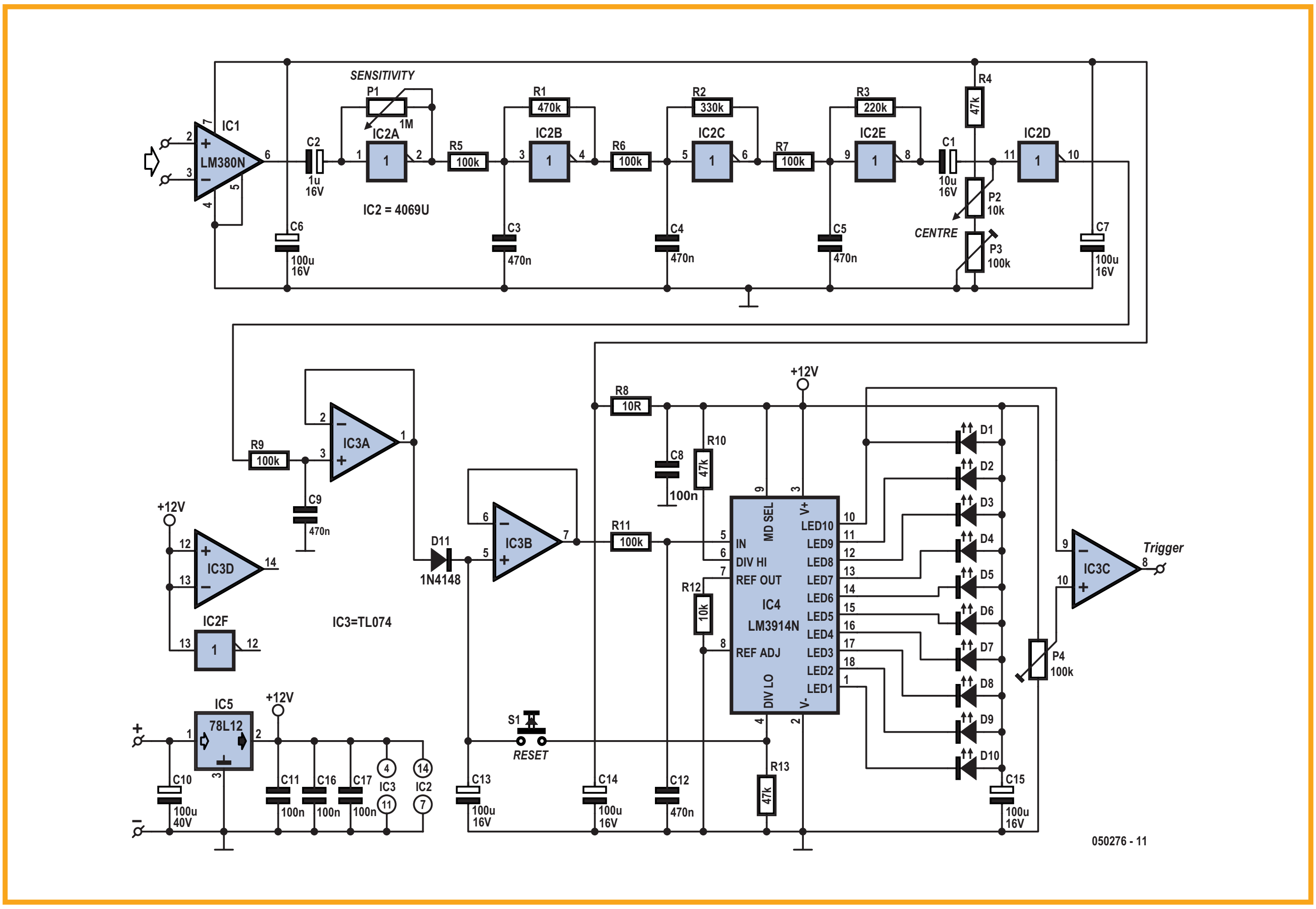


Figure 2. The circuit diagram shows the large number of amplification stages used. They ensure that even the smallest variations in the magnetic field can be detected.

netic field it will be detected by this circuit.

- Vehicle detector: approaching cars or trains can be detected over a large area around the magnetometer due to the vibrations they cause.
- Extremely sensitive vibration alarm: minute vibrations in the vicinity can be detected, such as a bouncing ball on a wooden floor tens of metres away.
- Magnet sensor: the circuit obviously reacts to nearby magnetised objects as well, such as a magnetised screwdriver half a meter away, or even an 'old-fashioned' 3.5-inch floppy disk.
- Cat flap opener: attach a magnet to the cat collar and when the cat comes close to the cat flap it will be opened automatically by the circuit.

Concept

There are basically two types of magnetometer: ones that give an absolute value of the magnetic field strength and others that show the change in the field strength. This circuit detects the variations.

Figure 1 shows an oscilloscope trace of the output of the circuit, when a strong loudspeaker magnet was moved at a distance of about a metre away from the sensor (an old mains transformer). The magnet is first tilted one way (at 0.5 s), then the other way (at 2.5 s), then the magnet is shaken backwards and forwards (from 5 to 6.5 s) and finally the magnet is slowly rotated. It is interesting to see that you can tell from the shape of the waveform in which direction the field changed.

When this circuit was first designed the author wanted to create a seismometer that was inexpensive and could operate in a stand-alone fashion (i.e. without the use of a PC or data logger). This resulted in a fairly simple circuit that used standard components, including a mains transformer as sensor and an LED bargraph as indicator. There is also a trigger (alarm) output that turns on when the full scale of the LED bargraph is reached.

Practical circuit

The most important part of the magnetometer is the detection coil. In the prototype a mains transformer was used (230 V/12 V, 2 A), but in theory nearly any transformer or coil could be used. The author found that the above-mentioned model worked well and gave the circuit a very good sensitivity. The primary and secondary windings of the transformer were connected in series (and in phase) to increase the sensitivity.

The coil is connected to the inputs of a type LM380 opamp (see **Figure 2**). This is really a power-amp IC that can deliver 2.5 W, but it turns out to be just right for this circuit because it has a fixed gain (50 times) and the output automatically settles to half the supply

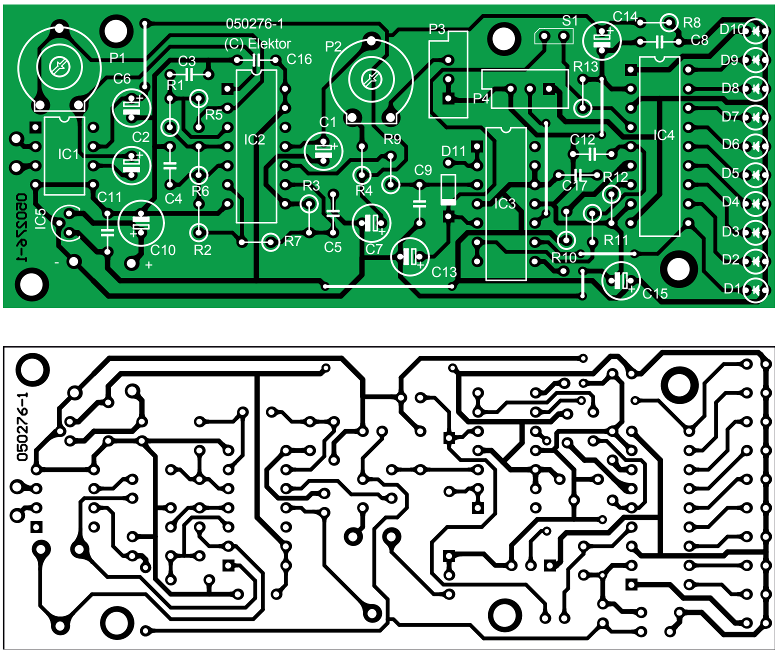


Figure 3. **A PCB has been designed for the circuit to make the construction easier**

voltage without the need for separate bias resistors at the inputs.

The low-frequency signal is then amplified further using a number of gates from an unbuffered 4069UB CMOS IC. An unbuffered CMOS inverter can be made to function as an amplifier with the addition of a resistor between the input and output. In this case four inverters have been used as sequential amplifier stages (IC2A/B/C/E) with passive RC low-pass filters in between (R5/C3, R6/C4, R7/C5). This provides an enormous gain to the output signal from the LM380. All the filter stages (another two follow later on) reduce frequencies above about 20 Hz, mainly to suppress interference from mains-borne signals.

Next, IC2D adds another dose of gain to the signal, where the DC offset to the input of the gate is provided by potential divider R4/P2/P3. After another RC filter (R9/C9) the signal is buffered by IC3A and fed to a halve-wave peak rectifier (D11/C13), which supplies a DC voltage to the input of the LED bargraph circuit. In this way a peak-hold function is implemented, which shows and holds the largest measured value on the display. Pressing S1 resets the LED display. If you don't need this peak-hold function you can replace D11 with a wire link and leave out C13 and S1. All changes in the signal level will then be shown on the LED bargraph display.

The rectified signal is fed via a buffer (IC3B) and a final RC filter (R11/C12) to the input of the well-known LM3914 (IC4), a much used LED driver IC that contains all the electronics to drive a 10-segment LED bargraph display (D1 to D10).

The reference input of the LM3914 has been set such that the signal strength is indicated relative to LED D5. LED D10 is on continuously to indicate that the circuit is powered up; it may be left out of the circuit if not required.

Opamp IC3C provides a trigger output that generates a logic high when the LED for the strongest signal level lights up (D1). P4 is used to set the trigger level.

The supply to the circuit is provided by a 12 V regulator, since any mains ripple on the supply line would be disastrous for the small signals we're amplifying. The power supply can be any mains adapter that has an output voltage of about 15 to 20 V DC (50 mA is sufficient).

Construction and setting up

With the help of the PCB artwork shown in **Figure 3** it shouldn't be too difficult to make a board or have one made for you. Make sure that you get the 8-pin package for the LM380 since the PCB has been designed for this. Keep in mind that you need the unbuffered version of IC2 (4069**UB**), otherwise the circuit will definitely fail to work! Use IC sockets for all ICs to make the construction easier and to help with any potential faultfinding. All resistors are mounted vertically. The reset switch is connected to the board via a pair of wires.

The circuit can be mounted in an enclosure that has suitable cutouts made for the LEDs, the reset switch and the power connector.

An old transformer works very well as a detector 'coil'. It should have all

COMPONENTS LIST

Resistors

R1 = 470kΩ
R2 = 330kΩ
R3 = 220kΩ
R4,R10,R13 = 47kΩ
R5,R6,R7,R9,R11 = 100kΩ
R8 = 10Ω
R12 = 10kΩ
P1 = 1MΩ preset
P2 = 10kΩ preset
P3,P4 = 100kΩ multiturn preset

Capacitors

C1 = 10µF 16V radial
C2 = 1µF 16V radial
C3,C4,C5,C9,C12 = 470nF
C6,C7,C10,C13,C14,C15 = 100µF 16V radial
C8,C11,C16,C17 = 100nF

Semicondcutors

D1-D4,D6-D10 = LED, red, 3mm
D5 = LED, green, 3mm
D11 = 1N4148
IC1 = LM380N-8
IC2 = 4069UB (unbuffered version)
IC3 = TL072CN
IC4 = LM3914N
IC5 = 78L12

Miscellaneous

S1 = pushbutton, 1 make contact
L1 = coil, e.g. discarded mains transformer 230 V / 12 V @2A
PCB, ref. 050276-1 from www.thepcbshop.com

windings connected in series, and you should take care that they are all in phase, otherwise the sensitivity will be reduced. Two short pieces of wire should be used to connect the transformer to the board.

Once all components have been soldered onto the PCB we can connect the mains adapter and start with the adjustments. First set the sensitivity control (P1) midway, as well as P2. Now turn P3 until the centre green LED (D5) lights up on the LED bargraph. During normal use, P2 can be used to adjust the display (you could also use an ordinary potentiometer for this) as and when necessary. Especially when the sensitivity is set to a high value you'll find that the null-point can vary. When the sensitivity is lowered via P1 it should be possible to obtain a stable setting that shows very little drift.

The final adjustment is the trigger level, set via P4. This isn't critical, and should be set such that IC3C switches reliably when LED D1 lights up and switches back again when D1 turns off.

Application tips

At the start of the article we already showed a few possible applications for this magnetometer. Most of these are fairly straightforward and there is no need to give detailed instructions. It is important that you should first 'play' a bit with the circuit to find out how sensitive it is, what it reacts to and what the best setting is for P1. Whilst experimenting you should have as few metal or magnetic materials as possible near the circuit, since they interfere with its operation.

You can make a simple seismometer by hanging an old loudspeaker magnet from the ceiling using a long piece of string and placing it just above the transformer. P1 should then be adjusted such that the LED bargraph remains just unlit. To make a vibration alarm that can detect passing traffic you should attach a magnet to the end of a long ruler. The other end of the ruler should be fixed to a large surface and the transformer should again be placed just below the magnet. You'll be amazed by the distance at which vibrations can be detected with this simple circuit!

(050276-1)

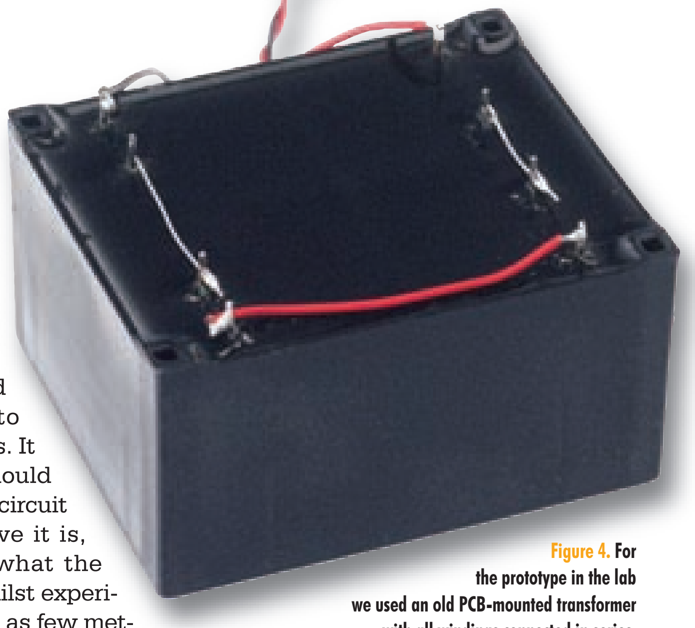


Figure 4. For the prototype in the lab we used an old PCB-mounted transformer with all windings connected in series.

New Technologies, new Tools

Using a hot-air workstation

Luc Lemmens

The soldering iron has been the pre-eminent tool since the year dot to 'stick' electronic circuits together. The first few generations of SMD parts could still be soldered with a soldering iron, even though it required a little more effort and accuracy. But the parts are forever getting smaller and smaller, and the connections have now become so minuscule and inaccessible these days that other equipment is required to get the job done. Our January 2006 SMD Oven – a new version of which will be published in the near future — is very appropriate for building a complete circuit board, but not when just fitting or replacing one component. For this task there is a more appropriate tool available, which is not all that expensive either: the hot-air iron or rework station. For about 110 pounds (approx. 145 euro) you will have a complete station that is ready to go.

As the name indicates, this iron works with hot air to achieve the solder connection or to de-solder a component. The name 'rework station' suggests that it is intended for repair work, but it also proves to be very useful when building prototypes. With a conventional soldering iron we have to take into account the size of the tip and the temperature. With the hot-air iron we have to deal with the size of the nozzle, the temperature and the airflow. There is thus an additional parameter and it requires a certain amount of experience and skill to use the iron effectively.

Nozzles are available in many types and sizes. There are those that are suitable for soldering an entire IC in one go, others are a little smaller and intended to deal with one or a few connections at a time. The choice of the correct nozzle is very dependant on the job to be done, but it is certainly not necessary to buy a complete arsenal of them. Fortunately, these nozzles have a much longer life expectancy than a soldering iron tip, so each nozzle is, in all likelihood, just a one-time investment.

The selection of the correct nozzle for the correct job is usually very easily made, the settings for the correct temperature and airflow are a little more complicated. This is really something that you will have to develop a knack for. When you start to work with a hot-air iron for the first time it will take a little while before you have found the correct settings and these will differ from iron to iron and job to job. It is, however, very important that the heat and airflow are applied only to the spot that you want to (de-)solder. Also, make sure that the airflow is not so strong, otherwise it is very easy to blow small parts away and that is obviously not the intention. It is a good idea to practise first on a scrap circuit board and/or components from the junkbox whose demise do not seriously hurt your wallet; it can take a while before you acquire a feel for this.

When using a hot-air iron it is common practice to use solder paste instead of solder. In a professional environment, a so-called 'dispenser' is used. This is a device that squirts the exact amount of paste on each solder pad. A good dispenser is quite expensive; if you do not have one of these it is possible to use a sharp implement to apply the paste to the PCB, for example a straightened paper clip. Not a fantastic method when doing a large production run, but it will do for a prototype. You could also put a small amount of solder on each pad using an ordinary soldering iron and solder, but this often results in unevenness that makes the correct positioning of components more difficult.

It is recommended to use a so-called 'pre-heater' in combination with the hot-air iron. This is a type of hotplate that pre-heats the circuit board so that the iron is now only required to push the temperature of the paste or solder that last little bit beyond the melting point.

All in all, a fine method that requires a little bit of practice to find the optimum settings and the best way of using this tool.

(075051)

Temperature from a
RF thermometers on the PC

Jeroen Domburg & Thijs Beckers

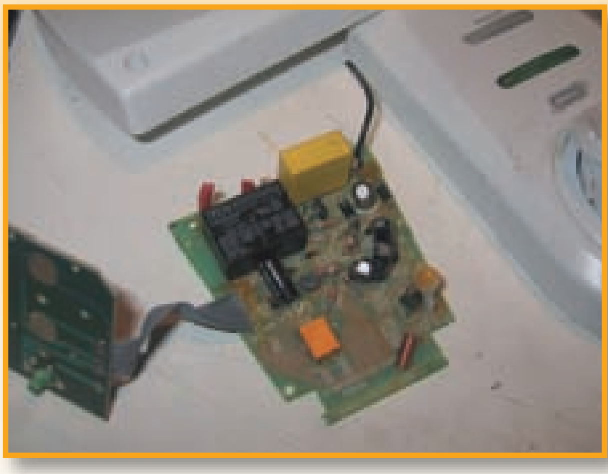


Figure 1. The inside of the remote controlled power point, now still with far too many parts.

Figure 2. the RF receiver occupies only a small part of the circuit board These parts (plus the SMD-IC on the other side) are enough to function as an RF receiver.

Weather stations with a wireless connection between the sensors and the base station don't cost that much these days. For a song add one of those click-on-click-off systems and you're ready to mod. This time we build a simple data logger system and keep an eye on the temperature using a PC.

The weather keeps us continually occupied. Some people have even made it their profession. At home too, we like to measure all kinds of things related to our climate. That is why weather stations are available in all types and sizes. If we want to know the temperature inside and outside then purpose-built indoor/outdoor thermometers are available for under a tenner.

Wireless

While in the past the outside sensor of these weather stations was connected with a wire, it is now fairly standard to use RF transmission for this data. It is however also easy to use these sensors for our own applications, without opening the sensors or the base station and risk voiding the warranty. That is because the wireless transmitters in these units usually make use of the 433-MHz ISM band, and finding a 433-MHz receiver is quite straightforward. At the better electronics retailers these shoiudl not set you back more than about ten pounds.
You could also use the receiving module from another device, provided it operates on the same frequency. A power point with remote control ('click-on-click-off' system) meets our requirements in this case (see **Figure 1**). After this, it is theoretically a piece of cake to hang the whole lot off a computer so that a nice database of recorded temperatures can be established.
Unfortunately, it is a little more awkward in practice. That is because there is no standard for the transmission of temperature data over an (ISM) 433-MHz connection using type-approved, licence free transmitters. Manufacturers are usually not so helpful as to send a description of the protocol along with the sensor. Sometimes someone else has already made an attempt at decoding the protocol. But if no-one has yet ventured there, there is only method left to discover this information: reverse engineering.

Designing the other way around

To be able to reverse-engineer we need two things. Firstly, we need a way to receive the signals and secondly we have to be able to make these signals visible. For the first, we can obtain, as already mentioned, a ready-made receiver. But to get into the spirit of reverse engineering, we disassembled an existing RF-controlled power point. An interesting aspect when disassembling an existing

Distance

About the author

Jeroen Domburg is an electrical engineering student at the Saxion technical University in Enschede. He is an enthusiastic hobbyist, with interests in microcontrollers, electronics and computers.

In this column he displays his personal handiwork, modifications and other interesting circuits, which do not necessarily have to be useful. In most cases they are not likely to win a beauty contest and safety is generally taken with a grain of salt. But that doesn't concern the author at all. As long as the circuit does what it was intended to do then all is well. You have been warned!

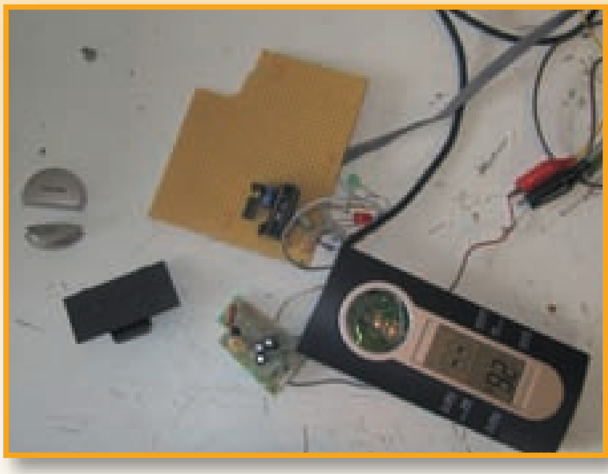


Figure 3. the first prototype of the receiver circuit. On the base station we can see what values the temperature modules are transmitting. Very handy as a check.

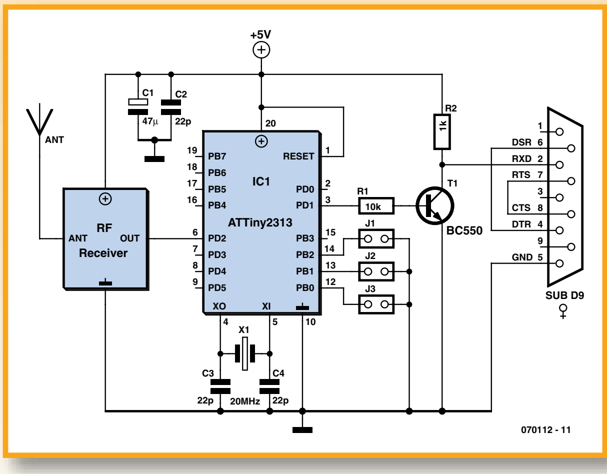


Figure 4 . The schematic once again clearly shown that the microcontroller is at the heart of the circuit.

device is that you get a glimpse into the thought processes of the designers. Some devices are put together in such a smart way that while looking at it you cannot avoid but have respect for the designers, while other devices are such a bungling mess that you nearly get annoyed with the whole design.
In any case, it is useful to note that designers, more often than not, build things in a modular fashion. It is also not unusual with such a click-on-click-off power point, that the power supply and RF-receiver share several components.
Taking the click-on-click-off power point apart was quite simple. It consists of a couple of capacitors and resistors to reduce the voltage from 230 V to a lower voltage, the RF receiver, a special chip for interpreting the received pulses and a transistor plus relay to switch the load.
The method of only keeping the RF receiver is quite straightforward. Just remove everything that you know has nothing to do with the RF receiver and in the end you will be left with an RF receiver (see **Figure 2**).
But be careful: on our board it turned out that there was a zener diode across the power supply rails to regulate the power supply voltage of the receiver. When connecting a bench power supply with a slightly higher voltage than the breakdown voltage of the diode alarming clouds of smoke were released… Annoying, particularly if it is the intention that the circuit continues to work.
A still functioning zener diode would have been useful. That is because its value is equal to the power supply voltage that the receiver needs. If, for example, it had contained a 7805-voltage-regulator IC then this would have been much easier to find.
With the disassembly of the RF receiver from the click-on-click-off power point we have successfully tackled the first problem. We now have a receiver board that generates a signal that is equivalent to the signal that is sent by the RF temperature transmitter.
The next step is to decode the signal. Normally an oscilloscope is eminently suitable to look at a signal, but this signal is sent only about once a minute. Without a storage scope it becomes very hard to take a good look at the signal. To be able to proceed we made an early start on the final circuit: an ATTiny2313 which has a serial connection with the PC (see **Figure 3**).

Hardware & software

The schematic of the circuit is shown in **Figure 4**. A power supply voltage of 5 V is indicated here, but if the RF receiver requires less or more, then this will have to be adapted of course. The AVR can operate from about 3 to 6 volts. If the power supply voltage is in this range then there is no need to change anything in the circuit. If the receiver runs off 12 V, for example, then it will be necessary to generate two power supply voltages and a resistor of 10 Ω or thereabouts will have to be added in series with the signal line from the RF-receiver to the AVR. The 12-V signal on this line is then attenuated by the resistor and the ESD diodes in the AVR.
Now that the signal pulses arrive at the AVR it is time to let it process the coded signal so that we can view it on the PC via the RS232 connection and figure out how the coding works. A simple assembly language program was written for this purpose, which stores the times between the signal edges of the received pulse train in the RAM of the AVR. At the end of the pulse train the code is transmitted via the serial port. In this way it is quite easy to determine what the bit timing is and what coding is used.

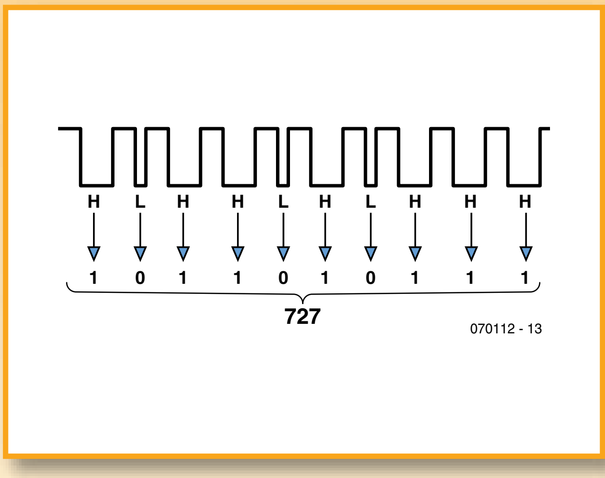


Figure 5. Here we see the coding of the RF signal. After a little puzzling we can find the temperature in this.

Figure 6. This transmitter is waiting patiently until it is brought into service.

Figuring it out

Both of the temperature sensors we tested used the length of the transmitted pulse as a way to send a bit, but that is where the similarity ends. With one sensor a short high pulse means '1' and a long high pulse means '0'. With the other sensor it is just the other way around, with a long pulse meaning '1' and a short high pulse meaning '0'. This was all easily deduced from the data sent by the AVR.

With a constant length of the high 'pulse' it is plausible that the data is coded in the low 'pulse' and the other way around (see **Figure 5**). The length of time that the signal is high is the same everywhere; the length of time that the signal is low indicates whether a '1' (long) or a '0' (short) is being transmitted. The signal represents a binary number with the temperature in tenths of degrees, increased by 50. The correct temperature is obtained thus:

$$(727\ /10) - 50 = 22.7°C$$

Although this type of coding seems to be the simplest way and is quite common, it is by no means the only method that could be used by the manufacturer. FM-, MFM-, RLE, or some other sort of coding could also be used. These types of coding can often be recognised by the variable length of both the low and high pulses.

Once the pulse duration of the long and short pulses is known, the meaning of the entire pulse train can be figured out. We do this by guessing the value of the short and long pulse, the temperature that is received by the base station (or is indicated on the sensor itself) and a lot of staring at the bits that are spit out by the AVR. With a bit of luck the temperature is immediately recognised in the mountain of zeros and ones. Without such luck we'll have to stare a little harder. The coding of the temperature into a binary value is not standard either. Some sensors send the temperature in tenths of degrees as a 12-bit number, other sensors send the value of each individual digit as a 4-bit number.

Negative numbers too are presented in different ways. Sometimes this is done with a separate bit, but a two's-complement number does also occur, just as increasing the temperature value by, for example, 30 degrees before transmitting it.

Once the coding has been found, it is merely a question of writing a piece of code to decode the temperature and put it on the serial data line.

More sensors

If more than one sensor is used, then this is not enough however. We also need to know which temperature comes from which sensor. Different brands of sensor are very likely to be able to be distinguished because they use a different protocol. If, however, we want to use multiple sensors of the same brand then things get a little more complicated.

The manufacturers have already encountered this problem and have found two solutions for this. The first is to simply add a 'channel' switch to the sensor. This setting can then be found in the binary data stream that the sensor generates.

The second solution is to generate a random number when the sensor is turned on, which is then sent with every temperature measurement. The chance that this random number is different for each sensor is quite large. In this way it is simple to determine which temperature belongs to which sensor.

In addition to the temperature and the ID, some sensors also send a checksum along, so that the receiver can determine whether the temperature has been received correctly or not. The present firmware for the AVR does not use this checksum, because a check for errors is already made at a lower level. If the pulse durations are outside a certain minimum or maximum, depending on the type of sensor, then the pulse train is ignored. This rejects the majority of errors so that a checksum is not necessary.

Your own Programming

At the time of writing this article only the two sensors that we used here were implemented in the code: the KW9010 and the WS7050 from Conrad Electronics (see **Figure 6**). If another sensor has to be read, then the code for this will have to be written first.

This is actually quite easy of you are familiar with the AVR assembly language. The framework for this is already in place. For the first few steps in this process there are a

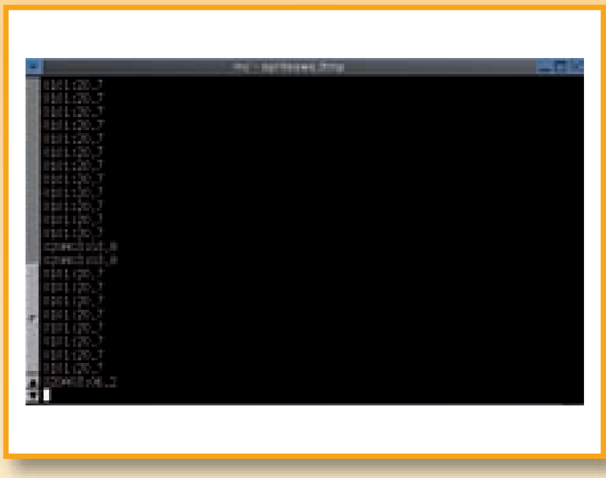


Figure 7. This is what the AVR makes from all this. Each time a sensor transmits something a line is added with the ID of the sensor and the measured temperature.

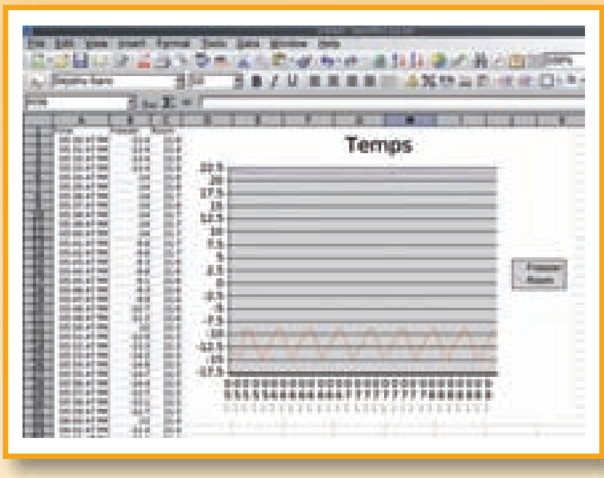


Figure 8. The measured temperatures are easily collected in a spreadsheet. This is a graph of room temperature (purple) and the temperature in the freezer compartment of the fridge (orange).

number of jumpers that make this job easier. J3 selects that for each received pulse train the lengths of the pulses are transmitted as hexadecimal numbers out of the serial port. J2 lets the AVR try to interpret these numbers itself. The AVR will then determine itself whether the data is stored in the high or low pulses and generates a line with the letters ‘s’ (for a short pulse) and ‘l’ (for a long pulse) repeated a number of times. After this it is up to the programmer to decide which is a ‘0’ and which is a ‘1’ and how the temperature is coded.
Once this is known, some programming will have to be done. First we have to find out the limits of the high and low pulse durations and the number of pulses. This will be used to determine the required protocol-decoder routine. Secondly, this routine itself has to be written. Although this looks tricky, there are already a few existing subroutines that have been designed to make most of these tasks much easier. Have a look at the existing implementation for more information.
J1 can come in handy while testing. Normally the AVR suppresses the debug information for each correctly recognised pulse train. By placing a jumper on J1, the AVR will show the debug information for each set of pulses.

To the PC

Because the processing of the temperature data is all done in the AVR, the data that is transmitted to the PC is quite simple. The COM port needs to be set to 115200 baud, no parity, 8 data bits and 1 stop bit. Each line of text that is transmitted is built up as follows:

```
ssss: tt.t
```

where ‘s’ is the unique hexadecimal ID of the sensor and ‘t’ represents the (decimal) temperature that the sensor has measured in degrees.
This data can be collected with a simple script or program that listens to the serial port (see **Figure 7**). This data can then be used to make useful and/or pretty graphs (**Figure 8**).
A few comments about the connection with the computer: because there is only one TxD signal, a single transistor has been used to convert the signal from the micro to an RS232 compatible level. This method works quite well for most serial ports. Some serial ports are a bit more critical with their signals. If that is the case the circuit around R1, R2 and T1 can be replaced with a standard MAX232 circuit (see **Figure 9**).
The firmware for this project can be downloaded free, of course, [1] and [2], and is released under the GPL [3]. If you have added an additional sensor type you can send the code to the email address in [2]. We will then add the code so that other readers can also benefit.

(070112-I)

Web links:

[1] www.elektor-electronics.co.uk, May 2007 page

[2] sprite.student.utwente.nl/~jeroen/projects/rftemp

[3] http://www.gnu.org/licenses/gpl.txt

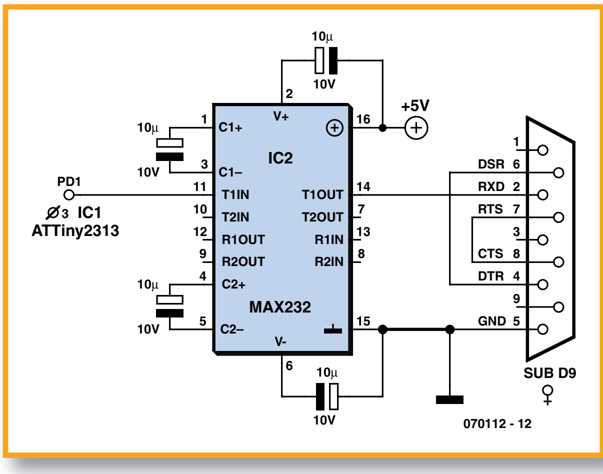
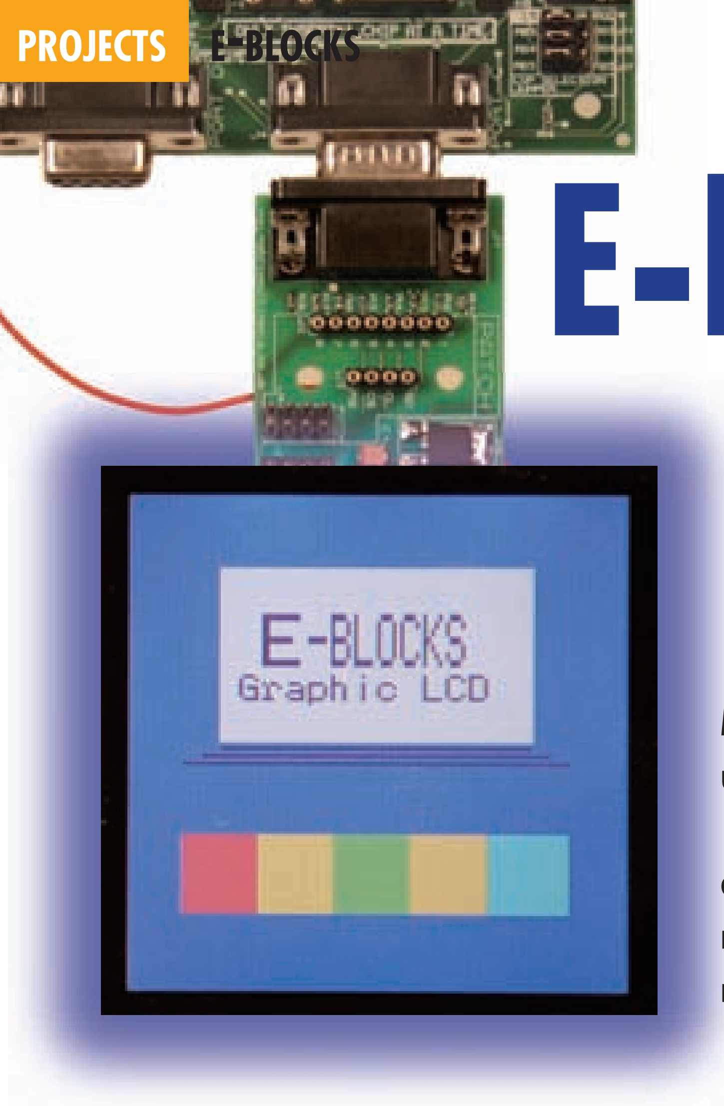


Figure 9. Should the combination of T1/R1/R2 not work properly then this can be used as an alternative.



E-blocks Grap

Understanding,

John Dobson & Ben Rowland

Most of you will by now be familiar with the commonly used alphanumeric LCD screen that has two lines and 16 characters. These are great – but by no means the only displays you can use. Here we look at the use of more advanced graphical displays which – thanks to the mobile phone – are now readily available.

The display pictured above features 132 by 132 pixels totalling at 17,424 individually addressable pixels. There is a maximum of 65,536 individual colours available for each pixel and a white backlight to provide maximum display visibility even in the dark. The interface is a 4-wire serial interface that operates using the SPI bus protocol. The display used is compatible with the popular Nokia 6100 colour LCD and also uses the Epson S1D15G14 controller chip [1]. Nokia 6100 LCDs are widely available for under £ 20 (approx. € 30).

Problems

From this short description it sounds like an ideal successor to the simple LCDs we are all used to — but there are some problems:

- Because theses displays are used in mobile phones the interface requires signals at 3.3 V — a problem if you are using 5V components.
- The backlight operates at 14 V — this means that phones that use these displays need some kind of 'whistler' (step-up) inverter circuit to convert the normal 5 V supply to 14 V.
- These devices are purely graphical: unlike the simpler LCD displays there is no inbuilt character set — you need to make your own!
- The displays are designed for mass production and often use an exotic surface mounted connector that's hard use in a prototype situation.

Fortunately for Elektor readers we have solved these problems as you will see. However, let's first look in a little more detail at how the display is used.

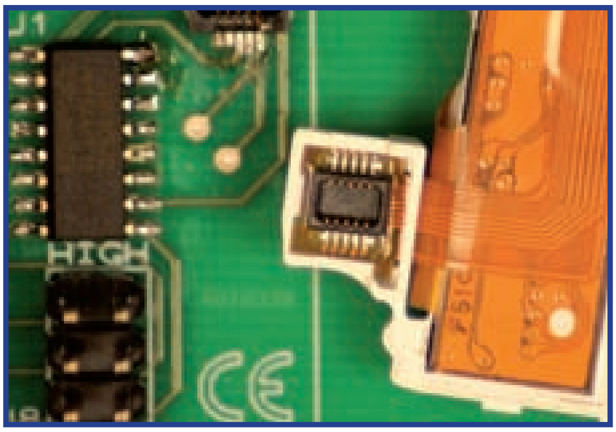


Figure 1. Close up of the original prototype PCB with display surface mount 'plug' and 'socket'.

Writing data

To send a data packet to the display the data has to be clocked in serial form. Fortunately the chip inside the display works in a serial form requiring only four pins. The timing diagram in **Figure 2** shows how this is achieved. The first bit of data to be sent is marked 'A' and tells the display whether a command or a parameter is being sent. Commands are sent as a logic 0 and parameters as a logic 1. Following the instruction bit is the data byte. This is transmitted one bit at a time starting with the most significant bit and ending in the least significant bit. Each bit is read into the graphical LCD at the change from Low-to-High on the clock input.

Command list

To help you control the display a number of commands are available for the built-in Epson controller. There are quite a few of these but the main ones are given in **Table 1**.

This gives you some clues as to how to use the display.

hic Colour LCD

programming... showing off!

For example, a startup sequence for the display would be as follows:
1. Send command 0x01 to reset graphics hardware.
2. Wait 10 milliseconds.
3. Send command 0x11 to bring display out of sleep mode.
4. Wait 40 milliseconds.
5. Send command 0x29 to switch on the display.
6. Wait 40 milliseconds.

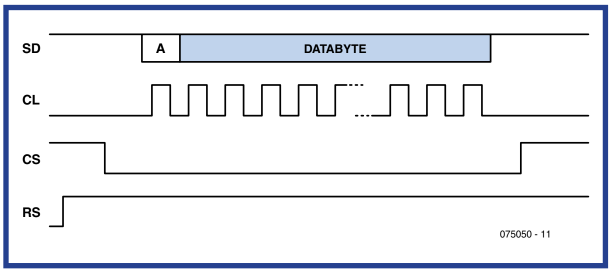


Figure 2.
Timing diagram for command sent to he LCD.

Dealing with colour

The display has two basic colour modes – 65,536 colours and 4,096 colours. One issue you have to resolve fairly early on is the colours you will use: for most application 65,536 colours is just a few too many, and has the added disadvantage that each pixel colour will need to be represented by two bytes of information.
4,096 colours is better in terms of memory usage and speed, great for photos but awkward for graphics.
Fortunately the display allows you to set up just a subselection of 256 colours from the 4096-colour palette. This allows us to represent colour information with just one byte of data which makes communication with the display a little easier, and quicker. But how do you select 256 colours from the palette of 4,096? In a 4096-colour palette there are four bits for each of red, green, and blue (2^{12} = 4096). That means 12 bits of information per pixel or 1.5 bytes. Hmm, somehow we need to reduce that to one byte.
So how is it done? Let's look at a possible solution. What we would like to do is split up each byte so that three bits represent the red part of the colour, another three the green part and two the blue. This is commonly called '3-3-2' and is a technique which has been used in digital video for some time. We suspect that short-changing the blue like this is based on our eyes being less sensitive to variations in blue compared to red and green – we are sure a reader out there will be able to confirm this. The proposed systems is given in **Table 2**.
If this system were possible then to get a colour of your choice you would simply approximate the colour you need in terms of its RGB content.
Fortunately this is possible with the use of another lookup table. This second lookup table allows you to match the colours in the 3-3-2 system with shades in the 4-4-4 12-bit system. Consider the following table for matching the eight red colours in the 3-3-2 system with those in the 4-4-4 system:

3-3-2	4-4-4
0	0x0
1	0x2
2	0x4
3	0x6
4	0x9
5	0xB
6	0xD
7	0xF

Table 1. LCD command list

Command	Hex value	Parameter	Function
SWRESET	01	-	Software reset
SLPIN	10	-	Send control chip into standby
SLPOUT	11	-	Control chip wake up
DISINVOFF	20	-	Normal display mode
DISINV	21	-	Invert display mode
ALLPXOFF	22	-	Turn off all pixels
ALLPXON	23	-	Turn on all pixels
WRCNT	25	1	Set contrast
DISPOFF	28	-	Turn display off
DISPON	29	-	Turn display on
CASSET	2A	2	Set column address
PASSET	2B	2	Set page address
RAMWR	2C	DATA	Write to RAM
RGBSET	2D	20	Set RGB colours

Here the eight available shades of red in the 3-3-2 system are matched to eight of the shades of red in the 4-4-4 system giving an approximate even mix of shades to the 3-3-2 system. This is used for both the Red and Green matching. Blue has to whittle the choices down further to only four out of the possible 16 shades as you can see here:

3-3-2	4-4-4
0	0x0
1	0x4
2	0xB
3	0xF

Fortunately you do not have to write code or lookup tables to implement all of this – the LCD is designed with this facility in mind and all you need to do is to write the 3-3-2 colour selection to the display on start up, using the command code 0x2D, to select the shades you want.
So, after initializing the display you need to send the following commands:

Table 2. Colour control/selection						
Colour	**R**	**G**	**B**	**Hex**	**Decimal**	
Black	0	0	0	0x00	0	
White	111	111	11	0xFF	255	
Red	111	0	0	0xE0	224	
Green	0	111	0	0x1C	28	
Blue	0	0	11	0x03	3	
Yellow	111	111	0	0xFC	252	
Orange	111	11	0	0xF8	248	
Lilac/Lavender	100	0	10	0x82	130	

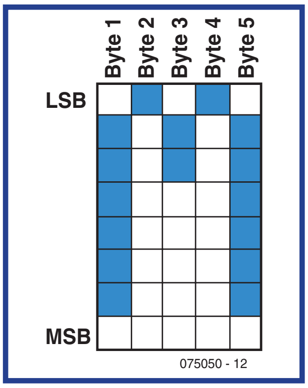


Figure 3. Example of letter M 'pixelled out'.

1. Send command 0x3A to set interface mode into pixel format.
2. Send parameter 0x02 to set: 8 bits per pixel.
3. Send command 0x20 to set: no colour inversion.
4. Send command 0x2D to build an 8-bit colour lookup table.
5. Send the 20-byte colour constants as parameters to build the lookup table:

```
0x00,0x02,0x04,0x06,0x09,0x0B,0x0D,
0x0F,0x00,0x02,0x04,0x06,0x09,0x0B,
0x0D,0x0F,0x00,0x04,0x0B,0x0F.
```

After this you are ready to start to write data into the display. Before that, however, more new concepts!

Windows with microcontrollers!

The graphical display is based on a memory device inside the display itself. When you are writing to the display you therefore need to tell the display where to show the data sent. In practice you define a subset of the display as a 'window'. The window can be a section as small as a single pixel, or it could be the entire screen area. A few steps must be taken when writing information to windowed areas.

1. Send command 0x2A to assign a 'column' address.
2. Send parameter upper left *x* coordinate of window (0 to 131).
3. Send parameter upper left *y* coordinate of window (0 to 131).
4. Send command 0x2B to assign 'page' address.
5. Send parameter bottom right *x* coordinate of window (X1 to 131)
6. Send parameter bottom right *y* coordinate of window (Y1 to 131)
7. Send command 0x2C to set the window as editable area.
8. Send parameter colour value to be assigned to top left pixel.
9. Continue sending parameter colour values until every pixel in that row has been assigned a colour.
10. Repeat steps 8 and 9 for all of the pixels in the specified window.

The concept of a 'column' address and 'page' address needs some explaining: unlike a conventional LCD display where you specify the character location in terms of the *x* and *y* location of the character, in a graphical display you specify an area of the screen you want to use. This corresponds to a block of memory inside the display device itself. Once you have specified a memory location or screen area then you sequentially dump the colour of each pixel in turn inside that block. You do not need to specify the *x* and *y* location of each pixel in the window — the display takes care of that for you. This might seem a strange technique but the device is managed in this way for a good reason: it allows very fast writing of images to the display, which is a great advantage for displaying photographs and even video.

Managing text

Having understood how to write to an area of the screen you should now be getting some ideas as to how you write a character to a particular location on the screen. As we learned earlier there is no in-built character set with this kind of display: you need to make one yourself. To output text to the display the first step is to create a window size of 5×8 to house the pixel information. Each character will take up five bytes of memory to fill the 5×8 window. It is then simply a case of going through the bytes 1 to 5 and checking the least significant bits. If the bit is a 0 then send a background colour, else, if the bit is a 1 then send a foreground colour. After completing this for all five bytes you then move onto the next least significant bits and so on until the windowed area is full of pixel data.
So for the letter 'M' illustrated in **Figure 3** the sequence would be: 0x7F, 0x02, 0x04, 0x02, 0x7F.
Similarly, for a lower case 'm' the sequence is 0x7C, 0x04, 0x18, 0x04, 0x78.
Of course constructing datastreams for each character as it is written is a little longwinded. In practice you need a lookup table which specifies the bitmap image for each character.

Managing graphics

Managing graphics is a little harder. For example, to draw a line you need to either declare a sequence of windows 1 pixel by 1 pixel wide and send one pixel to that window, or you need to declare a larger window and somehow calculate the data you need to send to the window to get the graphic you want.

Ready to go software

If you are starting to think that this all sounds great but is just too much like hard work then "don't panic Mr Mainwaring". What we have done is prepared a standard kit of hardware and software for you that makes life a great deal easier. The software consists of a number of C routines and lookup tables.
If C makes you come over all shaky then don't panic: these libraries fit nicely into Flowcode 3 and make the LCD accessible to programmers of all levels. We have

even provided a demo program in Flowcode 3 which produces the graphic you can see in the introductory photograph. You can use this Flowcode file as a starting point for all of your programs.
The Flowcode file is called **Example_file.fcf**. The C library is called **GFX_LCD_Functions.c**. Both files are contained in a zip archive file you can download free of charge from the Elektor website as file # **075050-11.zip**. The archive also contains a supplementary document called **GFxLCD Programming Strategy**. Lots of useful stuff in there even if you are not into E-blocks.
Note that if you are using Flowcode then you must have the C file in the same directory as the Flowcode file as Flowcode uses this as an external C library during the compilation process.

Text character map

Firstly we have constructed a standard set of character tables which allow you to use the display like a 22 by 15 character LCD display. Each character is made up of five pixel columns by eight pixel rows and this is based on the ASCII table. So, to write a character you simply write its ASCII equivalent. So far we have just allocated the main characters — those of you who need umlauts, accents or diacriticals will need to expand the table as required. **Listing 1** shows an extract only — the complete table is called **TXTCHAR.txt** and contained in the free download for this article.
The characters are split into arrays. Several are used because is some C compilers there is an upper limit on the size of the array.

Standard functions

Secondly we have prepared a standard set of functions which behave in the same way as conventional LCD displays with the following commands available to the user:

Lcd_init() initializes the display;
Lcd_clear() clears the display
Lcd_drawline (X1, Y1, X2, Y2, Colour) draws a line of the appropriate colour between pixels X1, Y1 and X2, Y2.
Lcd_print(String, X, Y, Size(0-2), FontColour, BackColour, StringLength) prints a string with character location X, Y, Size 0, 1, or 2 (size 0 is default, 1 uses 4 pixels per normal pixel, size 2 uses 9 pixels per pixel) with font and background colours. With this command you also need to specify the string length.
Lcd_box (X1, Y1, X2, Y2, Colour) draws a 1 pixel box based on pixel locations X1, Y1 and X2, Y2 with a colour of your choice.

Referring again to the introductory photograph, the complete program in C using our library is given in **Listing 2**.
The Flowcode file for this program is shown in **Figure 4**.

A new E-blocks module

You can buy the E-blocks graphical LCD module from the SHOP section on the Elektor website. The module has the LCD connected up and secured on a circuit board and is ready for connecting into an E-blocks system, from which it takes all control and supply signals. The extensive description of the LCD operation in this article goes to show that the module is also suitable for systems other than E-blocks.

(075050-I)

Listing 1. Text character map (extract)

```
rom char* ASCII3 = {0x36 , 0x49 , 0x49
   , 0x49 , 0x36, // 8 // 56 - 67
0x06 , 0x49 , 0x49 , 0x29 , 0x1E,    // 9
0x00 , 0x6C , 0x6C , 0x00 , 0x00,    // :
0x00 , 0xEC , 0x6C , 0x00 , 0x00,    // ;
0x08 , 0x14 , 0x22 , 0x41 , 0x00,    // <
0x24 , 0x24 , 0x24 , 0x24 , 0x24,    // =
0x00 , 0x41 , 0x22 , 0x14 , 0x08,    // >
0x02 , 0x01 , 0x59 , 0x09 , 0x06,    // ?
0x3E , 0x41 , 0x5D , 0x55 , 0x1E,    // @
0x7E , 0x09 , 0x09 , 0x09 , 0x7E,    // A
0x7F , 0x49 , 0x49 , 0x49 , 0x36,    // B
0x3E , 0x41 , 0x41 , 0x41 , 0x22};   // C
```

[1] Datasheet of S1D15G14 display at www.epson-electronics.de

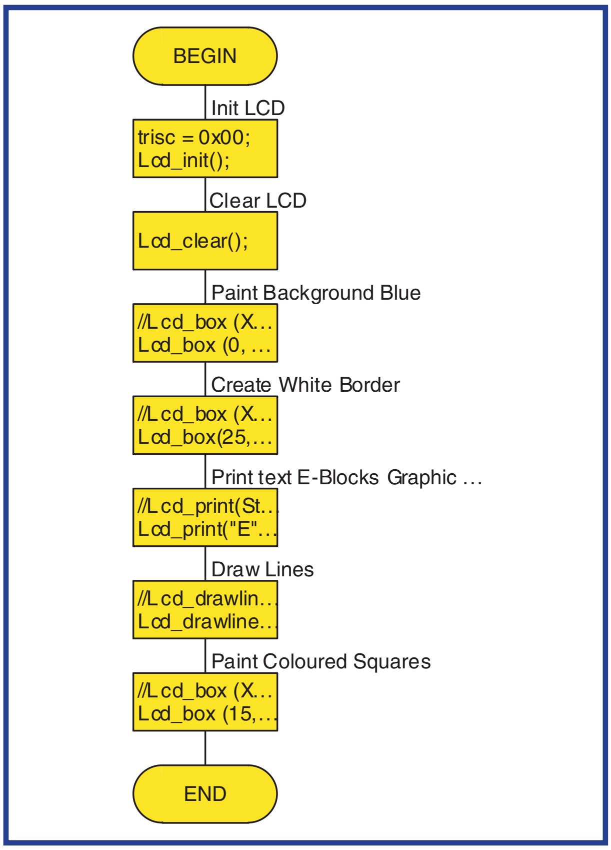


Figure 4.
Flowcode program producing the screen shown in the introductory photograph.

Listing 2. LCD demo program (example)

```
Lcd_init();
Lcd_clear();
Lcd_box (0, 0, 131, 131, BLUE);
Lcd_box(25,20,106,65,WHITE);
Lcd_print("E", 3, 2, 2, BLACK, WHITE, 1);
Lcd_print("-BLOCKS", 8, 2, 1,
   BLACK, WHITE, 7);
Lcd_print("Graphic LCD", 5, 6,
   0, BLACK, WHITE, 11);
Lcd_drawline (25, 67, 106, 67, BLACK);
Lcd_drawline (20, 69, 111, 69, BLACK);
Lcd_drawline (15, 71, 116, 71, BLACK);
Lcd_box (15, 90, 35, 110, RED);
Lcd_box (35, 90, 55, 110, YELLOW);
Lcd_box (55, 90, 75, 110, GREEN);
Lcd_box (75, 90, 95, 110, ORANGE);
Lcd_box (95, 90, 115, 110, BRIGHTBLUE);
```

Hexadoku

Puzzle with an electronic touch

For the month of May we've prepared a fresh Hexadoku puzzle for you to solve with brain power only! As before, there are fine prizes on offer: an E-blocks Professional Starter kit and three Elektor SHOP vouchers.

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

The puzzle is also available as a **free download** from our website (Magazine → 2007 → March).

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

(c) PZZL.com

Participate!

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

editor@elektor-electronics.co.uk
Subject: hexadoku 05-2007.

Alternatively, by fax or post to:

Elektor Electronics Hexadoku
Regus Brentford
1000 Great West Road
Brentford TW8 9HH
United Kingdom.
Fax (+44)(0)208 2614447

The closing date is
1 June 2007.

The competition is not open to employees of Segment b.v., its business partners and/or associated publishing houses.

Prize winners

The solution of the March 2007 Hexadoku is: **CA9F0**.

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

Patrick Leary (UK).

An **Elektor SHOP voucher worth £35.00** goes to:

Leo Hallbäck (N);

George Leith (UK);

Birger Egner (S).

Congratulations everybody!

Solve Hexadoku and win!

Correct solutions received enter a prize draw for an

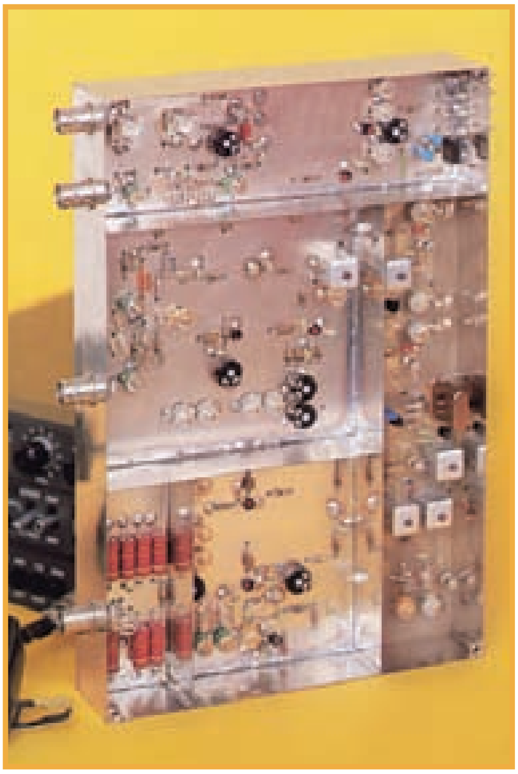
E-blocks Starter Kit Professional

worth **£248.55**

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

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

Transverter for the 70cm band (1981)



Jan Buiting

Designs for transverters are typically published when (1) a new frequency band is allocated to licensed radio amateurs and/or (2) big Japanese companies like Yaesu, Kenwood and Icom think the band is exotic and best left to a dozen or so half-witted experimenters. Six metres (50 MHz) is an example of a band that was 'Icom-free' for a number of years after it became available. 10 GHz (3 cm) is still totally free from Japanese plug & talk boxes and a great band for true experimenters.

'Transverter' is an acronym for (I think) transmitting/receiving-converter. A home-made transverter is used in combination with an existing shortwave or VHF rig to give access to a band you dif not have previously. The one for the 70 cms band (430-440 MHz) published in two parts in Elektor June and October 1981, is a fine example of a publication aimed at radio amateurs not willing to pay the exorbitant prices of commercial equipment available at the time. The same radio enthusiasts simply wanted SSB (single sideband) on 70 cms the way they had been able to enjoy it on shortwave as well as 2 m (144-146 MHz) for many years. As opposed to FM, SSB is a 'linear mode' requiring good linearity of all transmitter stages right up to the antenna connector. Good all-mode transceivers being available at the time for 2 m band, the designer of the Elektor 70 cm transverter, J. de Winter PE0JPW, went for the '288-MHz' concept, which means that a signal received on 432 MHz is downconverted to 144 MHz, but a 144-MHz transmitter signal of a few watts gets up-converted to 432 MHz via 374.4 MHz. The front cover of the June 1981 issue proudly showed an Icom IC211 2-m all mode transceiver in combination with the transverter in its tin-plate enclosure. Unfortunately, no finished example of the transverter has survived so I was unable to put it through its paces, or indeed print a photograph of the real thing.

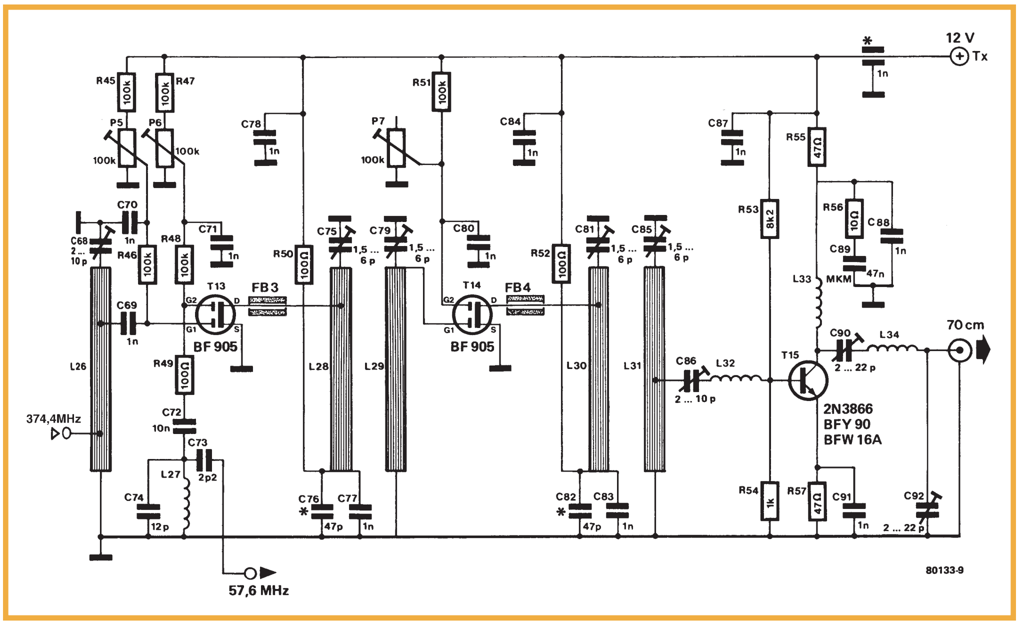
During the early 1980s, the 70 cm band had a particular attraction, not just for as a meeting place for amateurs with 100% home built equipment (including amateur television — ATV), but also for satellite communications that enabled cross-continental QSOs in CW and SSB, all using relatively low transmit powers (but highly directional antennas).

The June 1981 instalment of the article discussed in some detail the advantages of using a 2-m rig and 288-MHz RX down mixing over other much more complex transverter concepts based on intermediate frequencies like 336 MHz and 374 MHz for RX **and** TX. It also explained the need for a quartz crystal with an unusually high frequency (at the time!) of 57.6 MHz for the oscillator, mainly to prevent unwanted signals from the ×5 multiplier section supplying the 288-MHz injection signal to the mixer. Spectrum analyser screens were printed to prove the concept.

25 years ago, the transverter originally submitted by the author was Elektorised by senior designer Gerrit Dam PA0HKD and Ed Warnier PE1CJP (now PA1EW), the latter doing his apprenticeship with the company. The two ensured that the design was reproducible by Elektor readers as well as compliant with legal requirements in terms of harmonics and spurious signal levels. Gerrit (now retired) and Ed (now working as an RF maintenance engineer) remember that putting the design on a PCB (to Elektor standards) was a major headache at the time as they had to struggle not just with 'spurious' from the 288-MHz exciter section but also with PCB design staff quite unused to the vagaries of 400-MHz signals (but comfortable with 'DC stuff' like audio, microcontrollers and PSUs). In the end, they killed two (or was it three?) flies with one stroke by the use of micro-stripline inductors etched on the board. The third fly was known as Mr. Can't-wind-me-own-coils, and much dreaded in Elektor's Technical Queries department.

(075053-I)

Scans of the original article instalments from 1981 are available free of charge from the Elektor website.



ELEKTOR SHOWCASE

To book your showcase space contact Huson International Media

Tel. 0044 (0) 1932 564999 **Fax 0044 (0) 1932 564998**

ATC SEMITEC LTD

www.atcsemitec.co.uk

Thermal and current-sensitive components for temperature control and circuit protection;

- NTC Thermistors
- Current Diodes
- Thermostats
- Re-settable Fuses
- Thermal Fuses
- Temperature Sensors

Call today for free samples and pricing

Tel: 01606 871680 Fax: 01606 872938

AVIT RESEARCH

www.avitresearch.co.uk

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

See our webpage for more details. From £15.00.

BAEC

http://baec.tripod.com

"The British Amateur Electronics Club Archive Website. Archiving extracts from 140+ Newsletters from 1966-2002. Currently have interesting and useful selected articles from 12 Newsletters. Also a section about built electronics projects with schematics and photos. Plus useful info., downloads and links. NO ADVERTS!"

BETA LAYOUT

www.pcb-pool.com

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

EasyDAQ

www.easydaq.biz

We design & supply low cost USB/RS232 based data acquisition, automation & control products:

- USB connected & powered, 8 opto isolated voltage inputs chans, 4DIO & 4 onboard relays capable of switching 240V@10A. With Labview, VC & VB examples - £60

EASYSYNC

http://www.easysync.co.uk

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

ELNEC

www.elnec.com

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

FIRST TECHNOLOGY TRANSFER LTD.

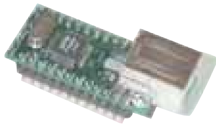
http://www.ftt.co.uk/PICProTrng.html

Microchip Professional C and Assembly Programming Courses.
The future is embedded.
Microchip Consultant / Training Partner developed courses:

- Distance learning / instructor led
- Assembly / C-Programming of PIC16, PIC18, PIC24, dsPIC microcontrollers
- Foundation / Intermediate

FUTURE TECHNOLOGY DEVICES

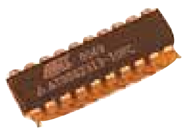
http://www.ftdichip.com



FTDI designs and sells USB-UART and USB-FIFO interface i.c.'s.
Complete with PC drivers, these devices simplify the task of designing or upgrading peripherals to USB

FUTURLEC

http://www.futurlec.com



Save up to 60% on

- Electronic Components
- Microcontrollers, PIC, Atmel
- Development Boards, Programmers

Huge range of products available on-line for immediate delivery, at very competitive prices.

LONDON ELECTRONICS COLLEGE

http://www.lec.org.uk

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

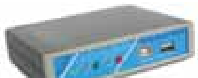
MODular ElecTRONics

www.modetron.com

- Plug and Program
- FREE application s/w
- Hobbyist ease-of-use
- Professional finish with enclosure and LEXAN faceplate
- We will design and brand your custom application
- Growing range of PSU's, i/o modules, displays and microcontrollers

MQP ELECTRONICS

www.mqp.com



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

NEW WAVE CONCEPTS

www.new-wave-concepts.com

Software for Hobbyists:

- Livewire - circuit simulation software, only £34.99
- PCB Wizard - PCB design software, only £34.99
- Circuit Wizard - circuit, PCB and breadboard design software, only £59.99

Available from all Maplin Electronics stores and www.maplin.co.uk

PCB WORLD

http://www.pcbworld.org.uk

World-class site: Your magazine project or prototype PCB from the artwork of your choice for less. Call Lee on 07946 846159 for details. Prompt service.

ROBOT ELECTRONICS

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

Advanced Sensors and Electronics for Robotics

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

SYTRONIC TECHNOLOGY LTD

www.m2mtelemetry.com

Supplier of wireless modules and accessories for remote monitoring M2M applications.

- GSM/GPRS TCP/IP modules
- Embedded GSM/GPRS modem
- Development Kits
- GPS modules
- GSM/GPS antennas
- Adapter cables

Online ordering facilities.

Tel: 01728 685802

VIRTINS TECHNOLOGY

www.virtins.com

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

SOURCEBOOST TECHNOLOGIES

http://www.sourceboost.com

Next generation C compiler and development products at highly affordable prices:

- C, C++, and Basic compilers for PIC12, PIC16, PIC18
- Modern IDE, with PIC simulator, source level debugger and virtual devices.
- RTOS for PICmicro.
- PIC based controller and Development boards.
- Download and try for Free from http://www.sourceboost.com

ULTRALEDS

http://www.ultraleds.co.uk

tel: 0871 7110413 / 01625 576778

Large range of low cost Ultra bright leds and Led related lighting products. Major credit cards taken online with same day depatch.

USB INSTRUMENTS

http://www.usb-instruments.com

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

www.elektor-electronics.co.uk

SHOWCASE YOUR COMPANY HERE

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

- For just £220 + VAT (£20 per issue for eleven issues) Elektor will publish your company name, website address and a 30-word description
- For £330 + VAT for the year (£30 per issue for eleven issues) we will publish the above plus run a 3cm deep full colour image - e.g. a product shot, a screen shot from your site, a company logo - your choice

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

I wish to promote my company, please book my space:
• Text insertion only for £220 + VAT • Text and photo for £330 + VAT

NAME:..ORGANISATION: ....

JOB TITLE:..

ADDRESS:..

....

....TEL: ....

PLEASE COMPLETE COUPON BELOW AND FAX BACK TO 00-44-(0)1932 564998

COMPANY NAME ....

WEB ADDRESS..

30-WORD DESCRIPTION..

....

....

....

....

elektor SHOP

Order now using the Order Form in the Readers Services section in this issue.

Elektor Electronics (Publishing)
Regus Brentford
1000 Great West Road
Brentford TW8 9HH
United Kingdom

Telephone +44 208 261 4509
Fax +44 208 261 4447
Email: sales@elektor-electronics.co.uk

More information on www.elektor-electronics.co.uk

CD-ROM BESTSELLERS

1 Elektor 2006

NEW

This CD-ROM contains all editorial articles published in Elektor Electronics Volume 2006. Using the supplied Acrobat Reader program, articles are presented in the same layout as originally found in the magazine. All free, printed, supplements our readers got last year, like the Visual Basic, C and i-TRIXX booklets are also contained on the CD. The Elektor Volume 2006 CD-ROM has a rather different look and feel than previous editions. It's gone through a makeover in more than one way!

ISBN 978-90-5381-207-5 | **£16.25 (US$ 28.75)**

2 USB TOOLBOX

This CD-ROM contains technical data about the USB interface. It also includes a large collection of data sheets for specific USB components from a wide range of manufacturers. There are two ways to incorporate a USB interface in a microcontroller circuit: add a USB controller to an existing circuit, or use a microcontroller with an integrated USB interface. Included on this CD-ROM are USB Basic Facts, several useful design tools for hardware and software, and all Elektor Electronics articles on the subject of USB.

ISBN 978-90-5381-212-9 | **£18.95 (US$ 34.95)**

3 Home Automation

This CD-ROM provides an overview of what manufacturers offer today in the field of Home Networking, both wired and wireless. The CD-ROM contains specifications, standards and protocols of commercially available bus and network systems. For developers, there are datasheets of specific components and various items with application data. End-users and hobbyists will find ready-made applications that can be used immediately.

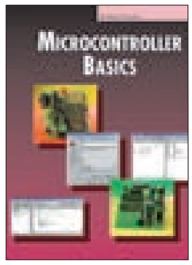
ISBN 978-90-5381-195-5 | **£12.95 (US$ 22.90)**

Visual Basic
for Electronics Engineering Applications

This book is targeted towards those people that want to control existing or home made hardware from their computer. After familiarizing yourself with Visual Basic, its development environment and the toolset it offers are discussed in detail. Each topic is accompanied by clear, ready to run code, and where necessary, schematics are provided that will get your projects up to speed in no time.

ISBN 978-0-905705-68-2
476 Pages
£27.50 (US$ 51.50)

Microcontroller Basics



Microcontrollers have become an indispensable part of modern electronics. They make things possible that vastly exceed what could be done previously. Innumerable applications show that almost nothing is impossible. There's thus every reason to learn more about them. This book offers more than just a basic introduction. It clearly explains the technology using various microcontroller circuits and programs written in several different programming languages. In the course of the book, the reader gradually develops increased competence in converting his or her ideas into microcontroller circuitry.

ISBN 978-0-905705-67-5
230 Pages
£18.70 (US$ 33.70)

BESTSELLING BOOKS Top-5

1. **Visual Basic for Electronics Engineering Applications**
   ISBN 978-0-905705-68-2 **£27.50 (US$ 51.50)**
2. **Microcontroller Basics**
   ISBN 978-0-905705-67-5 **£18.70 (US$ 33.70)**
3. **PC-Interfaces under Windows**
   ISBN 978-0-905705-65-1 **£25.95 (US$ 52.00)**
4. **Designing Audio Circuits**
   ISBN 978-0-905705-50-7 **£20.75 (US$ 42.00)**
5. **Modern High-end Valve Amplifiers**
   ISBN 978-0-905705-63-7 **£25.95 (US$ 52.00)**

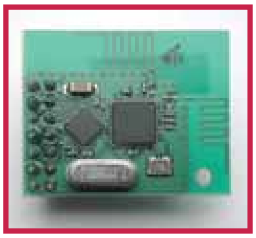
More bestsellers on www.elektor-electronics.co.uk

elektor SHOP

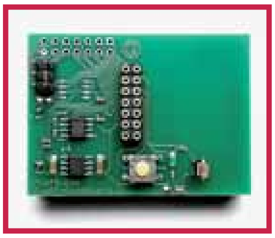
Order o
www.elektor-el

Order now using the Order Form in the Readers Services section in this issue.

Wireless USB in miniature
(March 2007)



iDwarf -168 Transmitter module (built & tested)
050402-91
£ 24.10 / US$ 45.45



iDwarf Node Board (built & tested)
050402-91
£ 17.20 / US$ 32.45

iDwarf Hub Board (built & tested)
050402-93
£ 17.20 / US$ 32.45

g-Force on LEDs
(April 2007)

PCB set, bare,
incl. 2 MMA7260 sensors,
BDM cable parts

060297-71
£ 10.00 / US$ 18.85

USB Stick with ARM and RS232
(November 2006)

Assembled and tested board

060006-91
£ 79.90 / $ 149.95

No. 365 MAY 2007

		£	$
Software Defined Radio			
070039-91	Ready-populated and tested board	72.45	126.50
070039-11	CD-ROM, project software	5.20	9.75
Thank your for Flying USB FliteSim			
060378-1	PCB, bare	www.thepcbshop.com	
060378-41	PIC18F2550I/SP, programmed	15.50	29.25
Universal JTAG Adaptor			
060287-1	PCB, bare, with programmed microcontroller	11.00	20.75
060287-41	EP900LC only, programmed	P&P only	P&P only
Magnetometer			
050276-1	PCB, bare	www.thepcbshop.com	
Speedmaster			
070021-91	Ready-populated and tested board (excl. R8C module)	51.70	97.45
Seismograph			
060307-1	PCB, bare	www.thepcbshop.com	
060307-11	CD-ROM, project software	5.20	9.75
060307-41	ATTiny45,programmed	10.35	19.50
ATtiny as RDS Signal Generator			
060253-41	Attiny2313-20, programmed	4.20	7.80

No. 364 APRIL 2007

		£	$
Battery Charge-n-Check			
050073-1	PCB, bare, main board	10.30	19.50
050073-2	PCB, bare, display board	10.30	19.50
050073-11	CD-ROM, project software	5.20	9.75
050073-41	ST7FMC2S4, programmed	16.90	31.85
g-Force on LEDs			
060297-71	PCB set, incl. 2 MMA7260 sensors, BDM cable parts	10.00	18.85
060297-11	CD-ROM, project software	5.20	9.75
Programmer for Freescale 68HC(9)08			
060263-1	PCB, bare	www.thepcbshop.com	
A Simple Mains Inverter			
060171-1	PCB, bare	www.thepcbshop.com	
Very Simple Clock			
060350-1	PCB, bare	www.thepcbshop.com	

		£	$
E-blocks Light Chaser Squared			
075032-1	PCB, bare	www.thepcbshop.com	

No. 363 MARCH 2007

		£	$
Attack of the SpYder			
060296-91	SpYder Discovery Kit	6.45	12.70
AVR drives USB			
060276-1	PCB, bare	10.00	18.85
060276-11	CD-ROM, project software incl. source code	5.20	9.75
060276-41	ATmega32-16PC, programmed	8.95	16.85
Wireless USB in Miniature			
050402-1	PCB, bare, iDwarf prototyping board	8.30	15.60
050402-91	iDwarf -168 Transmitter module (built & tested)	24.10	45.45
050402-92	iDwarf Node Board (built & tested)	17.20	32.45
050402-93	iDwarf Hub Board (built & tested)	17.20	32.45
Mobile Phone LCD for PC			
060184-1	PCB, bare	www.thepcbshop.com	
060184-11	CD-ROM, project software	5.20	9.75
060184-41	ATmega16-16PC, programmed	8.95	16.85
Scale Deposit Fighter			
070001-1	PCB, bare	www.thepcbshop.com	

No. 362 FEBRUARY 2007

		£	$
... 3, 2, 1 Takeoff!			
050238-1	Transmitter PCB, bare	www.thepcbshop.com	
050238-2	Receiver PCB, bare	www.thepcbshop.com	
MP3 Preamp			
060237-1	PCB, bare	www.thepcbshop.com	
A Telling Way of Telling the Time			
050311-1	PCB, bare	www.thepcbshop.com	
050311-31	CPLD, programmed	35.50	66.95
FPGA Course (9)			
060025-9-11	CD-ROM, course software incl. source code	5.20	9.75
Explorer-16 Value Pack			
060280-91	Four components packaged together in a single box	122.90	232.50

nline at
ectronics.co.uk

Due to practical constraints, final illustrations and specifications may differ from published designs. Prices subject to change. See www.elektor-electronics.co.uk for up to date information.

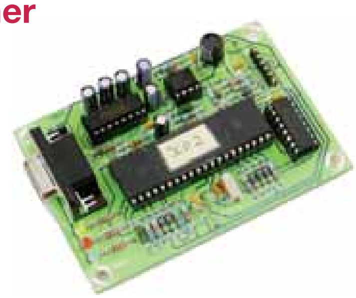
Elektor Electronics (Publishing)
Regus Brentford
1000 Great West Road
Brentford TW8 9HH
United Kingdom
Tel.: +44 (0) 208 261 4509
Fax: +44 (0) 208 261 4447
Email: sales@elektor-electronics.co.uk

Kits & Modules

PIC In-Circuit Debugger/Programmer

(October 2006)

Kit of parts including PCB, programmed controller and all components.



050348-71

£ 34.50 / $ 64.95

GameBoy ElectroCardioGraph

(October 2006)

PCB, ready built and tested

050280-91

£ 55.20 / $ 103.95

Elektor RFID Reader

(September 2006)

Ready-built and tested PCB with USB port for connection to the PC. Including USB cable; not including display and enclosure.

- Read and write 13.56 MHz RFID cards
- MIFARE and ISO 14443-A compatible
- Programmable

060132-91

£ 41.50 / $ 77.95

LC display

030451-72

£ 7.25 / $ 13.65

Matching enclosure

060132-71

£ 8.90 / $ 16.85

CD-ROM (all project software)

060132-81

£ 5.20 / $ 9.75

No. 361 JANUARY 2007		£	$
Sputnik Time Machine			
050018-1	PCB	www.thepcbshop.com	
050018-11	CD-ROM, project software (incl. source code)	5.20	9.75
050018-41	AT89C2051, programmed	3.40	6.45
Very Simple Clock			
060350-1	PCB	www.thepcbshop.com	
060350-11	CD-ROM, project software (incl. source code)	5.20	9.75
060350-41	PIC16F628-20, programmed	5.50	10.35
FPGA Course (8)			
060025-8-1	Software (incl. source code)	5.20	9.75
No. 360 DECEMBER 2006			
Shortwave Capture			
030417-1	PCB, bare (receiver board)	www.thepcbshop.com	
030417-2	PCB, bare (control & display boards)	www.thepcbshop.com	
030417-41	AT90S8515-8PC, programmed	11.40	21.45
No. 359 NOVEMBER 2006			
USB Stick with ARM and RS232			
060006-1	PCB, bare	11.00	20.75
060006-41	AT91SAM7S64, programmed	27.60	51.95
060006-91	Assembled & tested board	79.90	149.95
060006-81	CD-ROM, all project software	5.20	9.75
No. 358 OCTOBER 2006			
PIC In-Circuit Debugger/Programmer			
050348-1	PCB	5.20	9.75
050348-41	PIC16F877, programmed	17.90	33.75
050348-71	Kit, incl. PCB, controller, all parts	34.50	64.95
GBECG – Gameboy ElectroCardioGraph			
050280-91	PCB, ready built and tested	55.20	103.95
ECG using a Sound Card			
040479-1	PCB	5.20	9.75
040479-81	CD-ROM, all project software	5.20	9.75
No. 357 SEPTEMBER 2006			
Elektor RFID Reader			
060132-91	PCB, ready assembled & tested, with USB cable	41.50	77.95
030451-72	Standard back-lit LC display	7.25	13.65
060132-71	Matching enclosure	8.90	16.85
060132-81	CD-ROM, all project software	5.20	9.75
Experimental RFID Reader			
060221-11	Disk, all project software	5.20	9.75
060221-41	ATmega16, programmed	8.90	16.85
DiSEqC Monitor			
040398-11	Disk, PIC source & hex code	5.20	9.75
040398-41	PIC16F628A-20/P, programmed	5.50	10.35
USB/DMX512 Converter			
060012-11	Disk, all project software	5.20	9.75
060012-41	PIC16C745, programmed	6.90	12.95
No. 356 JULY/AUGUST 2006			
RC Servo Tester/Exerciser			
040172-11	Disk, project software	5.20	9.75
040172-41	PIC16F84(A), programmed	10.30	19.40
040172-71	Kit, incl. PCB, controller, all parts	22.70	42.85
LED Thermometer			
030190-11	Disk, project software	5.20	9.75
030190-41	PIC16F873-20/SP, programmed	16.50	31.00
Toothbrush Timer			
050146-11	Disk, project software	5.20	9.75
050146-41	AT90S2313-10PC, programmed	6.90	12.95
Easy Home Control			
050233-11	Disk, project software	5.20	9.75
050233-41	PIC16F84, programmed	10.30	19.40
Universal LCD Module			
050259-11	Disk, project software	5.20	9.75
050259-41	AT90S2313, programmed	6.90	12.95
1-Wire Thermometer with LCD			
060090-11	Disk, project software	5.20	9.75
060090-41	PIC16F84A-04CP, programmed	10.30	19.40

Products for older projects (if available) may be found on our website www.elektor-electronics.co.uk

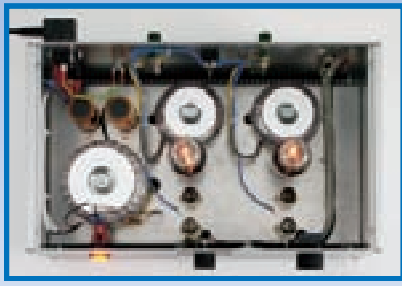
home construction = fun and added value

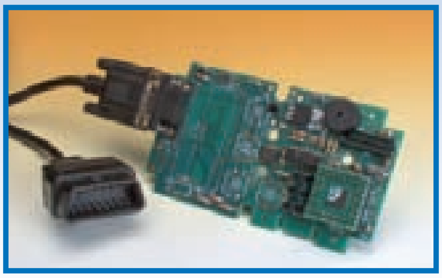
Market overview: Portable Multimeters with a Serial Interface

The great thing about multimeters with a serial interface is that they allow readings taken in the lab and on the road to be stored and processed on a computer. Datalogging, temperature and fault recording are just a few applications that come to mind. In this article, we cover the meter's possibilities and specs as well as the associated software.

Class-A Triode Push-Pull Amplifier

This year marks the 100th anniversary of Lee deForest's invention of the triode valve. Fittingly and with a bit of nostalgia, we present a triode amp that's cheap and easy to build. The design is based on 6AS7 valves in push-pull class-A configuration supplying an output power of 2 x 9 watts. A special feature of the amplifier is its switchable feedback, allowing you to select the best response for a music genre or volume setting.





Stand-alone OBD-2 Analyser

After the resounding success of the computer-linked OBD-2 analysers published in *Elektor Electronics* we now give you a stand-alone version. Compared to its predecessor, the new design has lots more features, is more compact and easier to build, not forgetting that it supplies error descriptions on the display, instead of just codes.

Also...

Digital Inductance Meter;
2.4 GHz WiFi Spectrum Analyser;
Web Oscilloscope;
New Fingerprint Sensors;
Hexadoku.

RESERVE YOUR COPY NOW!

UK mainland subscribers will receive the magazine between 24 and 27 February 2007.

The June 2007 issue goes on sale on Thursday 24 May 2007 (UK distribution only).
Article titles and magazine contents subject to change, please check www.elektor-electronics.co.uk.

NEWSAGENTS ORDER FORM

SHOP SAVE / HOME DELIVERY

Please save / deliver one copy of *Elektor Electronics* magazine for me each month

Name: . . . .
Address: . . . .
Post code: . . . .
Telephone: . . . .
Date: . . . .
Signature: . . . .

elektor electronics leading the way

Please cut out or photocopy this form, complete details and hand to your newsagent.
Elektor Electronics is published on the third Thursday of each month, except in July.
Distribution S.O.R. by Seymour (NS).

.elektor-electronics.co.uk www.elektor-electronics.co.uk www.elektor-electronics.c

Elektor Electronics on the web

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

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

Also on the Elektor Electronics website:

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

Order Form 05-2007

Please supply the following. For PCBs, front panel foils, EPROMs, PALs, GALs, microcontrollers and diskettes, state the part number and description; for books, state the full title; for photocopies of articles, state full name of article and month and year of publication.
PLEASE USE BLOCK CAPITALS.

Description	Price each	Qty.	Total	Order Code
CD-ROM Elektor 2006 NEW	£ 16.25			
CD-ROM USB Toolbox	£ 18.95			
Visual Basic for Electronics Engineering Applications	£ 27.50			
	Sub-total			
	P&P			
	Total paid			

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

Name

Address + Post code

Tel. *Email*

Date – – 2007 *Signature*

EL05

METHOD OF PAYMENT
(see reverse before ticking as appropriate)

- ☐ **Bank transfer**
- ☐ **Cheque** (UK-resident customers ONLY)
- ☐ **Giro transfer**
- ☐ VISA / MasterCard / JCB / Switch

Expiry date: ....

Verification code: ....

SWITCH ONLY:
Start date: ....

Issue number: ....

Please send this order form to *
(see reverse for conditions)

Elektor Electronics (Publishing)
Regus Brentford
1000 Great West Road
Brentford TW8 9HH
United Kingdom
Tel.: +44 208 261 4509
Fax: +44 208 261 4447
www.elektor-electronics.co.uk.
sales@elektor-electronics.co.uk

*USA and Canada residents may (but are not obliged to) use $ prices, and send the order form to:
Old Colony Sound Lab
P.O. Box 876, Peterborough
NH 03458-0876. Tel. (603) 924-6371, 924-6526,
Fax: (603) 924-9467
Email: custserv@audioXpress.com

Subscription Order Form 05-2007

Yes, I am taking out an annual subscription to Elektor Electronics and receive a free 1GB MP3 player.

I would like:

- ☐ **Standard Subscription (11 issues)**
- ☐ **Subscription-Plus (11 issues plus the Elektor Volume 2007 CD-ROM)**

* *Offer available to Subscribers who have not held a subscription to Elektor Electronics during the last 12 months. Offer subject to availability. See reverse for rates and conditions.*

Name

Address + Post code

Tel. *Email*

Date – – 2007 *Signature*

* *cross out what is not applicable*

EL05

METHOD OF PAYMENT
(see reverse before ticking as appropriate)

- ☐ **Bank transfer**
- ☐ **Cheque** (UK-resident customers ONLY)
- ☐ **Giro transfer**
- ☐ VISA / MasterCard / JCB / Switch

Expiry date: ....

Verification code: ....

SWITCH ONLY:
Start date: ....

Issue number: ....

Please send this order form to

Elektor Electronics (Publishing)
Regus Brentford
1000 Great West Road
Brentford TW8 9HH
United Kingdom
Tel.: +44 208 261 4509
Fax: +44 208 261 4447
www.elektor-electronics.co.uk.
subscriptions@elektor-electronics.co.uk

ORDERING INSTRUCTIONS, P&P CHARGES

Except in the USA and Canada, all orders, except for subscriptions (for which see below), must be sent BY POST or FAX to our Brentford address using the Order Form overleaf. On-line ordering: http://www.elektor-electronics.co.uk
Readers in the USA and Canada may (but are not obliged to) send orders, except for subscriptions (for which see below), to the USA address given on the order form. Please apply to Old Colony Sound for applicable P&P charges. Please allow 4-6 weeks for delivery.
Orders placed on our Brentford office must include P&P charges (Priority or Standard) as follows:
UK: £4.00 Europe: £5.00 (Standard) or £7.00 (Priority) Outside Europe: £8.00 (Standard) or £12.00 (Priority)

HOW TO PAY

All orders must be accompanied by the full payment, including postage and packing charges as stated above or advised by Customer Services staff.

Bank transfer into account no. 40209520 held by Elektor Electronics (Publishing) / Segment b.v. with ABN-AMRO Bank, London. IBAN: GB35 ABNA 4050 3040 2095 20. BIC: ABNAGB2L. Currency: sterling (UKP). Please ensure your full name and address gets communicated to us.
Cheque sent by post, made payable to Elektor Electronics (Publishing) / Segment b.v.. We can only accept sterling cheques and bank drafts from UK-resident customers or subscribers. We regret that no cheques can be accepted from customers or subscribers in any other country.
Giro transfer into account no. 34-152-3801, held by Elektor Electronics (Publishing) / Segment b.v. Please do not send giro transfer/deposit forms directly to us, but instead use the National Giro postage paid envelope and send it to your National Giro Centre.
Credit card VISA, Access, MasterCard, JCBCard and Switch cards can be processed by mail, email, web, fax and telephone. Online ordering through our website is SSL-protected for your security.

COMPONENTS

Components for projects appearing in Elektor Electronics are usually available from certain advertisers in this magazine. If difficulties in the supply of components are envisaged, a source will normally be advised in the article. Note, however, that the source(s) given is (are) not exclusive.

TERMS OF BUSINESS

Delivery Although every effort will be made to dispatch your order within 2-3 weeks from receipt of your instructions, we can not guarantee this time scale for all orders. **Returns** Faulty goods or goods sent in error may be returned for replacement or refund, but not before obtaining our consent. All goods returned should be packed securely in a padded bag or box, enclosing a covering letter stating the dispatch note number. If the goods are returned because of a mistake on our part, we will refund the return postage. **Damaged goods** Claims for damaged goods must be received at our Brentford office within 10-days (UK); 14-days (Europe) or 21-days (all other countries). **Cancelled orders** All cancelled orders will be subject to a 10% handling charge with a minimum charge of £5·00. **Patents** Patent protection may exist in respect of circuits, devices, components, and so on, described in our books and magazines. Elektor Electronics (Publishing) does not accept responsibility or liability for failing to identify such patent or other protection. **Copyright** All drawings, photographs, articles, printed circuit boards, programmed integrated circuits, diskettes and software carriers published in our books and magazines (other than in third-party advertisements) are copyright and may not be reproduced or transmitted in any form or by any means, including photocopying and recording, in whole or in part, without the prior permission of Elektor Electronics (Publishing) in writing. Such written permission must also be obtained before any part of these publications is stored in a retrieval system of any nature. Notwithstanding the above, printed-circuit boards may be produced for private and personal use without prior permission. **Limitation of liability** Elektor Electronics (Publishing) shall not be liable in contract, tort, or otherwise, for any loss or damage suffered by the purchaser whatsoever or howsoever arising out of, or in connexion with, the supply of goods or services by Elektor Electronics (Publishing) other than to supply goods as described or, at the option of Elektor Electronics (Publishing), to refund the purchaser any money paid in respect of the goods. **Law** Any question relating to the supply of goods and services by Elektor Electronics (Publishing) shall be determined in all respects by the laws of England.

January 2007

SUBSCRIPTION RATES FOR ANNUAL SUBSCRIPTION

	Standard	Plus
United Kingdom	**£41.90**	**£48.80**
Surface Mail		
Rest of the World	**£54.50**	**£61.40**
USA & Canada	**US$ 95.50**	**US$106.50**
Airmail		
Rest of the World	**£68.90**	**£75.80**
USA & Canada	**US$120.00**	**US$131.00**

HOW TO PAY

Bank transfer into account no. 40209520 held by Elektor Electronics (Publishing) / Segment b.v. with ABN-AMRO Bank, London. IBAN: GB35 ABNA 4050 3040 2095 20. BIC: ABNAGB2L. Currency: sterling (UKP). Please ensure your full name and address gets communicated to us.

Cheque sent by post, made payable to Elektor Electronics (Publishing) / Segment b.v.. We can only accept sterling cheques and bank drafts from UK-resident customers or subscribers. We regret that no cheques can be accepted from customers or subscribers in any other country.

Giro transfer into account no. 34-152-3801, held by Elektor Electronics (Publishing) / Segment b.v. Please do not send giro transfer/deposit forms directly to us, but instead use the National Giro postage paid envelope and send it to your National Giro Centre.

Credit card VISA, Access, MasterCard, JCBCard and Switch cards can be processed by mail, email, web, fax and telephone. Online ordering through our website is SSL-protected for your security.

SUBSCRIPTION CONDITIONS

The standard subscription order period is twelve months. If a permanent change of address during the subscription period means that copies have to be despatched by a more expensive service, no extra charge will be made. Conversely, no refund will be made, nor expiry date extended, if a change of address allows the use of a cheaper service.
Student applications, which qualify for a 20% (twenty per cent) reduction in current rates, must be supported by evidence of studentship signed by the head of the college, school or university faculty. A standard Student Subscription costs £33.50, a Student Subscription-Plus costs £40.40 (UK only).
Please note that new subscriptions take about four weeks from receipt of order to become effective.
Cancelled subscriptions will be subject to a charge of 25% (twenty-five per cent) of the full subscription price or £7.50, whichever is the higher, plus the cost of any issues already dispatched. Subsciptions cannot be cancelled after they have run for six months or more.

January 2007

INDEX OF ADVERTISERS

Advertising space for the issue of 25 June 2007
may be reserved not later than 29 May 2007
with Huson International Media – Cambridge House – Gogmore Lane – Chertsey, Surrey KT16 9AP – England – Telephone 01932 564 999 – Fax 01932 564998 – e-mail: gerryb@husonmedia.com to whom all correspondence, copy instructions and artwork should be addressed.