



elektor

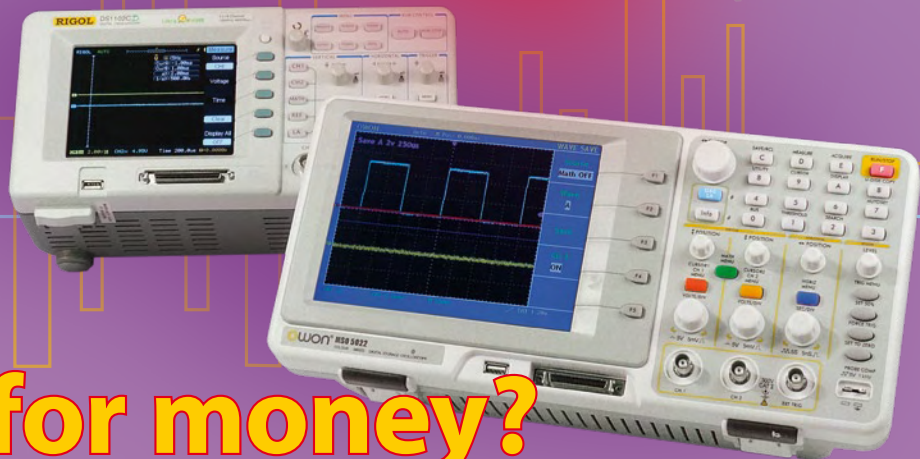
electronics worldwide

450MHZ SWEEP GENERATOR ... ATM18 RELAY BOARD ... GPS RECEIVER ... BASCOM AVR

Go with the Reflow

Elektor's **SMT Oven**
for home & lab reflow soldering
Plus everything you need to know on SMT

1
2



Value for money?

digitale **oscilloscopes**
for bargain prices



Go with the Reflow

Do-it-yourself SMD reflow oven controllers were published in the January 2006 and December 2007 issues of Elektor — and what a response they got from you! To us it was just another proof that surface mount technology (SMT), however sneaky for tininess, is 'hot' and does not stop many Elektor readers from slapping together the odd circuit using this technology. Not forgetting schools and small labs of course, which at some point will feel a compelling need to start 'baking' circuits.

Because Elektor is not your usual paper-churning publishing house we set out to find a ready-made SMT reflow oven, specifically one with improved accuracy and control as compared with a modified pizza oven, and suitable for retailing to our readers. Our quest for an apt product quickly took us into China but it was not without pitfalls like CE and RoHS approvals, flaky manuals, deep seas, high winds and customs red tape for container loads of ovens. We managed to pull it off however and proudly present the Elektor SMT Reflow Oven. It is our belief that this tool will empower many an electronics enthusiast to securely exploit SMT / SMD / SMA and provide a new impulse to his or her activities in the field of electronics.

In good Elektor tradition the use of the oven is backed up with illustrated theory and hands-on information to enable you all to master virtually every aspect of SMT assembly: workshops, magazine articles, gizmos and tools — all in the pipeline!

Alongside the heavy coverage of the SMT Oven in this issue the lab and editorial teams have again managed to produce many pages worth of projects and articles that hopefully provide an incentive to solder and assemble, learn about new products and technologies, or just while away for a few hours browsing the pages (in offices too!). There sure is something for everyone.

Wisse Hettinga
International Editor



In this cluster of articles we cover not just the ins & outs of the new Elektor SMT oven but also how to deal with those tiny components you just can't afford to ignore anymore for up to date circuit board design and manufacturing. We also cover the past and future of SMT and present a handy guide to preparing boards for reflow soldering.

Elektor SMT Precision Reflow



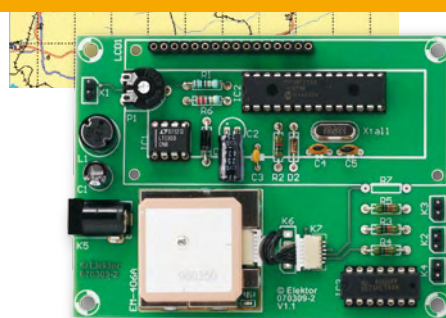
Come see us at:

- AES Convention, San Francisco, October 2-5
- Embedded Systems, Boston, October 27-30
- Audio Amateur Inc. / Elektor USA booth



34 Multi-purpose GPS Receiver

Stand-alone GPSs when teamed them up with suitable electronics can perform our positioning or navigation tasks just as accurately as manufactured products everyone seems to have in their cars recently. This article shows how to get two such devices up and running.



44 Communicating with CAN

Despite the fact that the CAN protocol is a serial protocol, it can't just be connected to (the serial port of) a computer. The all-round USB-CAN adapter described here provides a compact and simple solution!

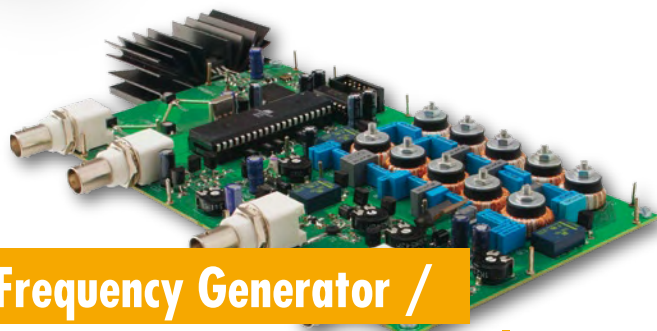


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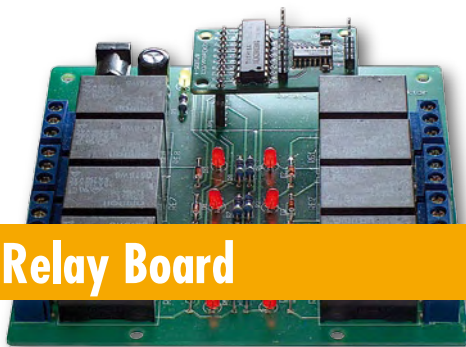


Oven 22-32



54 RF Sweep Frequency Generator / Spectrum Analyser

The instrument described in this article combines the functions of a sweep frequency generator and a spectrum analyser. In the SFG mode, it can be used to measure the frequency characteristics of selective components or circuits at frequencies up to 450 MHz.



62 ATM18 Relay Board

Now that our ATM18 project with the levitating magnet in the previous issue has become truly active, we can use a relay board to implement even more external effects.

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elektor international media

Elektor International Media provides a multimedia and interactive platform for everyone interested in electronics.

From professionals passionate about their work to enthusiasts with professional ambitions.

From beginner to diehard, from student to lecturer. Information, education, inspiration and entertainment.

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

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for home & lab reflow soldering
Plus everything you need to know on SMT

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

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Visit China with Elektor



combine electronics
and culture



Elektor's second Study Trip to China is planned for 9–18 November 2008. And you can join us! Check your diary today and visit the Elektor website for more detailed information.

During this 10-day trip we will visit the China Electronics Fair in Shanghai, a professional industrial electronics fair with an area of no less than 60,000 m². We will also pay at least one visit to the well-known 'electronics high street' in Shanghai. As the name suggests, this street is entirely dedicated to electronics shops, each vying to be the largest. In addition, a variety of interesting company visits are on the itinerary (with a tour of the production department). We are also organising a business conference where you can obtain a wealth of information about doing business (and how not to do business) in China. Naturally, there's also time for culture. We will visit the Forbidden City, Tiananmen square, Beijing Olympic Stadium and the Great Wall.

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Places are strictly limited

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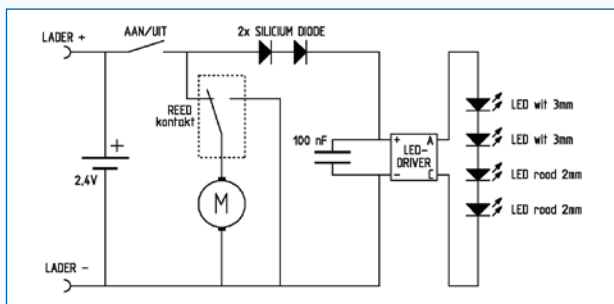
Printed in the Netherlands

Free LED Driver

Dear Editor — I've been an Elektor subscriber for over 30 years and still enjoy every copy. The September 2007 issue came with a free LED driver board, and in the accompanying article I read that the board could be used with several LEDs in series. Being a model railway enthusiast, it struck me that that the little board might be used for by Falter coach model. The coach contains a 2.4-V battery (2 off 1.2 V rechargeables) I thought I could use for vehicle lighting comprising four LEDs.

After a few quick tests the circuit worked just fine with four LEDs, however the 2.4-volt supply voltage caused start failures on occasions. I lowered the supply using two diodes and then the circuit worked perfectly. The schematic shows the complete circuit of the coach with the LED driver and the LEDs and the photo shows the results. Thanks for the board I got from you at no charge.

Fred van Etteger (Netherlands)



A brilliant application, Fred, thanks for that. However, two diodes in series to reduce the driver supply voltage seems wasteful — one diode would be tight on the maximum supply voltage, so it all looks quite critical. It may be an idea to connect two LED drivers in series, although admittedly we have not tried this ourselves.

Ring Flash

Dear Elektor — from an old tech, a big "thank you guys" for a consistently excellent magazine.

The Ringflash article (February 2008) is really inspiring, however there two minor

errors on the circuit for the Kodak disposable flash, Fig. 1 on page 52.

- the label for the 300 Volts output should read V- Flash (300 V). The inverter section is negative-ground, but like many of these units the high-volt-

age section is positive-ground — the main electrolytic is shown correctly.

- in the (discarded) trigger section, what is shown as the second neon, NE2, is in fact the (300>350V!) shutter flash trigger contacts.

When I asked the local photo processor for a used disposable camera I had twenty forced on me! Several different brands! There is considerable variation in physical form, circuit, quality, and accessibility, with the Kodak being one of the better and more common. This pile contains not only working flash units; but at least, an almost fresh alkaline AA battery, a LED or neon, a 350 V low-ESR electrolytic of 80 to 160 μ F, one 22 nF/350V, and a high-voltage diode, etc.; plus several different lenses, and some springs. This trove will help considerably with my next valve guitar amp build.

Application of a hot-air paint-stripping gun to a few old computer boards has yielded a snowstorm of useful components; dead PC power supplies (also available free) have 80 to 90% recoverable components, and the cases make good project platforms. What do you do with the hands-free set, squashed \$600 digital camera, and 1 GByte flash drive you found in the street?

And all this normally goes into landfill rather than recycling — what a terrible everyday waste of useful electronic stuff, free for the asking.

Roly Roper (Australia)

As you may have gathered from the 'Modding & Tweaking' series of articles by various authors, we also enjoy taking apart the odd bit of defunct electronics, if only out of curiosity how stuff can be made so cheaply. When I was young I picked up the odd TV set or radio from the street before garbage collection day. This 'grot' as my parents called it, actually provided a good stock of electronic components to reuse in my own projects.

Compact fluorescent lamps (2)

Dear Sir — I read with great interest the letter by Andrew Denham on Compact Fluorescent lamps (Mailbox, May 2008). I would like to add two things to the discussion on this CFLs and light sources.

I would like to see a dimmable CFL system. I have used special dimmers and chokes to control 'normal' fluorescent tubes with mediocre results. For CFLs, a special wall dimmer that signals to the lamp's control electronics would need to be designed to replace the standard phase control dimmer unit.

There is a new light source available: the Luxim Plasma Light. The LIFITM is a pill-sized plasma light with an output of some 140 lumens per watt. Further information may be found at:

www.lifi.com/pdfs/TechBriefHowLIFIWorks.pdf
The review by Treehugger is also worth mentioning: www.treehugger.com/files/2008/04/luxim-plasma-lifi-light-bulb-led-cfl.php
I hope that my comments are of interest.

Ian Goodall (UK)

Very useful remarks and additions there Ian, many thanks.

Wiring up

Dear Editor — now over 40 years ago I managed without too much of a problem to wire up a control panel for controlling the then cutting edge technology of the teleprinter network and needing some 2240 separate wires and some 120 control switches. As far as I remember I only made one wiring error and that took all of 30 minutes to put right. I now want to use the output of a computer mouse or similar to drive a display to show the movement of the table on a milling machine in my workshop. I did have the absurd thought that by simply walking to a specialist dealer and asking for bits that would

work together I could with only minimum difficulty arrive at the right set of components. This it now looks is impossible no one publishes in any form a list or book saying the output of which component will be okay as the input to the next component in the chain. In my case the output of the mouse or coder will be okay as an input to the driver for the display. Could either you or another reader please let me in on the secret of how it is done? With the vast quantity of various components available in the market place it would take for ever to line up the various parameters!

Phil Pumphrey (UK)

Yes Phil the days of simple electronics seem to have vanished 'not with a bang, but a whisper' to quote a great poet. If readers are able to help Phil, write to the Editor, please.

Improving the Mugen amplifier

Dear Editor — I believe the linearity of cathode follower V2a in the Mugen amplifier (*Elektor* October 2007, *Ed.*) may be improved by connecting the lower end of R7 (22kΩ) to output of the amplifier (junction 21,22) instead of to ground. The modification enables R7 to function as a real current source, reducing the current fluctuations in the ECC88. The result is better cathode tracking and reduced distortion.

Guido Tent (Netherlands)

Thanks for the tip Guido, we spread the word and hope Mugen constructors will find it useful.

SAPS-400

Dear Elektor — this is to express my disappointment with the article on the SAPS-400 power supply published in the June 2008 issue of *Elektor*. Firstly, the supply has no power factor correction (PFC) hence does not reflect state of the art technology, especially for such high power. Secondly, a components list and detailed construction guidance is missing.

The article says "There are many more considerations to be kept in mind during the design, such as Eddy currents, varnishing to avoid vibration or mechanical noises, etc, but these fall out of the scope of this description." This seems somewhat contradictory to me as you first mention the aspects to be taken into consideration and then decide not to describe them in detail. This makes me wonder about the purpose of publishing the article as it looks like a description of a commercial item for sale only.

J.H. Stil (Netherlands)

Sorry to read you did not like the article. Others did, and we tried to make it as interesting as possible for our wide readership. Concerning the PFC aspect, the author's research indicates that many changes in equipment classification were implemen-

ted in 2004. PFC is only required in Class D equipment and no longer in Class A which covers audio gear. Class-A and Class-D, by the way, are not related to the design of the amplifier.

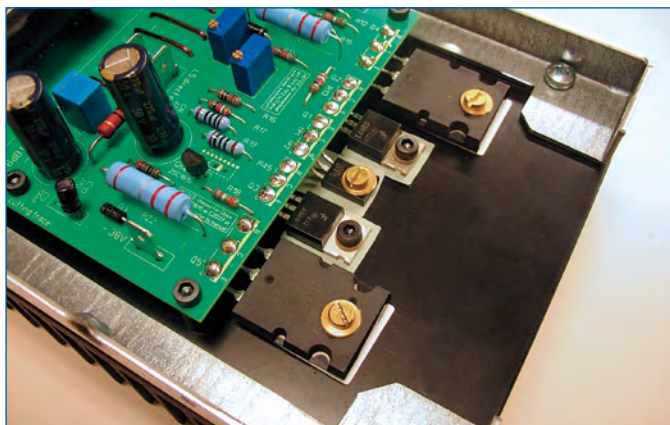
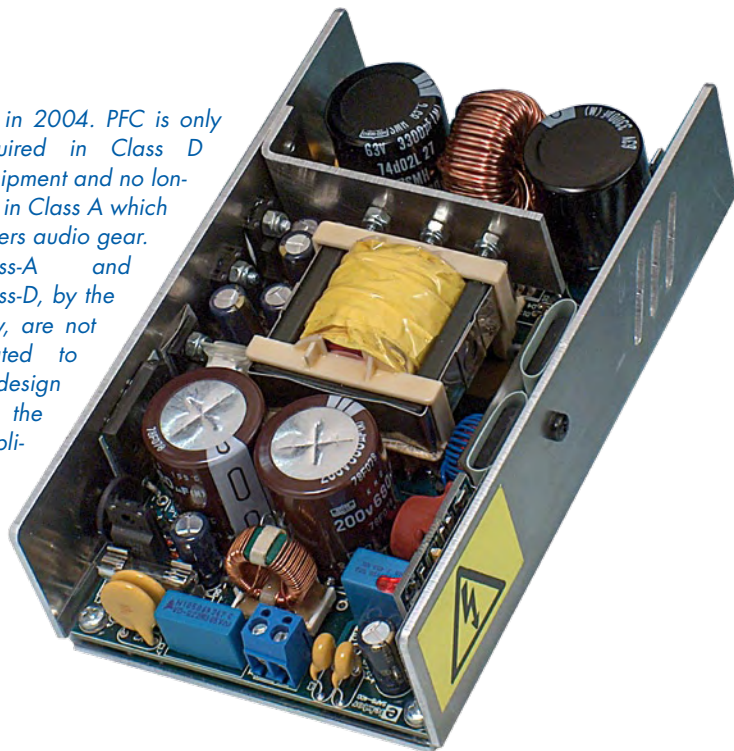
Consequently there is no legal requirement to provide for PFC in the SAPS-400 — and even if it were, it would only apply to equipment with a total power exceeding 75 watts. The effective power of audio equipment is taken as 1/8th of the maximum power, i.e. 50 watts in the case of the SAPS-400 and well below the limit. None the less, PFC may be implemented in future versions of the supply.

There is no parts list as arguably this project is not suitable for home construction from parts. The custom wound transformers and other special components are hard to obtain as one-offs and even a kit of parts would cost more than the ready-assembled module. Besides, there are also electrical safety aspects to consider. Details on incorporating the unit in equipment are included with the module, as well as available online from our website, together with some measurement results.

The purpose of the text you quote from the article is to indicate just a few of the many aspects to be duly considered during design and test. The accompanying article 'Cool Power' and the free supplementary document from or website provide in-depth discussions of the problems and pitfalls when designing an SMPSU for the specific purpose of

powering audio amplifiers. The intention of the three articles is to explain the operation of the main circuit in the supply, discussing options available for designing a switch-mode power supply and providing an introduction into developing one's own power supplies.

In view of the special character of this design and the fact that similar units are few and far between on the market we are confident of the interest in the articles as well as the SAPS-400 ready-made module available through the Elektor SHOP.



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- Please send your MailBox correspondence to:

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Mini-PCI and PCI video capture

The new BVM MP-6010 video capture card is the latest addition to the family of mini-PCI and PCI form factor cards that enable a PC to be used as the heart of a security/surveillance video system, processing and storing multiple input video feeds for later review and analysis. The MP-6010 mini-PCI card is a high performance and cost-effective board with four-channel video and audio inputs and a single video and audio output channel. The compression parameters for each input channel can be independently configured. It supports 120 fps NTSC at 740x480 and 100 fps PAL at 704x576 formats, has programmable OSG, MPEG4 and MJPEG



audio and vision compression and operates under Windows XP, Windows 2000 and Linux. Scode DVR software is supplied, enabling the PC display to be configured with different combinations of inputs

and events such as motion image detection to generate a programmable OSG, MPEG4 and MJPEG audio and vision compression and operates under Windows XP, Windows 2000 and Linux. Scode DVR

software is supplied, enabling the PC display to be configured with different combinations of inputs and events such as motion image detection to generate an interrupt to bring the particular feed to the forefront of the display.

The complete family consists of four mini-PCI boards ranging from a single input / output board to a 16 feed input unit; the five-strong PCI form factor units range from four input boards, expandable to manage 24 feeds, to eight input units, again expandable to manage 24 feeds.

www.bvmltd.co.uk

(080713-1)

Elektor trip to China: programme finalised

Elektor's second study trip to China is beginning to take shape. After the flight on 9 November, a busy programme kicks off offering nine days worth of interesting meetings with the Chinese electronics industry. A new feature of the trip is a specially staged business conference where participants have an opportunity to contact representatives of the Chinese industry and government. On top of that, European experts on China report on their experiences, explaining points to pay attention to when doing business with Chinese partners.

The trip also comprises a number of company tours. This time round some highly interesting electronics manufacturing companies will be visited, including **Neways** and



Ximec, specialized not only in PCB manufacturing and finished products, but also in research and design (photograph: Neways company presentation). Neways specializes in hybrid technologies, covering circuit mounting on a ceramic carrier with the advantage of higher component density

on boards. Test & measurement equipment manufacturer **Rigol** is best known for its low-cost oscilloscopes, but also has signal generators, digital multimeters and virtual instruments in its product range. Participants may visit production facilities in these and other companies, which is not normally allowed

to foreigners.

The trip to China also comprises a visit to the China Electronics Fair, one of the five largest electronics exhibitions in all of Asia. Shanghai's 'Electronics Highstreet' is of course not skipped – imagine a street worth's of every conceivable electronic component including all the latest microcontrollers, graphic displays and lots more. Last but not least, the trip offers sightseeing and a good deal of Chinese culture.

Places available at the time of printing!

www.elektor.com/china-trip

www.neways.de

www.rigolna.com

(080693)

World's first 0302 1.0 μ F 2-element capacitor array

Murata has introduced the world's first 0.9x0.6mm (0302) 1.0 μ F 2-element capacitor array, part number GNM0M2R60E105M. This new 0302-size 2-element capacitor array has achieved 1.0 μ F per element, which is unprecedented even for a single 0.6x0.3 mm (0201) device.

Capacitor array products help to reduce mounting surface area and mounting costs compared to mounting multiple monolithic capacitors. Due to its structure, a capacitor array can achieve



greater capacitance in the same footprint compared to multiple

monolithic capacitors. By applying Murata's cutting-edge dielec-

tric material technology, each element of the 0302 capacitor array is able to achieve 1 μ F with higher capacitance than current technology allows for a single 0201 ceramic capacitor.

The GNM0M2R60E105M capacitor array is suitable for general use although the 1 μ F model is typically used as a decoupling capacitor for mobile phones, mobile PCs, and digital AV equipment. Samples are available now.

www.murata.eu

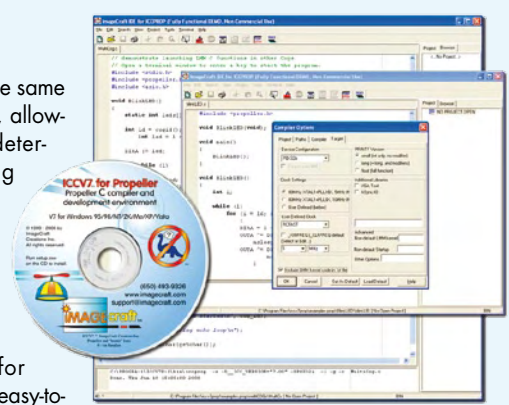
(080713-IV)

ICC for Propeller

ICC for Propeller, from Image-Craft, is an ANSI C development tool for the Parallax Propeller chip. The IDE features project-based design and supports C86 dialect source and C-based Propeller objects. The Propellent Library is directly supported by the IDE for ease in build-to-run development cycles. ICC for Propeller comes in both a Standard Version (#32385) and also a Non-Commercial Version (#32380). Both versions feature an ANSI C compiler for Propeller LMM code generation with an editor, project

manager, and code browser. The Non-Commercial version supports programs as large as 16 k while the Standard version supports programs as large as Hub RAM. The Propeller chip makes it easy to rapidly develop embedded applications. Its eight processors (cogs) can operate simultaneously, either independently or cooperatively, sharing common resources through a central hub. The developer has full control over how and when each cog is employed; there is no compiler-driven or operating system-driven splitting of tasks among multiple cogs. A shared system clock keeps

each cog on the same time reference, allowing for true deterministic timing and synchronization. Three programming languages are available: C (via ICC for Propeller), the easy-to-learn high-level Spin (native), and Propeller Assembly (native) which can execute at up to 160 MIPS (20 MIPS per cog). ICC for Propeller is available for



purchase from Parallax, Inc.
www.parallax.com

(080713-V)

Single-Chip solution Receives Top Honours

Micronas announced that LCD HDTV products based on their VCT-Premium have recently been rated top of the class by leading industry publications.

Sony's brand-new KDL-52W 4000 LCD TV was rated best of all tested 52" Full HD LCD TVs by the German magazine 'Video' in July. In May, HDTVTest.co.uk rated the KDL-40W 4000 "the best LCD HDTV — in terms of both picture and sound quality — in 2008", and 'What Hi Fi, Sound & Vision' testified in June: "One of the sharpest, punchiest, most detailed HD performances yet; terrifically balanced and clean SD playback." JVC's LT-42DR9 was rated best among all tested 42" LCD TVs by the German consumer test maga-



zine 'Heimkino' in June, and 'What Video & Hi-Def TV', from the UK, awarded the 42DS9 a full five-star verdict: "The 42DS9 delivers the

finest picture quality we have yet seen from a JVC LCD TV." With the growing adoption of Blu-ray™, movies are increasingly

being delivered at 24 frames per second (fps). The VCT-Premium supports this 24p mode — showing true cinematic video quality. Micronas' VCT-Premium is the third generation of Micronas' VCT-family of single-chip flat-panel TV processors, providing a complete solution for a Full HD LCD TV featuring integrated audio, video, teletext, and on-screen display (OSD). TVs powered by VCT-Premium can accept content with standard or the new extended color space (x.v.Color™) and expand the color formats to work with Wide Color Gamut panels. VCT-Premium is shipping in mass-production to leading worldwide LCD TV manufacturers.

www.micronas.com

(080713-III)



Old Problems solved by new solutions

The problem of obsolescence in electronics is a common issue for manufacturers. Often manufacturers end up in expensive last time buy operations or desperately searching the world to find the remaining stock in existence. Enterpoint's Craignell

modules offer an alternative to these costly procurement operations, often with performance improvements as an additional benefit. The initial release of the new range of Craignell modules from UK based Enterpoint offer alternative procurement solutions for hard to find components in DIL28, DIL32, DIL36 and DIL40 packages. The heart of the Craignell modules is a Xilinx™ Spartan™-3E FPGA which performs the logic or memory function of the obsolete component being replaced. The high density of the FPGA solution allows functions

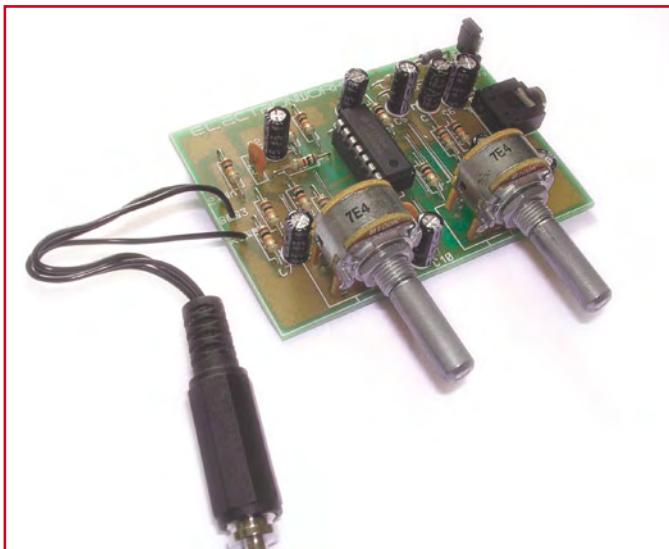
of up to 500,000 gates to be implemented. This allows logic functions as complicated as an 8088 microprocessor or memory devices as large as 16 Mbit to be replicated in a single Craignell module. In addition to the FPGA, Craignell modules contain power regulators and I/O buffering to allow operation from a single supply between 3 V and 5.5 V and can tolerate and drive CMOS levels on all I/Os making the module highly adaptable. Enterpoint offers the Craignell modules in either raw un-programmed format for customers to

implement their own logic functions or as turnkey solutions with design of replacement logic functions already implemented. Typical replacement, or enhancement, functions replicated in Craignells include Microprocessors, UARTs, PIOs, Counter Timers, Clock Generators SRAM, Eeprom, Flash, FIFOs and Dual Port memories. The Craignell module range is priced from £ 25 (US\$ 50), in 100 off quantities.

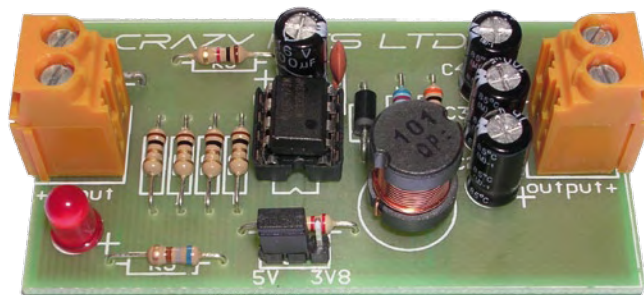
www.enterpoint.co.uk

(080713-VII)

Electronworks electronic kits

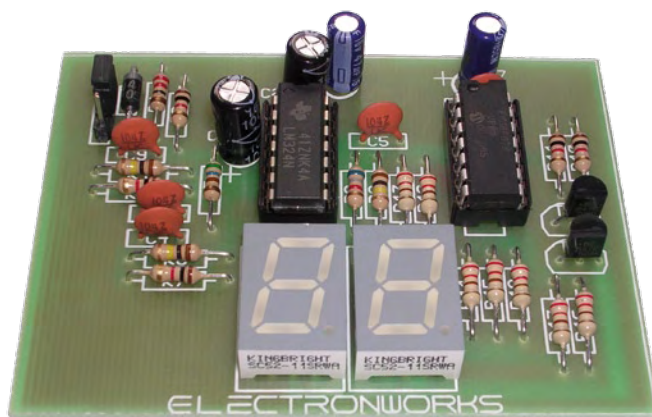


You don't have to be mad in life.... Second thoughts, yes you do. Electronworks have taken some of life's insanity (and lots of their own) and put it into electronic kits. Electronworks' aim is to make learning electronics fun and to bring you a range of kits that are both practical and educational. A whole tonne of kits and ideas is available for unleashing in the



coming months, so if you are young or old, new to electronics or a seasoned veteran you will find something to suit your needs.

For example, Electronworks' MP3 booster amplifies the output of your MP3 player, so you can fill the room with music via your PC



Omniscient PIC32 compiler

HI-TECH Software recently launched an 'omniscient' ANSI C compiler for Microchip's PIC32 family of microcontrollers that can boost real-time performance by 25% or more, and can provide nearly double code density. HI-TECH C® PRO for the PIC32 MCU Family is the only PIC32 compiler that optimizes stack and register allocation across all code modules prior to generating the object code. Smaller code generally executes more quickly and requires smaller, less expensive flash memory for storage. The HI-TECH C PRO compiler has an omniscient code generator (OCG) that collects comprehensive data on every register, stack, pointer, object and variable declaration across the entire program. It uses this information to optimize register usage, stack allocations and pointers across the whole program. It also ensures consistent variable and



object declarations between modules and deletes unused variables and functions. HI-TECH C PRO is the only PIC32 compiler with this capability. The majority of other PIC32 compilers are based on GCC compilation technology which generates code one-module-at-a-time, without comprehensive cross-module data. Without knowing how objects are used across the whole program, it is impossible to achieve the same

level of optimization as an OCG compiler. In code density benchmarks, HI-TECH's OCG compiler achieves code that can be as much as 40% smaller than that generated using industry leading GCC-based PIC32 compilers. The smaller code size can cut device costs by reducing the amount on on-chip flash required. HI-TECH Software also provides its own Eclipse-based IDE, HI-TIDE™ 3, including full project management,

a flexible editor and a fast, accurate simulator. HI-TIDE connects to the HI-TECH C JTAG Debug Interface, which is provided free of charge with the HI-TECH C PRO compiler package. HI-TECH C PRO for the PIC32 MCU Family is available now through September 30, 2008 for the introductory price of US\$ 1595, after which it will sell for US\$ 1995. It includes, free of charge, HI-TECH Priority Access™ (HPA) — 12 months access to updates and technical support — as well as a 30 day money back guarantee. Multi-user, and educational user discounts are available. A fully functional 45-day trial version of HI-TECH C PRO for the PIC32 MCU Family can be downloaded, free of charge, at HI-TECH's website.

<http://microchip.htsoft.com>

(080713-VI)

Free step-by-step guide to REACH

Farnell has produced a step-by-step guide to REACH regulations (Registration, Evaluation and Authorisation of Chemicals). The easy-to-read document, downloadable from the company's Global Legislation website (www.global-legislation.com), is designed to support electronics design and other engineers in quickly assessing the impact of REACH, and understanding how to achieve compliance with the regulations.

Written in collaboration with ERA Technology, the guide condenses 280 pages of regulations into five easy-to-read pages and has already been adopted by AFDEC members, FBDi in Germany and NEDA in the United States as their

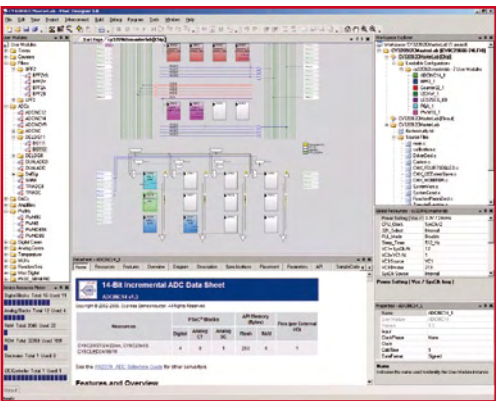
recommended reference guide to customers. The guide is complimented by a PDF covering recent guidance around 'Substances in Articles'.

REACH, currently in its pre-registration phase, is an integrated system for Registration, Evaluation and Authorisation of Chemicals across the EU and currently covers an estimated 30,000 substances. The regulations aim to



improve the protection of human health and the environment while maintaining competitiveness, and enhancing the innovative capability of the EU chemicals industry.

www.farnell.co.uk
(080713-VIII)



Cypress Semiconductor Corp. (introduced PSoC Designer™ 5.0,

combined the revolutionary PSoC Express™ visual embedded system

Cypress PSoC Designer™ 5.0 released

the industry's first and only integrated design environment that includes both code-free and high-level language programming modes in one package.

Cypress has

design tool with the full-featured PSoC Designer software to create a new design paradigm — users can now start projects in a drag-and-drop visual design mode (system-level view) and then move to code-based design in C language (chip-level view) to refine and customize their projects, all from within a single tool.

In addition to integrating the PSoC Express functionality, the new PSoC Designer 5.0 tool includes the more powerful version 9.61 of

the HI-TECH C® PRO compiler for the PSoC® Mixed-Signal Array. The new compiler includes a new 'Lite' mode that designers can use free of charge without any time or code-size limits usually associated with free compilers. Users can download PSoC Designer 5.0 free of charge.

www.cypress.com/psocdesigner
www.cypress.com/psoc
www.cypress.com/psoctraining
(080713-IX)

Artificial sounds from hybrid cars

Farnell has produced a step-by-step guide to REACH regulations (Registration, Evaluation and Authorisation of Chemicals). The easy-to-read document, downloadable from the company's Global Legislation website (www.global-legislation.com), is designed to support electronics design and other engineers in quickly assessing the impact of REACH, and understanding how to achieve compliance with the regulations.

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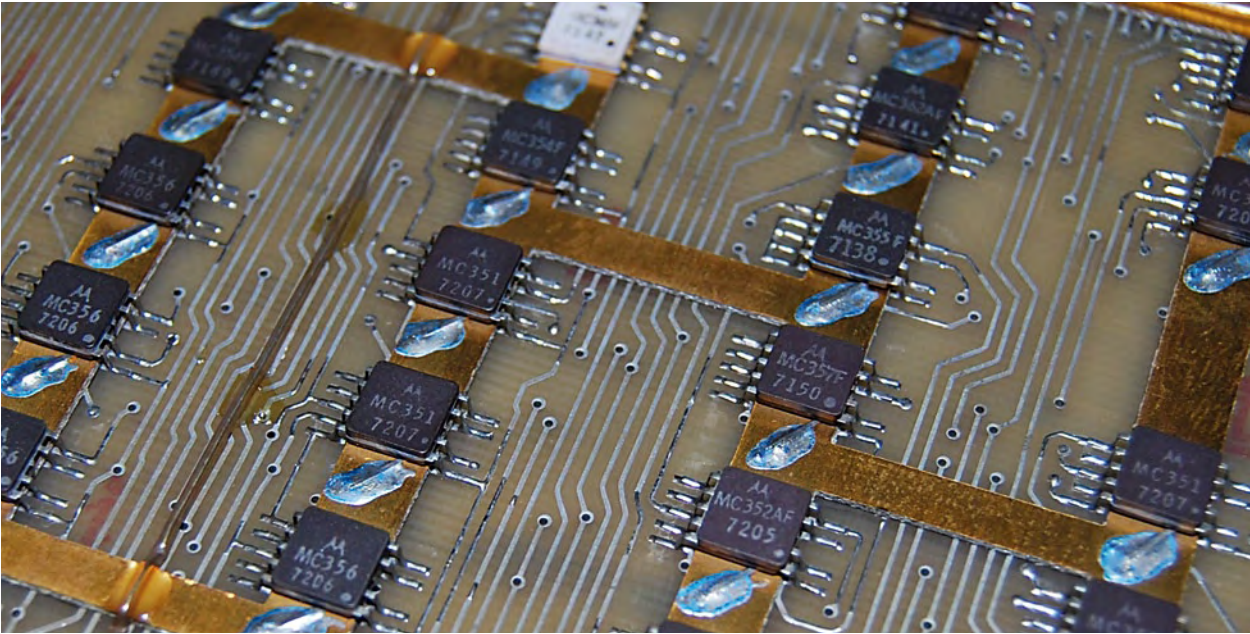
www.farnell.co.uk
(080713-VIII)

The SMD Success

SMDs have been with us since the

Ernst Krempelsauer (Elektor Germany)

The introduction of the SMD package is closely linked with the development of the first integrated circuits at the beginning of the 1960s. It was not until the 1980s and 1990s, however, that SMDs began to dominate the market, the tiny packages enabling the manufacture of ever more technologically sophisticated mobile phones, notebooks and PDAs.



These early SMD ICs are M300 series MECL (Motorola emitter-coupled logic) devices from 1967. (Photograph: NRW Finance Authority Computer Centre)

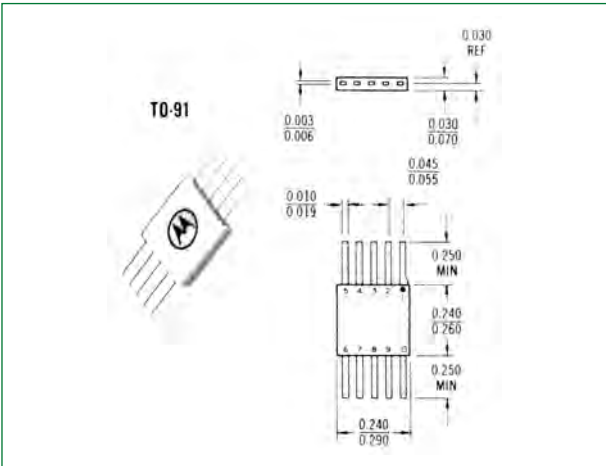


Figure 1. TO-91 flatpack package, from an old Motorola data sheet.

When the first integrated circuits went into mass production it was of course essential to design a suitable package. It was clear that the cylindrical metal transistor-style cans left something to be desired in terms of heat dissipation efficiency and ease of making internal connections. One of the first packages intended specifically for ICs was the 'flat-pack', designed by Yung Tao at Texas Instruments in 1962. It measured approximately 6 mm by 3 mm (1/4 inch by 1/8 inch) and had ten flat leads, five on each side.

In appearance it was very similar to a modern SMD package. **Figure 1** shows a 10-pin flatpack (later standardised as 'TO-91') of the type used for example by Motorola for their very high speed MECL logic family. These flatpack logic devices, which were soldered to the copper side of a printed circuit board, enabled the construction of powerful (for the time) mainframe computers with clock frequencies

Story

dawn of IC history, 46 years ago

of up to 20 MHz (see **Figure 2**). Passive components, on the other hand, had leads with a round cross-section which were fitted through holes in the board and soldered on the reverse side. Most ICs, however, became available in the DIL package, first designed by Bryant Rogers at Fairchild in 1964, two years after the flatpack. The DIL package is still a familiar sight today (**Figure 3**).

The path to success

As the example of the 'antique' computers mentioned above indicates, SMD-type devices were first used in applications where considerations of performance and reliability outweighed considerations of cost. Hybrid circuits, with miniature components surface-mounted on a ceramic substrate, were a kind of (somewhat expensive) stepping stone on the way to modern surface-mount technology. SMDs were for a long time more expensive than their leaded brethren, but the advantages of compactness and reduced circuit board production and assembly costs smoothed the way for their widespread adoption. SMD boards do not require holes to be drilled for the components and (because they are smaller) are inherently cheaper. A further advantage is their superior RF performance, which benefits analogue and digital circuits alike. This is a result not only of the overall smaller dimensions, but also, and more significantly, because the components do not have leads with attendant inductance and parasitic capacitance. The RF properties of SMD circuits are also more reproducible: small differences in the lead length of through-hole devices and in distances, both from component to component and from component to board, all affect RF behaviour.

A further decisive factor in favour of SMDs is the increased reliability of machine-assembled boards: failure rates can be reduced by as much as a factor of 100. And, as their market share has increased, SMDs have also generally become significantly cheaper than conventional components.

The progress of SMD technology is inextricably linked with the development of GSM mobile phones over the last decade or so. Enormous leaps have been made in miniaturisation, cost reduction, production quality control, robustness and in improving RF performance by packing these tiny devices together as closely as possible.

Evolution

In a conventional (carbon) film resistor the leads are connected to caps fitted to either end of a ceramic tube, which is coated with the resistive material. If we dispense with the leads and simply solder the caps directly to the pads of a printed circuit board we have made an SMD resistor. This kind of cylindrical SMD package is known as a MELF (metal



Figure 2. Flatpack logic ICs soldered to the top surface of the printed circuit board were an essential part of this 1960s mainframe computer, the most powerful of its time. The board comes from a Telefunken TR440, first produced in 1969. (Photograph: NRW Finance Authority Computer Centre, <http://www.rzf-nrw.de>)

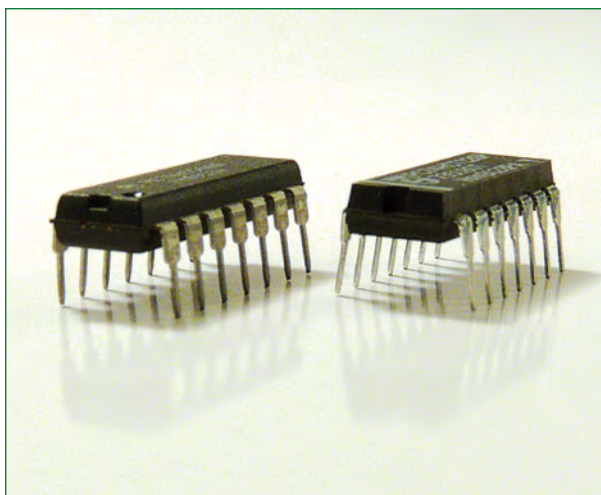


Figure 3. The trusty DIL package was first used in 1964, two years after the first SMD-style flatpack package.



Figure 4. Diodes without wires: the cylindrical MELF package is a derivative of the leaded package.

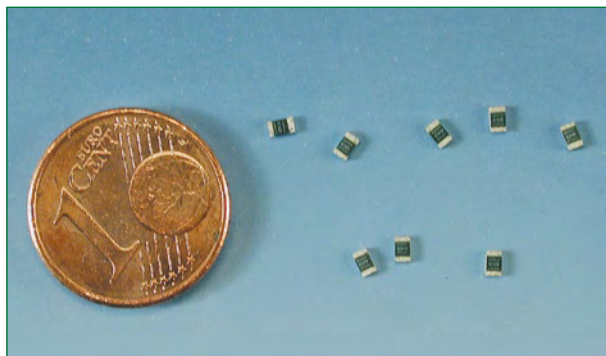


Figure 5.
Most SMD components
come in chip-style
packages.

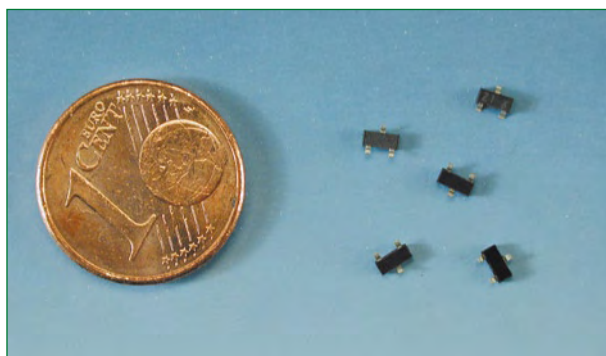


Figure 6.
SMD transistors and
smaller ICs have
connections along the
edges of the package.

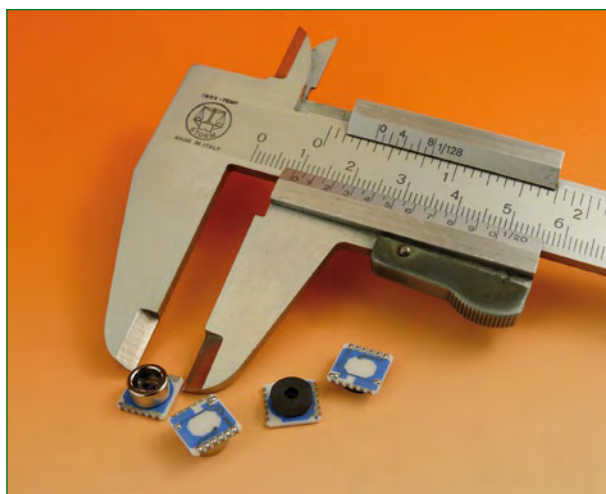


Figure 7.
Even special-purpose
devices such as this
MS5534-CP/-CM pressure
sensor from Intersema
(www.intersema.com) are
frequently available in
SMD packages.



Figure 8.
A device in a BGA (ball grid
array) package, here with
'only' 169 solder balls.

electrode leadless face), mini-MELF or micro-MELF, depending on its size. This package is still used, chiefly for diodes (**Figure 4**), NTCs, PTCs and high pulse load, high voltage and high stability resistors.

The majority of SMD components are rectangular in shape: the so-called 'chip' package (**Figure 5**). Resistors and capacitors have connections formed by caps at either end, while transistors and smaller ICs have leads along the long edges (**Figure 6**). As technology has advanced SMD packages have become smaller and smaller, with modern devices measuring less than 0.5 mm along an edge. SMD packages are also being introduced for more and more of the bulkier components, such as inductors, connectors, switches and relays, as well as for specialised components such as microphones and other sensors (**Figure 7**). The main demand here is not for miniaturisation but rather for the SMD components to be able to withstand the temperatures of reflow soldering without damage or adverse effect on service life.

It was not long before SMD ICs outgrew the restrictions of placing connections around the edge of the package. Gradually such packages are being superseded by a design where the connections take the form of a grid of hemispheres on the underside of the device. The pitch of the grid can range from 1.5 mm down to below 0.5 mm (see **Figure 8**). The so-called BGA (ball grid array) package allows ICs to be manufactured with over 1000 connections. Soldering requires a precision-controlled reflow system, and joints can only be inspected using X-ray equipment. Development of SMD package designs still continues apace: you can read more in the article elsewhere in this issue by my colleague Clemens Valens.

(080714-1)

Literature and Internet Links

'SMD (Surface Mounted Device)',

Elektor December 1985.

Christian Tomanik: 'SMDs? Don't panic!'

Elektor January 2003, p. 44 and February 2003, p. 32.

<http://smithsonianchips.si.edu>

(National Museum of American History's Chip Collection)

<http://homepages.nildram.co.uk/~wylie/ICs/monolith.htm>

(The first monolithic integrated circuits, by Andrew Wylie)

<http://www.hbci.com/~wenonah/history/edpart6.htm>

(Tommy Cichanowski's History of 'Western Technology': The Integrated Circuit Era)

www.vaxman.de/historic_computers/telefunken/tr440/tr440.html

(photograph of the Telefunken TR440 mainframe)

www.rzf-nrw.de/museum/museum4.html

(technical information on the Telefunken TR440 mainframe, in German)

http://en.wikipedia.org/wiki/Surface-mount_technology

(main Wikipedia page on SMD)

EasyPIC5 C Starter Pack—everything needed to start developing PIC projects in C for just £189



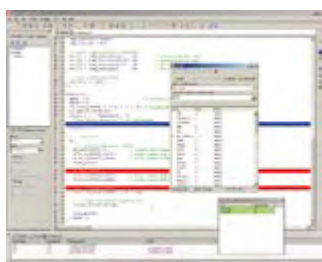
The EasyPIC5 C Starter Pack contains everything needed to start learning about and developing with PIC microcontrollers using the C programming language. The package contains the popular EasyPIC5 development board, a full version of MikroElektronika's powerful mikroC compiler, USB and serial cables, blue backlit 16x2 character and 128x64 graphic LCDs, touch-screen overlay for graphic LCD, DS1820 temperature sensor and a 40-pin enhanced Flash PIC16F887 microcontroller—all for just £189.

The EasyPIC5 C Starter Pack is well-suited to beginners and experienced developers alike and comes with high-quality printed documentation and a large number of easy-to-understand example programs for a number of PIC microcontrollers.

The **EasyPIC5** supplied in the starter pack is a full-featured development board for PIC10F, 12F, 16F and 18F microcontrollers in 8, 14, 18, 20, 28 and 40-pin packages. The EasyPIC5 incorporates an on-board USB-based PIC programmer and in-circuit debugger as well as a useful selection of built-in I/O devices such as LEDs, switches, 7-segment displays, potentiometers, RS-232 interface, PS/2 and USB connectors and provision for fitting of the included LCD displays, touch-screen and DS1820 temperature sensor. What's more, all of the PIC's input/output lines are available for connection to your own circuits or to any of our huge range of low-cost optional add-on boards such as Ethernet, RS-485, CAN, LIN, IrDA and RFid communications, EEPROM, SD/MMC and Compact Flash storage, 12-bit A/D and D/A, and many useful interfacing and prototyping boards.



Supplied in the EasyPIC5 C Starter Pack is a full version of MikroElektronika's **mikroC**, a powerful integrated development environment and C compiler for PIC12, PIC16 and PIC18 microcontrollers. With its built-in user-friendly features, mikroC makes developing code for PICs easier than ever. When used in conjunction with the EasyPIC5 development board, mikroC provides full in-circuit debugging capabilities. mikroC also provides a library of ready-written routines that provide support for all of the EasyPIC5's on-board I/O devices and optional add-on boards. This enables programs to be quickly constructed even when working with advanced features such as CAN, Ethernet and USB communications, character and graphic LCDs and touch-screen, and EEPROM, MMC/SD and Compact Flash data storage. mikroC also incorporates useful tools such as LCD custom character generator, GLCD bitmap generator, USART, HID and UDP terminals and 7-segment display decoder.



EasyPIC5 BASIC Starter Pack and **EasyPIC5 Pascal Starter Pack** also available at £149 each. Similar starter packs also available for 8051, AVR and dsPIC—please see our website at www.paltronix.com for prices and full details.

Get an oscilloscope, logic analyser and much more with the PoScope USB-based Instrument for only £79



With a PoScope you get:

- Dual-channel oscilloscope
- Spectrum analyser
- Dual-channel chart recorder
- 16-channel logic analyser with UART, SPI, I2C and 1-wire serial bus protocol decoding
- 8-channel pattern generator
- Square-wave/PWM generator

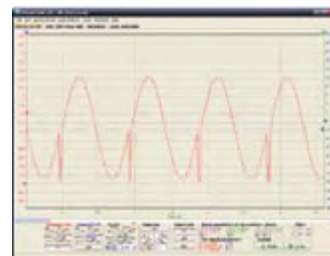
This latest version of the popular PoScope is a must-have tool for those developing microcontroller-based projects or with a general electronics interest and provides the features of six instruments in one compact PC-based unit at an incredibly low price.

The PoScope connects to one of your desktop or laptop PC's USB interfaces (USB 1.1 or USB 2.0), is Windows XP and Vista compatible and comes with easy-to-use software.

The PoScope provides two BNC connectors for oscilloscope, spectrum analyser and chart recorder inputs and a 25-way female D-connector for logic analyser and pattern generator input/outputs. Supplied with USB connecting cable and software and manual on CD-ROM.

A PoScope Bundle is also available for £119, which additionally includes two high-quality oscilloscope probes and a logic analyser test lead and clip set.

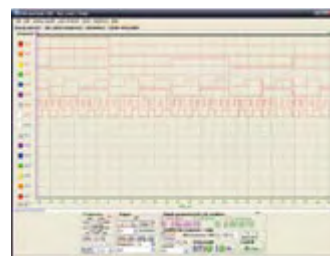
The **dual-channel oscilloscope** provides voltage and frequency measurement, absolute, differential and external triggering, adjustable pre-trigger, marker measurements and filtering. Specifications include a 100Hz ~ 200kHz sampling rate, 1126 samples/channel (1 channel) or 563 samples/channel (2-channel) memory depth with pipe reading of 64k samples per channel, 10-bit resolution A/D and input voltages from -20 ~ +20V.



Dual-channel oscilloscope view

The **spectrum analyser** provides Hamming, Hanning, Blackman and Blackman-Harris window functions.

The **chart recorder** provides dual-channel recording at sampling rates from 0.01Hz ~ 200kHz with a maximum record time of 24 hours at Fs < 100Hz. A/D resolution and input voltage range are again 10-bit and -20 ~ +20V respectively.



Sixteen-channel logic analyser view

The **logic analyser** provides 16 channels (eight when pattern generator in use) with a sampling rate of 1kHz ~ 8MHz, internal and external clocking, versatile triggering and an input range of 0 ~ +5V. Memory depth ranges from 1544 bits/channel (Fs <= 1MHz) to 128 bits/channel (Fs <= 8MHz). Built-in **serial bus protocol decoding** facilitates the decoding of UART, SPI, I2C and 1-wire serial buses.

The **pattern generator** allows eight of the logic analyser's channels to be used to provide output waveforms from 1kHz ~ 1MHz with a memory depth of 1544 bits/channel and an output voltage of 0V for logic "0" and 3.3V for logic "1".

The **PWM generator** provides a 7.8125kHz output with a 1 ~ 100% adjustable duty cycle. Square waves can also be output with a 50% duty cycle and an adjustable frequency ranging from 3.91kHz to 1MHz.



UART, SPI, I2C and 1-wire decoding view

Please see our website at www.paltronix.com for further products including components, microcontroller development tools, prototyping aids, educational robot kits, test equipment and wireless communications products.

Pix-Cell GSM Controller

New product—the Pix-Cell is a stand-alone controller offering GSM/GPRS communications, three digital inputs, three 10-bit analogue inputs, SPDT relay output and RS-232 interface priced at £129.



ZeroPlus Logic Analysers

A range of powerful 16 and 32-channel logic analysers with advanced serial bus protocol decoding including CAN, LIN, USB, UART, SPI, I2C, 1-wire and more. With prices from only £125, there's a logic analyser in this range to suit all needs and budgets.



Universal Development System

The UNI-DS3 is a versatile microcontroller development system supporting PIC, dsPIC, 8051, AVR, ARM and SoC devices with an extensive range of built-in I/O features and on-board USB programmer priced from £109.



SMT of the Future

Whatever next to solder (or not)?

Clemens Valens (Elektor France)

So you finally mastered hand soldering a 0805 package and now you're expected to migrate to 0603 and next up is 0402! Did you know that there exist 0101 size resistors? That's 0.3 mm by 0.22 mm! Imagine hand soldering such a part when just seeing it is a challenge on its own. That's why our foxy browser was fired up to prepare ourselves for what we may have to mount (on boards) tomorrow.

Electronic component packaging has always been driven by consumer demand. Admit it — you too want smaller and niftier electronic gadgets that offer more yet cost less. Nobody expects a mobile phone to be just that — we want it to be feature-packed and consequently electronic product manufacturers have to fit ever more 'functionality' into forever shrinking products. By implication, electronic component manufacturers have to cram more transistors into smaller housings.

Now if you thought that these new, invariably smaller, housings were invented by chip manufacturers, you're mistaken. Electronic component package design is not just a science — it's a thriving business and industry with conferences, dedicated magazines, exhibitions and large multinationals like Amkor [1], ASAT [2], ASE [3], Flip Chip [4] and Tessera [5] in the arena. So what are all these people doing and what have they been up to lately?

BGA

All right, you've heard about BGA (Ball Grid Array) packages, you probably have seen them, you may even have steered clear of them, but did you know that there are as many different BGA packages as there are inkjet cartridges? Asking for plain-vanilla 'BGA' only gets you an obliging smile — the insider asks for µBGA, Face-up µBGA, µBGA-W, PBGA, HSBGA, L2BGA, CSBGA, EBGA, HPBGA, SBGA, TSBGA, TEPBGA, CLTBGA, VBGA, VFBGA or fpBGA. Impressive? This list isn't even exhaustive...

Luckily for us electronic part end users, a BGA is usually just a BGA — a flat bit of hard material with lots of small metal beads on the side that is supposed to be fixed to the PCB. The only thing we notice is the growing number of components that come packaged as BGA, the growing number

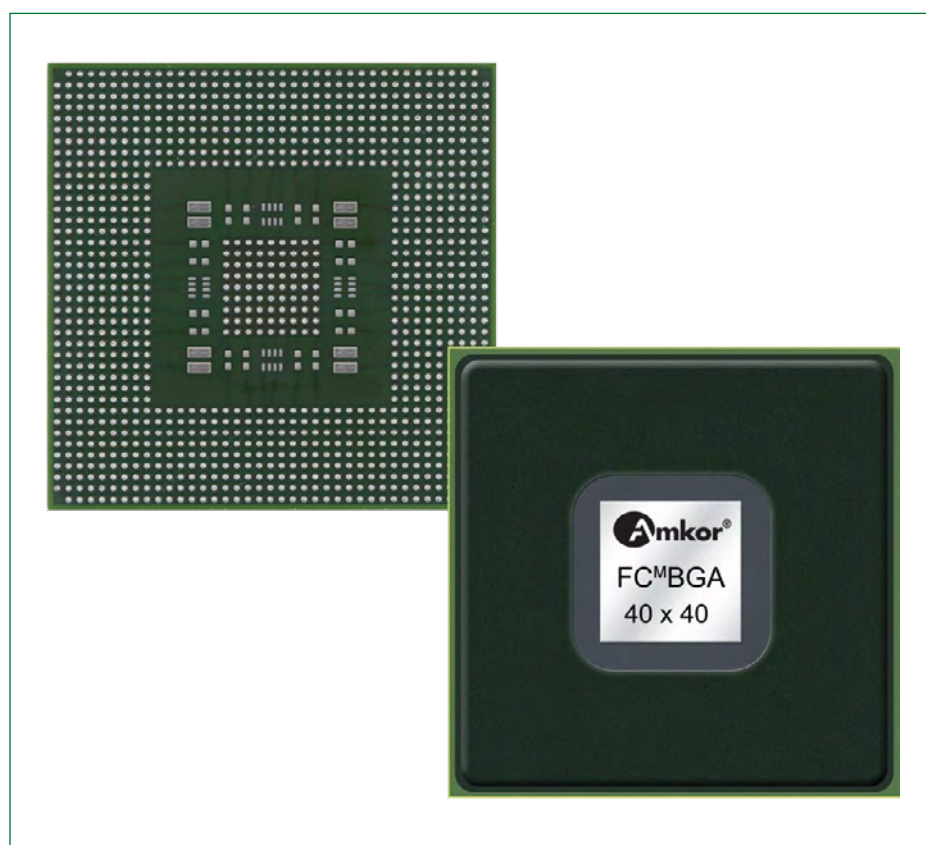


Photo 1.
Amkor's latest BGA package, the FC^MBGA (Flip Chip Moulded BGA), up to 1229 (or was it 1228?) contacts with JEDEC standard 1.0 mm pitch on a 40 by 40 mm surface. (courtesy Amkor)

of beads (some have over 1500!) and their decreasing pitch, which is currently down to 0.40 mm.

No more leads?

As you will have gathered from the above, BGA packages will play an increasing role in future electronics. Does this mean that we will no longer see any component leads? No, leaded packages, or 'exposed pad packages' like SOIC, SOP, QFP and PLCC, will keep their place because even though they take up relatively large amounts of board space, they do have their advantages, notably when it comes to heat dissipation, testability, ground plane connectivity and mechanical strength. Compatibility with most existing SMT mounting processes is another very important reason for making such packages stick around for some time to come.

Compatibility considerations and long life cycle products also assure the availability of the good old DIP for many years to come.

Leads are not always bits of metal sticking out of a package. A so-called Dual or Quad Flat No-lead (DFN or QFN) package is considered a 'leadframe' package, but it does not really have leads. Instead, its connections are just exposed metal pads on the bottom and the sides of the package that are soldered to the board. You can get QFN parts with more than 120 pins and although they are difficult to mount, pins are easily probed.

No more solder?

Not only Fred in the Shed is hindered by seemingly impossible to mount components, the professional board assemblers are affected too. Tools are needed not only to properly mount these highly integrated, high pin count, fine-pitched parts, but also to test and repair the boards that use them.

Soldering is becoming more and more difficult with RoHS and other ecological requirements. This is why chip packagers and board manufacturers are currently looking into solderless mounting techniques.

3D chips

Even though 1,500 connections on a BGA is a staggering number, there are always people who want more. However with continually diminishing board space, components can only grow in height (like cities), which is done by adding more levels.

Several techniques for stacking chips in packages have been developed. Some use — surprise! — BGA to interconnect the chips. This technique, called ball stacking, is mainly used for memory chips that can easily be wired in parallel. A related technology is Package on

Package (PoP), where chips are pre-packaged before being stacked and allowing existing chips to be used.

Chip stacking is another way of getting more in less space. In this case the chips, which may come from different chip manufacturers, are simply glued on top of each other, without connections between them.

Wafer Level Packaging (WLP) is the latest trend. With this technology the wafer is bonded directly to the external connections (beads, you guessed it) without interconnecting wires. WLP is currently being used for relatively small components with few I/O like linear, analogue and passive devices.

Contrary to a System on a Chip (SoC) where the whole circuit is built on one and the same chip, a System in a Package (SiP) contains several chips and even passive components in one package. A SiP is more flexible than a SoC because not many circuits are suitable for being integrated on one chip. The 'P' of a SiP may be a BGA, but not necessarily so.

The funny thing with chip scale packaging techniques (CSP, not to be confused with Chip Scale Package, a BGA-style package only slightly larger than the chip) is that even though dies are getting thicker, packages are getting thinner. Currently BGA packages can be as thin as 0.4 mm.

(080662-1)

Internet Links

- [1] www.amkor.com
- [2] www.asat.com
- [3] www.aseglobal.com
- [4] www.flipchip.com
- [5] www.tessera.com

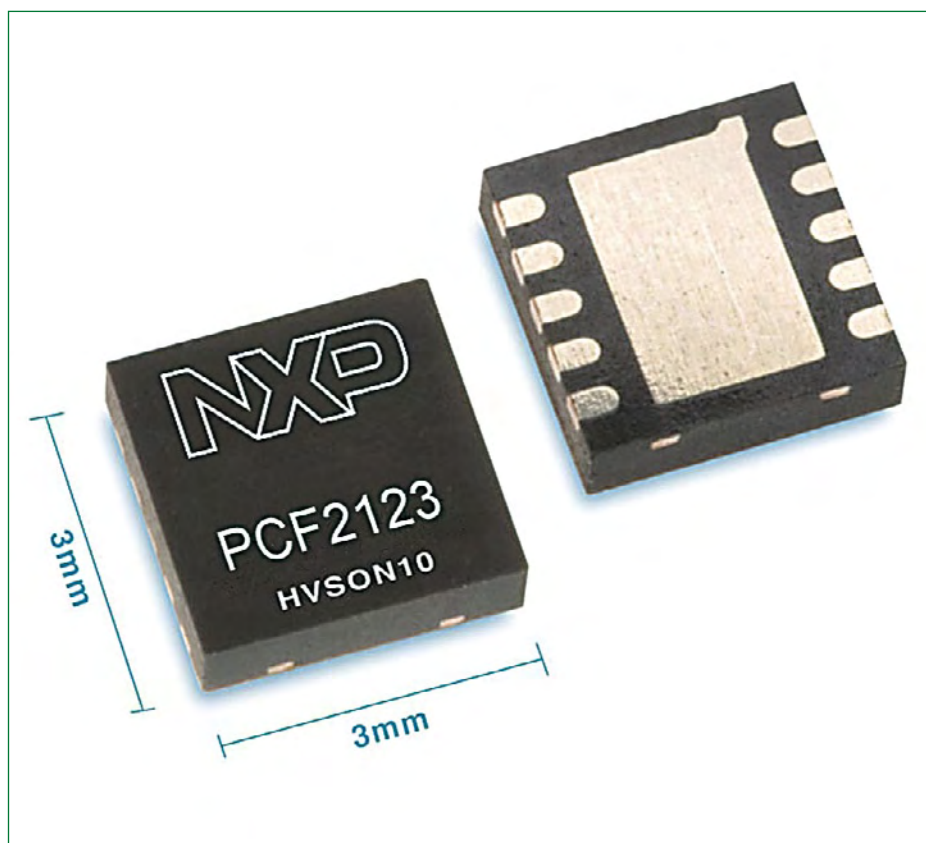


Photo 2.
This new real time clock (RTC) from NXP comes in a tiny 11-pad QFN housing. The big pad in the middle often serves as a ground pin, heat sink or both, or simply to improve mechanical strength. (courtesy NXP Semiconductors)

Elektor SMT Preci

what you set is what you get

Jan Buiting

The Elektor SMT reflow oven will faithfully handle most if not all your soldering of projects using surface mount devices (SMDs). The oven is particularly suited for use not just in Colleges, workshops, clubs and R&D laboratories, but also by the advanced electronics enthusiast. This precious workbench tool is at home where SMD boards have to be produced to a variety of requirements on size, components and soldering materials. Apart from the handle on the drawer giving access to the PCB tray, the user interface consist of an LCD and five buttons on the front panel. From now on, “anyone can play SMD” although some funny smells, burned or half cooked products can be expected as you practice — just don’t tell Teach or the Missus and get your oven mittens out.

Technical Specifications

Line voltage	230 VAC
Line frequency	50-60 Hz
Max. power consumption	1650 W
Internally fused	10 A
Heating methods	far-infrared radiation and hot air (mixed heating)
Operating system menus	English, German (partly), Chinese
Modes of operation	● Solder (5 user-defined temperature phases) ● Repair (rework) (1 user-defined temperature phase)
Temperature phases (curve sections)	pre-heat → heat (soak) → solder (reflow) → heat retention → cool down
Time / Temp. range for pre-heating phase	0 to 5 min. / 70 °C
Time / Temp. range for heating phase	0 to 5 min. / [pre-heat temp.] to 220 °C
Time / Temp. range for soldering phase	0 to 60 s. / [heat temp.] to 280 °C
Temp. range for heat preservation phase	[solder temp.] to [[solder temp.] – 50 °C]
Temp. range for cool down phase	70 °C to [heat retention temp.]
Time / Temp. range for Repair mode	0 to 90 min. / 70 to 250 °C
Effective tray area	280×280 mm (11×11 inch)
Size	418x372x250 mm (16.5×14.6×10 inch)
Weight	16.7 kgs (net)
Case and finish	steel, high-gloss grey lacquer finish
CE and RoHS	approved (relevant tests applied for by Elektor)

Do not...

- ... replace the internal fuse until the electrical fault condition has been lifted.
- ... operate other electrical appliances on the same power outlet as the oven.
- ... use the oven to heat foodstuffs.
- ... place the oven in a tightly enclosed space —a minimum 20 cm (8 inch) clearance is required from any wall or object.
- ... place combustible materials or liquids in, on or near the oven.
- ... place the oven on a table cloth, to prevent blocking the air intake.
- ... operate the oven at high ambient temperature and/or humidity conditions.
- ... operate the oven without a proper Protective Earth (PE) connection.
- ... open the tray until the oven has finished the cool down phase and even then use safety gloves.
- ... ignore manufacturers’ advice on using SMD components, associated reflow parameters and tools.

SMTprecision Reflow Oven



Buzzer (inside)



A small buzzer acknowledges pushbutton presses and is activated on fault conditions to alert the user(s).

User interface

The success or failure of a reflow soldering process on a printed circuit board designed for SMT parts is wholly determined by your settings for temperature and duration of the various phases the board is taken through in the oven. Fortunately, reflow soldering materials are well documented and following the manufacturer's advice (often presented in tables) for the temperature and duration of the 'phases' is a good way to be successful, even the first time round!

The LCD/pushbutton area on the front panel of the oven offers a convenient way of defining just about every useful temperature curve, the shape and length of which will be governed by the materials at hand, plus your personal preferences and experience.

The bright blue LCD (liquid crystal display) will tell you what options to pick and values to set from the oven menus, as well as report on operating status.

The control buttons have acoustic feedback through the buzzer. The RUN, ,  and SET buttons may have different functions depending on the menu texts appearing above them on the LCD.

Board tray with handle

The net surface area of 280×280 mm, slotted steel bottom plate and guide support rails of the PCB tray allow your circuit board(s) to be placed and removed easily, as well as moved in and out of the oven without a risk of tilt, vibration or shock. Be sure to wear safety gloves when removing a hot PCB before the end of the cool down phase (not recommended).

(actual model supplied may differ slightly from sample shown here)

Power on/off switch

A heavy-duty double-pole illuminated rocker switch that connects or disconnects the line voltage to/from the internal circuitry. Always switch the oven OFF when not in use for some time.

Power cord receptacle

An IEC line power (110-250 VAC) appliance socket. An approved power cord and a power line outlet with protective earthing (PE) must be used.

Extraction fan

The air extraction fan is controlled as a function of internal temperature and assists the cool down process. It also helps to remove fumes from the instrument. Keep the fan area clean and clear.

Fuseholder

Do not unscrew the fuseholder unless the fuse has to be replaced **after** resolving an electrical fault in the oven. The power cord must be pulled **before** removing or installing the fuse.

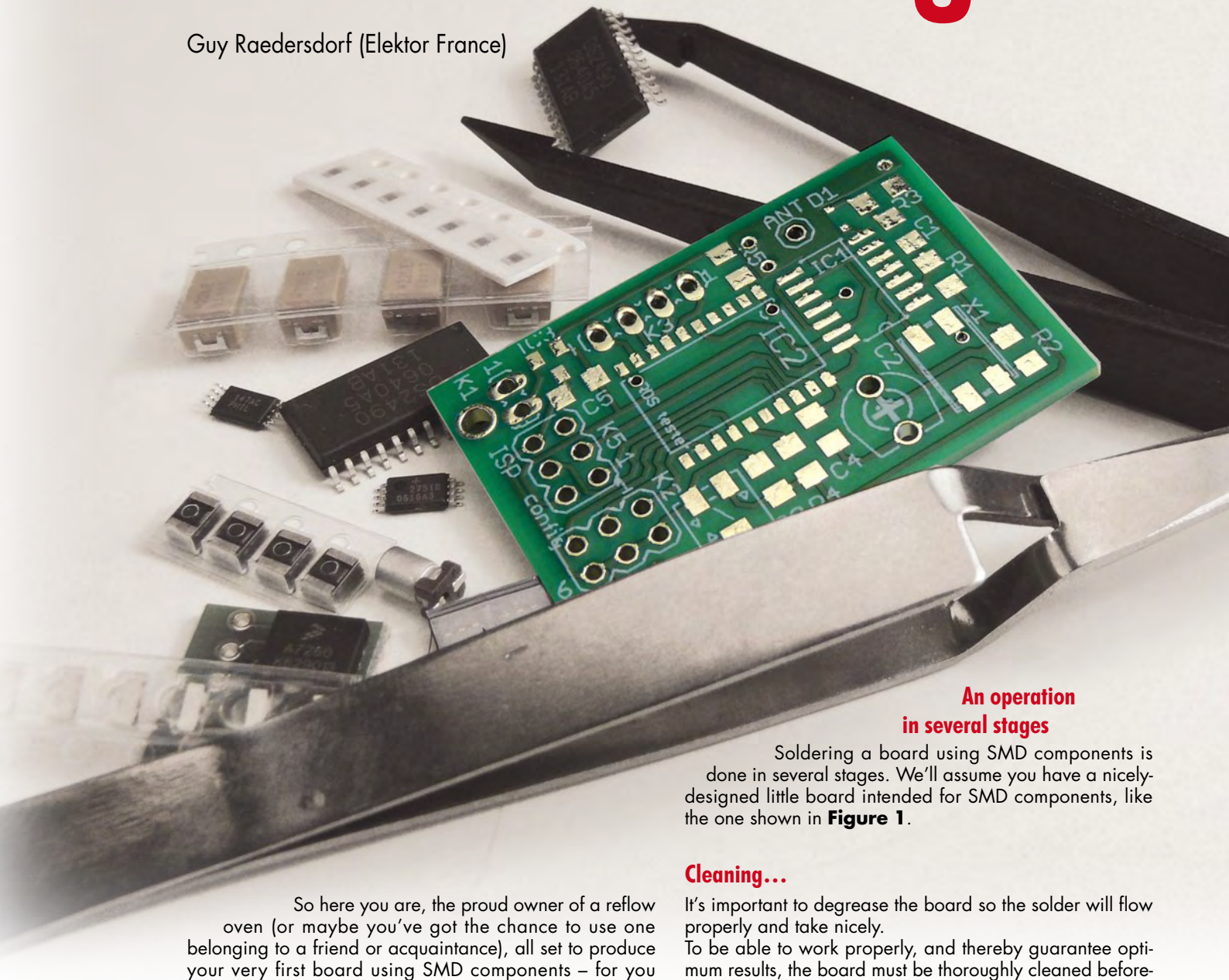
Air intake (under)

The bottom of the case has large slots to allow fresh air to be taken in. The oven stands on four 20-mm high rubber feet.

(080663-1)

Before Baking...

Guy Raedersdorf (Elektor France)



An operation in several stages

Soldering a board using SMD components is done in several stages. We'll assume you have a nicely-designed little board intended for SMD components, like the one shown in **Figure 1**.

Cleaning...

It's important to degrease the board so the solder will flow properly and take nicely. To be able to work properly, and thereby guarantee optimum results, the board must be thoroughly cleaned beforehand and the solder pads perfectly clean and free from grease. The whole outcome of the reflow soldering process depends on this. Use isopropyl alcohol for this job. Once you are satisfied with your work, you can go on to the next stage.

Applying the soldering paste

Once the cleaning stage is over, you can have fun with the dispenser or syringe used to apply the soldering paste or cream where (and only where!) it's needed. The success of the whole reflow operation is largely dependent on how carefully the soldering paste is applied. So you need to make sure you apply enough, but not too much — this takes a bit of doing to get it just right! There are two options: either do it by hand, applying the required amount of paste to each pad, or use a sort of pre-cut template, a stencil that can be made with the help of a

So here you are, the proud owner of a reflow oven (or maybe you've got the chance to use one belonging to a friend or acquaintance), all set to produce your very first board using SMD components – for you always have to start somewhere.

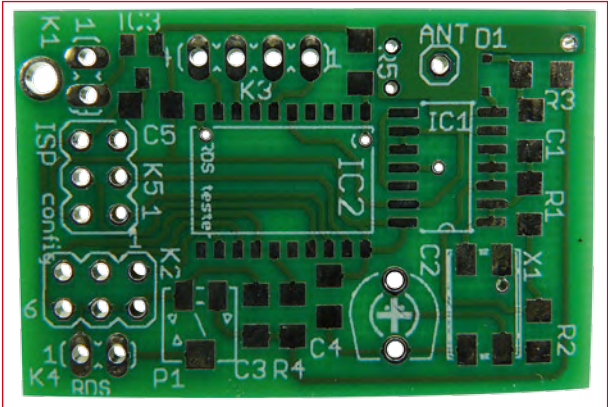
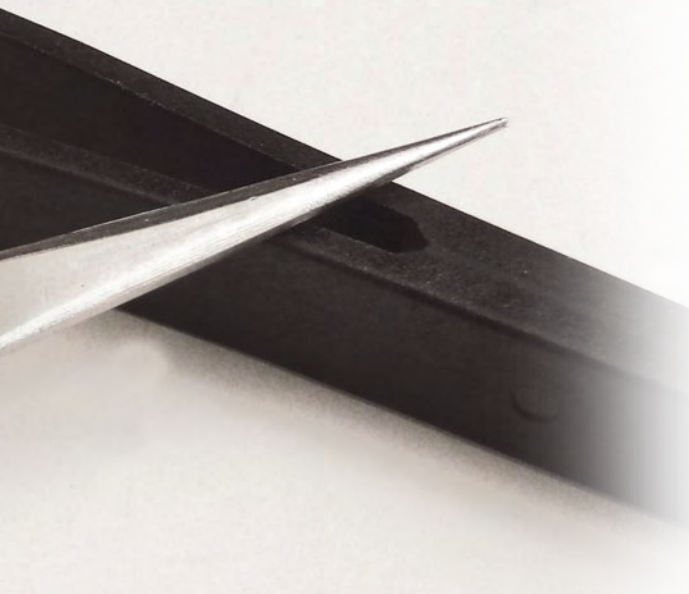


Figure 1.
The bare board has been cleaned using a cleaning product such as alcohol.

Preparing a board for reflow soldering

It's all very fine having a super 'professional' reflow oven like the one mentioned in this cluster of short articles, only to risk being disappointed with the results. But this is just what is in danger of happening if you don't take a minimum of care in preparing your boards for 'baking', as this is actually the most important thing, given the temperatures involved.



suitably-engraved piece of epoxy PCB. Here, we've opted for the first approach.

So the most important thing here is to arrive at the right quantity: neither too little paste (poor soldering = poor contacts) nor too much (creating more shorts than are strictly necessary!). Using commercially-available dispensers, it's not easy to apply the small amount of paste needed for proper soldering of tiny components like resistors or capacitors. Instead, you can use a small syringe (**Figure 2**) bought from the chemist's (without a needle, of course!), with a diameter of around 1 mm (to allow the paste to flow through it smoothly). However, a larger dispenser is very suitable for applying the paste to the larger pads for a multi-pin SMD IC. It's enough to leave a small, continuous, cross-wise trail in the centre of the pads, as during soldering capillary action will 'draw' the soldering paste over the copper pads (**Figure 3**).

It's a good idea to have some way of inspecting your work close up — a magnifying glass (10x) or a bench lamp with a large magnifier.

One little pitfall to be wary of: if the pads or lands are larger than the component (especially with 2-pin components), the component is in danger of floating and becoming misaligned. On the other hand, if the pads are in accordance with the component manufacturer's recommendations, the component is 'sucked' by the molten paste and aligns itself automatically.

Note: if you examine the soldering paste under a microscope, you can see it's made up of thousands of tiny beads of solder coated in a sort of resin that will disappear during reflow soldering.

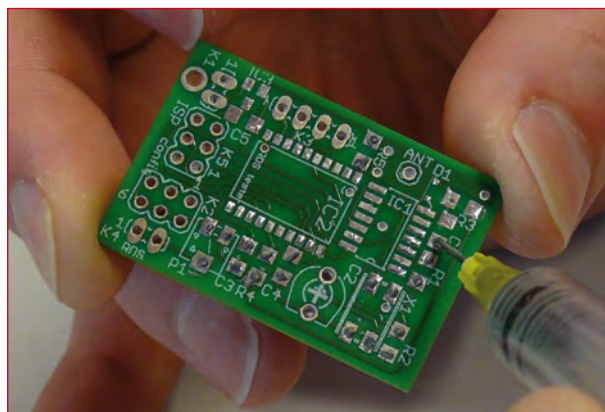


Figure 2.
A dispenser like the one being used here is a practical tool for applying the soldering paste.

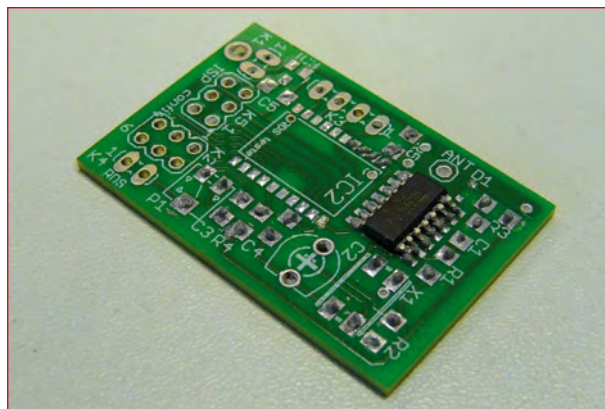


Figure 3.
Without using a stencil, it's virtually impossible to apply the paste to each contact without some overspill.

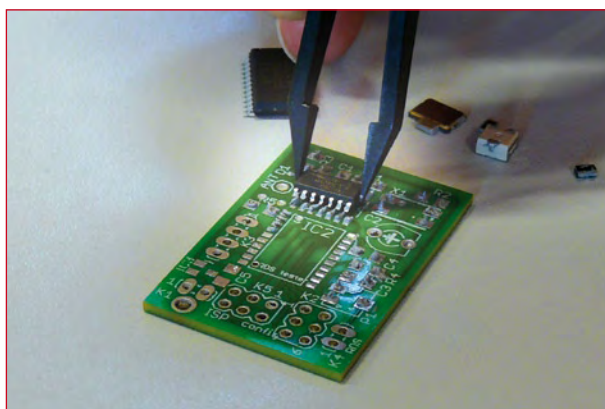


Figure 4.
Dozens of different types of SMD tweezers and pliers are available. What you need is a pair of sprung tweezers, to avoid getting cramp when fitting small SMDs.

Figure 5a.
An electric suction pipette lets you position larger SMD components accurately. More compact versions do exist...

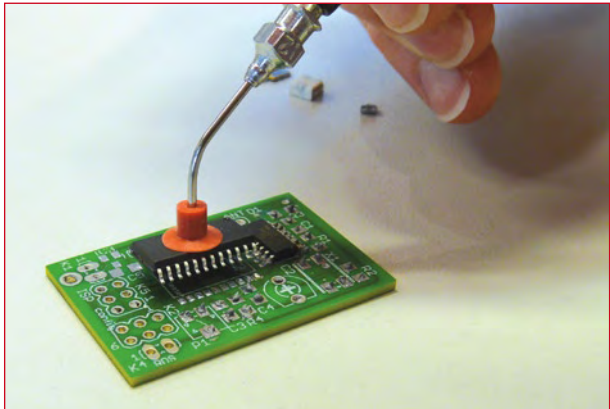


Figure 5b.
Close-up of fitting a multi-pin component using an electric suction tool.

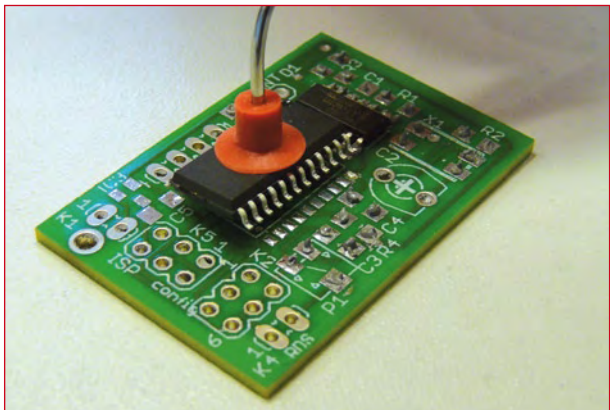


Figure 6.
Our first 'guinea pig' is ready to face the IR heat in our reflow oven.



Fitting the components

Now it's time to fit the components. For the smaller components, you can use a pair of SMD tweezers (**Figure 4**), for those with a nice flat surface (particularly multi-pin ICs), a suction pickup tool will prove ideal (**Figures 5a** and **5b**). Take care that the components are placed perfectly straight, as the slightest misalignment can lead to a disappointing result after soldering. Once the components have been soldered, it's quite possible that you may notice some (slight) asymmetry in a series of small components arranged in aligned rows; this is all part of the deal.

After critically examining your work one last time (positioning, polarity, value, and type of components), all that remains to be done is to place the finished board (components uppermost, obviously) on the rack in the reflow oven drawer (**Figure 6**).

Some tips...

Soldering paste is prone to hardening. Low temperatures prevent its going off too quickly. So don't forget to keep your soldering paste in the fridge when you're not using it. A lower temperature will avoid its drying out, so hopefully it will keep for some months, way beyond the 'use by' date. If you take your paste out of the fridge, you'll need to leave it time to get back up to room temperature.

The characteristics of the soldering paste have a noticeable influence on the values to be set on the reflow oven. Lead-based pastes, not recommended if you want to respect the RoHS directives, have a lower melting point than lead-free pastes. The reflow temperature must be some 20 °C higher than the melting point of the paste. Use the so-called 'no-clean' paste, which obviates the need to remove flux residues.

Care should be taken not to inhale the vapours given off by soldering pastes.

Sources of information

The Internet is an outstanding information tool. If you go off looking for information about soldering SMD components, you come across some brilliant ideas, like the one from Dean F. Poeth II [1], who suggests making a sort of pair of tweezers with a multimeter function, so that you can instantly check the value of an SMD component before fitting it to the board. Of course, you do have to select the appropriate range for the component concerned (R, C, or L). There are also commercial versions of this type of instrument that switch over automatically to the type of component held in the tips to give its value (Ω , μF , or μH) [2]. Brilliant!

Conclusion

As we have seen, soldering SMD components takes even more care than the traditional soldering that many of us used for years before SMD components came along. As the saying goes, "Patience is a virtue"...

In this article, we're not going to attempt to deal with 'correcting' a board coming out of the reflow oven once the soldering operation has been completed. This side of things will be dealt with in the article 'Baking...!' in this cluster of articles.

(080692-1)

Internet Links

[1] <http://poeth.com/SMD.htm>

[2] www.smt-tool.com/

For further reading

http://en.wikipedia.org/wiki/Surface-mount_technology

<http://sss-mag.com/prototyp.html>

www.curiousinventor.com/guides/Surface_Mount_Soldering

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
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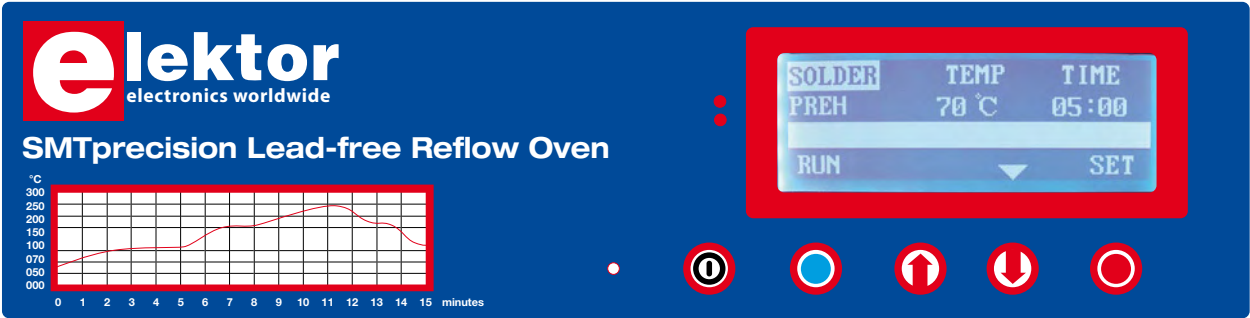
Other Products: Stencils, Keypads, Frontpanels,
Flex PCB, Enclosures, Turnkey Services

Baking...

Guy Raedersdorf (Elektor France)

So here in front of you is the lovely circuit board that you've been taking such great care with. The only problem is that the SMD components are only held in place by no more than capillary effect of the soldering paste. To make the connections permanent, the board will need to be 'baked' in the reflow oven.

Figure 1.
The front of the reflow oven is as simple as could be. From left to right, the On/Off button, the button to start the process, the  and  buttons, and the store / confirm button.





Here's a sort of photo-story of this operation, which doesn't involve any special tools.

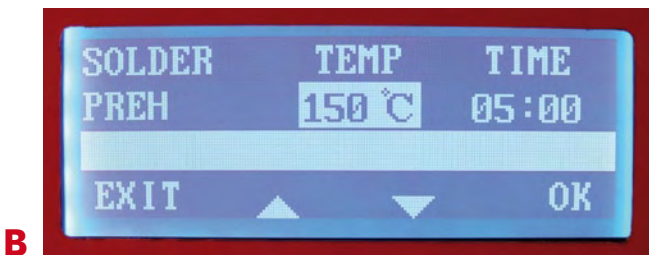
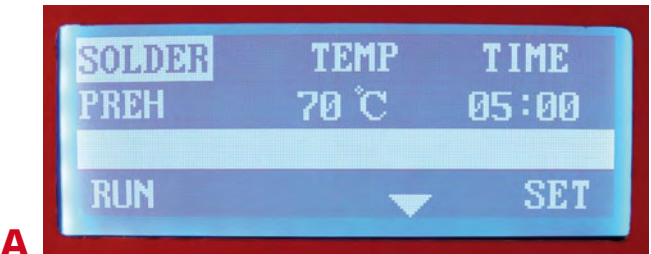
We're off!

Once you have the board prepared (soldering paste applied, all the components fitted and correctly positioned), it is time to place the PCB, with all the usual precautions, onto the tray in the reflow oven. Let's close the drawer and off we go.
You are in front of the reflow oven, which looks like **Figure 1**. Before moving on to the soldering operation proper, you need to start by defining the oven settings, i.e. how it behaves over time. Temperature and time are crucial factors. Generally, manufacturers of soldering paste and components give optimum temperature values for the former,

and maximum periods not to be exceeded for the latter. A reflow soldering process graph will look something like the one given in the 'Soldering curve' box.

Your finger... in the pie


Let's take a look at the various stages in the form of screen representations.
At start-up, you are offered the possibility of choosing your language.
Then you get to **Screen A**, with the terms **SOLDER**, **TEMP**, and **TIME** on the top line that don't change. (There is also a **REPAIR** function, which we'll come back to later). You can navigate around the menu structure by using the  and  keys.
You can go on to select the operating mode, which offers a choice between **PREH** (PREHeat), **HEAT** and **SOLDER**, **KEEP** and **COOL**. The left-hand column is the only one where the text changes, since the **TEMP** and **TIME** parameters vary according to the elements entered by the user and the current process (PREH, HEAT, COOL, REPAIR). Before you can move on to the actual soldering, you need to start by entering the settings for the operation, which can vary depending on the soldering paste used and the characteristics and size of the board not forgetting those tiny components on it.



Settings

Now you will be entering the temperature and time settings for each phase of the reflow soldering process.

Preheating (PREH)

This mode (**Screen B**), which you activate using the  key, is used to bring the board and components gradually up to the correct temperature, thereby avoiding any internal stresses on the board or components.

...or how to use the Elektor Reflow Oven

Using the SET key (on the right-hand end), you can define the preheating temperature and duration (**Screen C**). The **⬆** and **⬇** keys allow you to set the temperature, which can be from 70 to 150 °C. Once the elements are OK, press SET, or else RUN (without saving modifications) to go back up to the previous level.

Once the temperature has been defined, pressing SET again lets you adjust the duration (TIME). The time range is from 0 to 5 minutes (05:00). SET stores the value, and RUN will take you back to the start of the flowchart.

Heating (HEAT)

Pressing the **⬇** key moves you on to the HEAT function (**Screen D**). The setting procedure is similar to that described above. This menu defines the soak temperature (max. 240 °C) and the time for which this temperature is maintained (HEAT).

Soldering (SLDR)

Then you move on to the Solder step (SLDR) (**Screen E**). Press SET to store the soldering temperature and move on to the time. Press SET again to store this setting. The upper temperature limit is around 280 °C. Once the setting has been stored using SET, you can go on to set the required time (from 250 to 280 °C, the soldering time cannot exceed a maximum of 30 seconds; below 250 °C the limit goes up to a maximum of 60 seconds).

Temperature Retention (KEEP)

For the 'KEEP' phase of the process it is possible to define a temperature only (**Screen F**).

Finally, all soldering processes end with a period of...

Cooling (COOL)

This parameter (see **Screen G**) too can be modified using the corresponding controls (OK, **⬆** and **⬇**). Logically, there is no option to set the time — the temperature falls to a certain threshold, and that's all there is to it.

It's worth noting that the system is intelligent and only offers the option of **⬆** and/or **⬇** if it is logically possible.

Off we go!

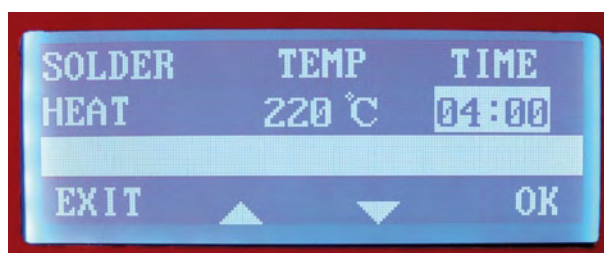
Pressing the RUN key starts the automated process, which will then follow the settings you've just made. On the display (**Screen H**), you see 'Working...' which will stay there until the process is finished. The PREH (**Screen I**), HEAT, SLDR, KEEP, and COOL steps will be displayed one after another.

During preheating (PREH), the temperature increases gradually until it reaches the set value, where it remains for the set time. When the preheat time has elapsed, the temperature rises again in the HEAT mode (Soak stage. **Screen J**) until it has reached the set value, this stage being maintained for the length of time set for soaking. Then the oven moves on to solder mode (SLDR) (**Screen K**) which lasts for just the few tens of seconds that have been set.

The system has just gone into temperature retention mode (KEEP, **Screen L**). When this period comes to an end, the



C



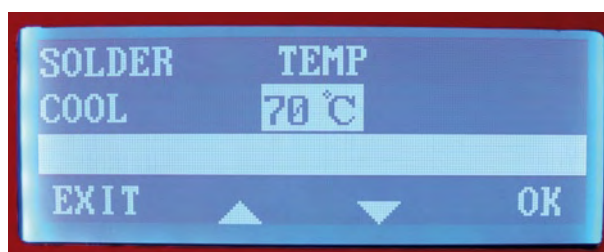
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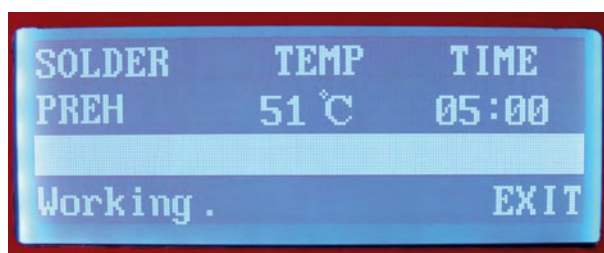
E



F



G



H

Soldering curve

Here it's the practical side of things we're interested in, so we're not going into theoretical details. But it's worth being aware that a reflow soldering curve is shaped something like the one in the **figure** here. It has five stages: Preheating, Heating, Soldering, Retention, and Cooling down.

Very often, the sections blend into one another, giving a continuous curve. However, some manufacturers of components, PCB materials and soldering pastes do suggest giving some of the reflow soldering steps a 'plateau', to allow the elements involved to better absorb the thermal shock and thereby avoid the stresses that might cause malfunctions. So an optimum duration and temperature can be set for each of these steps, except for KEEP and COOL (down).

Normally, soldering paste manufacturers give a duration of 5–6 minutes for the whole process. Some ovens, like the one described here, possess more flexible settings in terms of times and temperatures. The curve gives a good idea of the reference temperatures and times (it's worth noting that in the case of lead-free soldering paste, the peak of the curve reaches a higher temperature (235 °C to 250 °C or even 255 °C, instead of 208–230 °C), which it maintains for a few tens of seconds (typically 45 to 70 s). At 70 °C the operation is over but be sure to wear safety gloves when removing your board from the oven if you can't wait for the COOL phase to finish.

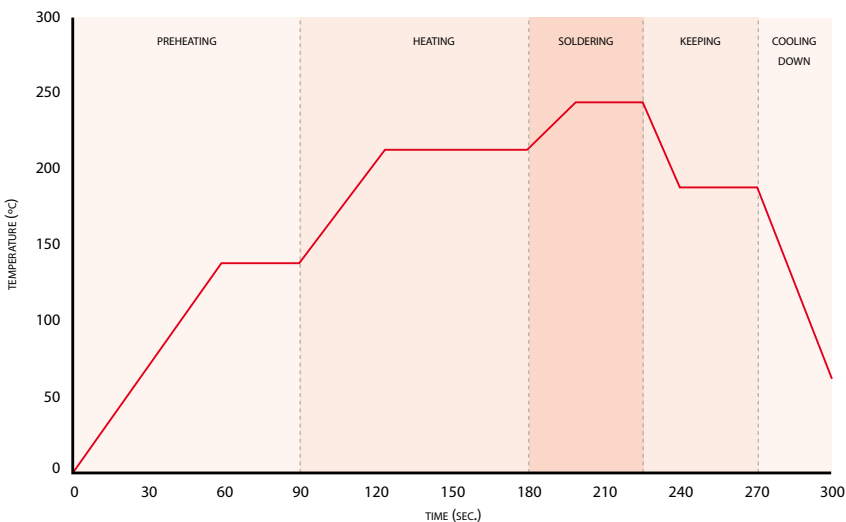


Figure A. Example of a temperature profile during a soldering operation.

IR heating elements are put into standby (or turned off completely). The cooling period (COOL) starts (**Screen M**) and the internal extraction fan runs until the temperature inside the

oven has dropped to virtually that of the surrounding air. When the operation is over, the oven announces this by '**Completed**' (**Screen N**).

There is one option left that doesn't apply to normal soldering...

Repair
The 'REPAIR' mode (displayed at the top left — no screen dump for this) is used in the event that a soldering operation has failed to produce the desired result, or if SMD components are to be salvaged from a board! Here too you can set the temperature and time to the required values using the **⏮** and **⏭** buttons.

The time is limited according to the temperature range selected: between 70 and 150 °C, there is no time limit; between 150 and 200 °C, the maximum time is 60 minutes; and between 200 and 250 °C, 5 minutes maximum. If you've applied the soldering paste and fitted the components with the necessary care and attention, the board you take out of the reflow oven will hopefully look like the one in **Figure 2**. If not, get out the ingredients again...

Is that all?
An intelligent device implies displaying messages not only when everything's working as it should, but also in the event of problems.

In this event, a large **ERROR** appears on the second line, and the bottom line explains in plain language the nature of the unit's 'worries' — excessive temperature, heating element(s) not working, etc.



Conclusion

Once the settings to be used for a particular operation have been correctly defined, using the reflow oven ought not to present any problem. Preparing the board is what takes all the care and attention.

(080664-L)

Internet Links

www.curiousinventor.com/guides/Surface_Mount_Soldering

www.seed-solutions.com/gregordy/Amateur%20Radio/Experimentation/N2PKVNA/SMT.htm

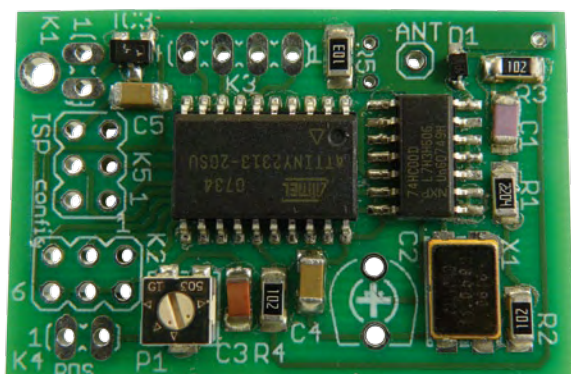
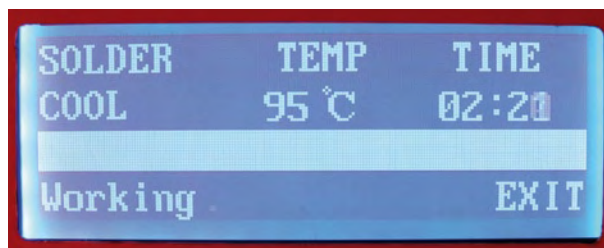


Figure 2. The result of an earlier try-out.



L



M



N

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Effective PCB area: 280 x 280 mm (11 x 11 inch)

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Multi-purpose GPS

For those who are keen to know everything!

Christian Tavernier (France)

Although satnav systems have been in our cars for some years now, it's only recently that stand-alone GPSs have appeared aimed at the amateur market. Despite their small size and often very affordable prices, they have nothing to envy their predecessors, and if we team them up with suitable electronics, they can perform our positioning or navigation tasks just as accurately as the manufactured products.



Although these receivers are relatively simple to use, Internet research shows that many amateur electronics or robotics enthusiasts don't know how to set about exploiting these little technological jewels. So in this article we're suggesting three different projects where you can learn how to use these receivers.

Totally standardized dialoguing – or almost!

Historically, the first GPS information was used by mariners, and Naval ones at that. No surprise then that the GPS should have adopted the NMEA (National Marine Electronics Association) communication protocol, originally designed to facilitate data exchange between the various instruments on board, long before GPS even existed.

If you only want to build the GPS receivers described here, the subtleties of this protocol aren't of any great importance to you. However, if you want to modify these receivers or perhaps build a GPS receiver into your robot, we invite you to read the box about it.

Then you'll be able to see that it's still relatively simple... well, almost!

In fact, although all current GPS receivers do indeed respect the hardware part of the protocol, along with the basic character format, during our experimenting we noticed that certain receivers do take a few liberties with the frame content. The format of certain data – for example, altitude or ground speed – can actually vary from one device to another, making decoding the data a bit more complicated (pun intended). We'll come back to this later.

The receiver chosen for these projects

For these projects, we've chosen the EM-406A receiver, made in South-east Asia (where else, these days?) by Globalsat Technology Corporation [1] and available from Lextronic [2], amongst others.

This receiver is very compact at only $30 \times 30 \times 10.5$ mm yet offers characteristics that will be the envy of certain car model manufactures. Fitted with an SiRF Star III, it achieves a remarkable sensitivity of -159 dBm – to the point

that the author was able to acquire 8 satellites even with it shut in a metal desk drawer located inside a reinforced concrete building.

Powered from a voltage between 4.5 and 6.5 V, the GPS receiver draws just under 45 mA. The only slight niggles in this fanfare of praise are the technical documentation – which, although it gives the appearance of being comprehensive, is in fact inaccurate, particularly in terms of the NMEA frames format; its output level – described as 'TTL', it isn't really, which may pose problems of interfacing with certain microcontrollers, as we'll be seeing further on; and finally, the format of certain data in its NMEA frames, which is a little... 'creative'!

Despite this, the EM-406A is still an excellent choice, as you're about to see. However, as all GPS receivers output the NMEA frames used by these projects, there's nothing to stop you choosing another model of receiver, or even using your car satnav, provided its data output is accessible – and that's usually the case with the better models.

Receiver



43.150315, 6.032759

Route Nationale 97

A570

A57

Rue du Docteur Sch...

Rue du Docteur...

Ave...

de Draguignan

Claude Fabre de Préfese

des Plantades

chemin du Portugal

DISPLAYTECH 204A

The first project on offer is extremely

simple, and makes it possible to interface the GPS receiver with the RS-232 serial port of any computer equipment,

and hence, a PC. It will enable you to use your PC for navigation using different pieces of software – and not neces-

The NMEA standard was created to facilitate the exchange of data between electronic navigation equipment. So it's only to be expected that the GPSs use it, since the first users of these devices were mariners.

The standard used by GPS receivers is NMEA version 0183, which states that data transmission occurs in asynchronous serial form with 8 data bits, 1 stop bit, and no parity, at a speed of 4,800 b/s. This standard operates by sending messages or frames, all organized in the following way:

A frame always starts with the character \$ (dollar) followed by two letters that identify the type of sender (GP in the case of a GPS, but you might also find EP for a position beacon, HC for a compass, etc.). Then come three other letters identifying the type of frame for the sender concerned. In the case of GPSs, the RMC frame is the most common (for the simplest devices, the only one even), but you do also find GGL, GGA, GSA, etc.

Then come the various data fields, each separated by commas. The order and size of these fields depend on the frame involved and so there is no common rule for all the frames. The * (asterisk) character immediately follows the last data (i.e. with no separating comma) and precedes a 2-character checksum, calculated by performing an exclusive OR on all the message characters from \$ to * inclusive. So here, for example, is what an RMC frame provided by a GPS looks like:

\$GPRMC,114630.325,A,4315.0426,N,00603.2734,W,0.20,307.53,
310508,,E*54

If one data element is missing from a field, the place for it must be present all the same, so you may find two successive commas, as shown at the end of the example above. The various frames arrive in an order not defined in the standard, since they are in any case clearly identifiable by their header (the five letters following the \$ character).

The standard defines more than 30 frames just for GPSs alone. So it's quite out of the question for us to reproduce them all here, especially since the majority of GPS receivers provide only a few of them. So we're offering you just the two most useful frames in the two tables here. You can find out all about the others in the instructions for your GPS, if it provides them.

As far as the EM-406A receiver used for these projects is concerned, it provides the GGA, GLL, GSA, GSV, RMC, and VTG frames, the formats of which are (more or less) described in its data sheet, downloadable from the manufacturer's website (see address list).

Before investigating these formats, do note that the RMC frame is the minimum frame needed for navigation, and is sometimes the only one used by the simplest devices.

Contents of a typical GGA frame	
Format	Signification
\$GPGGA	Indicates the start of the frame, the sending device, and the type of frame
hhmmss.dcm	Time in UTC, to the nearest thousandth of a second
ddmm.mmmm	Latitude in degrees, minutes, and fractions of minutes
N or S	North or South
dddmm.mmmm	Longitude in degrees, minutes, and fractions of minutes
W or E	West or East
X	'fix' indicator : 0 = fix invalid, 1 = fix valid, 2 = fix valid, differential mode
NN	Number of satellites being used
XX	HDOP horizontal dilution of precision
AAAA	Altitude in metres above sea level
M	Altitude units (M for metres)
DDDD	Difference in altitude between the WGS84 ellipsoid and sea level
M	Difference units (M for metres)
SSSS	Age of the differential data in seconds
NNNN	Differential station ID
*XX	End of frame indicator and checksum

Contents of a typical RMC frame	
Format	Meaning
\$GPRMC	Indicates the start of the frame, the sending device, and the type of frame
hhmmss.dcm	Time in UTC, to the nearest thousandth of a second
A ou V	Valid (A) or invalid (V) data
ddmm.mmmm	Latitude in degrees, minutes, and fractions of minutes
N or S	North or South
dddmm.mmmm	Longitude in degrees, minutes, and fractions of minutes
W or E	West or East
VVV	Ground speed in knots
CCC.CC	True heading in degrees and fractions of degrees
JJMAAA	Date
XXX	Variation
E or W	Sense of the correction (East or West)
*XX	End of frame indicator and checksum

sarily of the payware type, as we'll be telling you below about some excellent freeware.

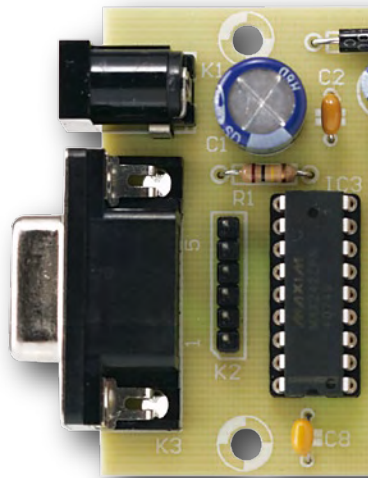
This interface will also let you display, on the PC, the NMEA frames actually transmitted by the GPS receiver. If you plan to build this receiver into a project of your own, or modify the software for the stand-alone GPS receiver we're proposing, this will prove a very handy investigative tool.

Figure 1 gives the circuit diagram of this interface, which shows a certain originality, as it can be powered either from a PC's USB port or by an exter-

nal PSU (depending on the position of jumper JP1: external towards the outside, USB towards the inside of the PCB). This board can be connected to the PC in two ways: via either a COM port or a USB port.

In the case of the serial approach, the MAX242 converts the receiver's (almost) TTL output signal levels into RS-232 levels, and vice-versa. In this case, use of an external power supply will be obligatory. As both the MAX and the GPS receiver need +5 V, a common or garden 3-terminal regulator will allow us to obtain this from any voltage between +8 and

+12 V applied to power socket K1. For the USB link, we could use the Elektor/FTDI TTL-232-R cable (SHOP item 080213-71) which will connect header K2 to the PC's USB port. In addition, activating the EN signal via the USB cable allows the MAX242 to disable the RS-232 port transceivers,



GPS/PC adaptor

thereby protecting the USB cable from overloads if the COM port is still connected (dual connection is possible!). We recommend you not to use both power supplies at the same time.

If you are only ever going to be powering via the USB, the supply components (K1 to C3) may be omitted, and JP1 fitted towards the inside, or even replaced with a wire link.

Even though most of the communications will be going from the GPS to the PC, it should be noted that this interface is bi-directional, as the EM-406A receiver is capable of understand-

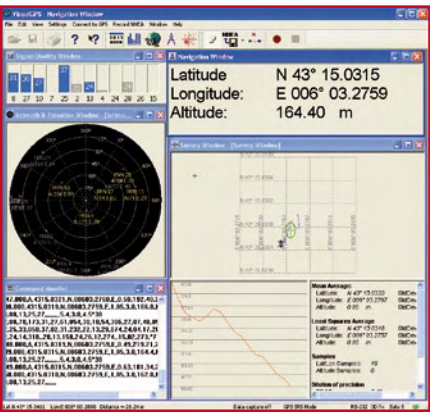


Figure 3. VisualGPS offers a very comprehensive display.



Figure 4. GPS TrackMaker has a cartography system.

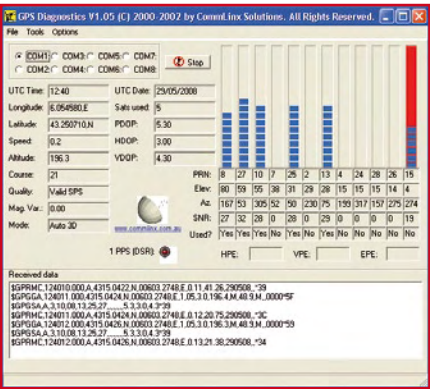


Figure 5. GPS Diagnostics lets you display and decode the NMEA frames.

start', i.e. acquire the satellites very quickly if it has not been moved since it was powered-down, as long as it hasn't been left without power for too long. To exploit the data provided by the GPS, you can use one of the count-

less free or paid up applications available on the Internet. A simple Google search will offer you an overwhelming choice, but as far as we're concerned, we recommend you try, for example:

– **VisualGPS** [3], one of the most comprehensive, offering (Figure 3) both a decoded display of the GPS data and the contents of its output frames, with the added possibility of saving them to a file. Take care, though, not to get muddled up: VisualGPS is free, while VisualGPSXP is paid for.

– **GPS Track Maker** [4], just as free, also allows the GPS output data to be displayed, but also offers navigation facilities (Figure 4) by means of a large number of maps that can be downloaded from the Internet.

– **GPS Diagnostics** [5] has a slightly less rich interface (Figure 5), but does still display all the data output by the GPS receiver, along with the raw content of the frames it provides.

So whether you opt for GPS Diagnostics or VisualGPS, you'll have an excellent tool for saving the frames provided by the GPS receiver and then if necessary analyse them at leisure. Let's not forget these frames are just a series of ASCII-coded characters (as shown in the box), and so can be manipulated using any text editor.

A very simple stand-alone GPS receiver

This first receiver is very simple to construct – so much so that we haven't even designed a PCB for it. However, *let's render unto Cæsar that which is...* Lextronic's. It actually comes straight out of Application Note 36 relating to the Cubloc circuits from Comfile Technology, a well known advertiser in the French edition of Elektor.

As Figure 6 shows, the circuit is incredibly simple: apart from the GPS receiver itself, it requires only an LCD display – admittedly a bit special, we'll be coming back to that later – and a Cubloc CB220. Let's not forget that this circuit, which we've already discussed in our Summer 2007 special robotics double issue, is in fact a hybrid microcontroller, similar in concept to the famous Basic Stamps from Parallax, with which it is also pin compatible. Though still based on an Atmel ATmega128 processor, the Cubloc CB220 is more

powerful than the Basic Stamp and has a much fuller and better-performing Basic interpreter.

The GPS receiver serial output is connected to the input of the UART built in to the CB220, which in turn drives the display – an LCD alphanumeric type with 4 lines of 20 characters – via just the two port lines P8 and P9. An I²C bus is available, and the CLCD display from Comfile Technology [6] is also fitted with this type of interface, referred to by Comfile as 'Cunet'. Only pull-up resistors for the I²C bus SDA and SCL lines need to be added.

Switch S1 lets you choose two different display screens: the first indicates the first eight satellites received with their respective levels in the form of bargraphs; the second displays time, latitude, longitude, number of satellites being received, and indicates if the details displayed are valid.

The 9-pin sub-D connector marked J1 is not used in normal operation — only during the programming phase of the CB220, which is carried out from the serial port of any PC running the free Cubloc Studio development software. Given the simplicity of the circuit, we built the project on prototyping board, also on offer from Comfile under part no. 'CB220 proto', as the price of about € 10 (approx. £ 7.50) is less than the cost of the items you'd need to build it.

Board wiring amounts to fitting resistors R1 and R2, the connectors for the display and the connection to the GPS receiver. For the latter, we proceeded in the same way as for the RS-232 interface above, but with only 3 pins, as this project operates only in the direction GPS → microcontroller.

Take care! The CB220 can be powered using an unregulated voltage between +5.5 V and +12 V via its pin 24 (VIN), and it will then output a stabilized voltage of +5 V from its pin 21 (VDD). However, this option must not be used in this particular project, as the CB220's built-in regulator can't supply the combined current of the GPS receiver and display together. So the whole circuit needs to be powered via pin 21 (VDD) of the CB220, which in this case becomes its power input.

If you still want to use the jack wired onto the CB220 prototype board, two minor modifications need to be made. The first is to slightly bend pin 24 of the CB220 so that it no longer enters the

This listing is provided in the form of source code, and in BASIC moreover, and is well covered in the aforementioned application note, so we won't repeat these comments here. But we do still recommend you to only study



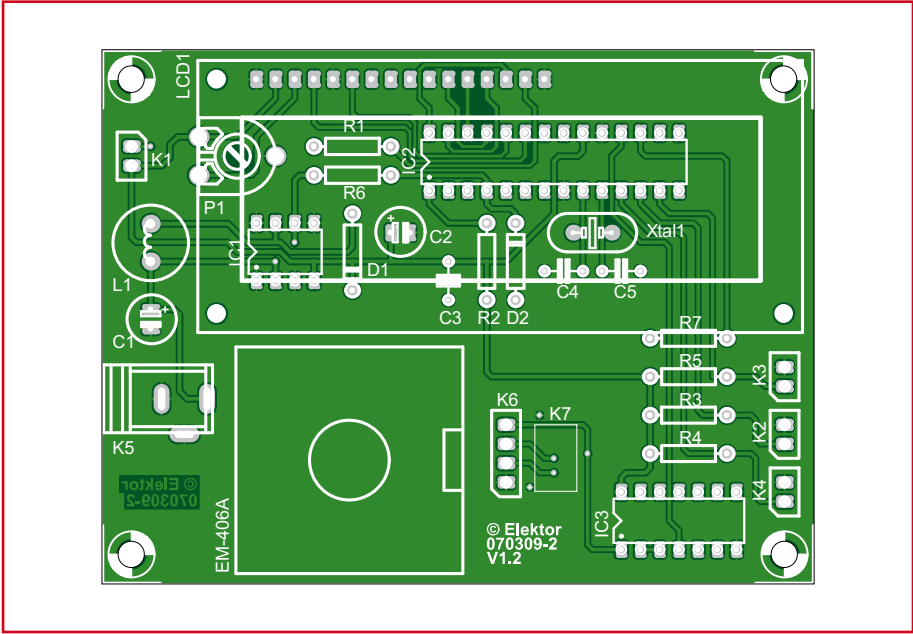
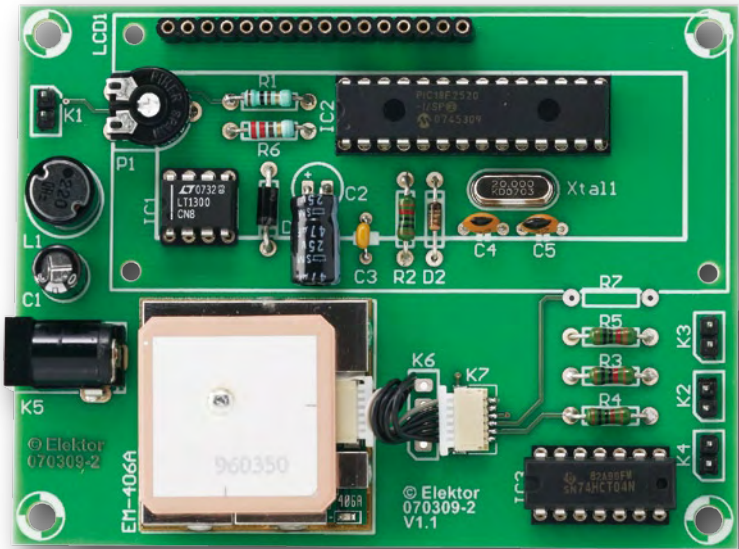


Figure 8. Component overlay for the comprehensive self-contained GPS receiver.



The wiring for the very simple stand-alone GPS receiver on the CB220 prototype board amounts to very little.

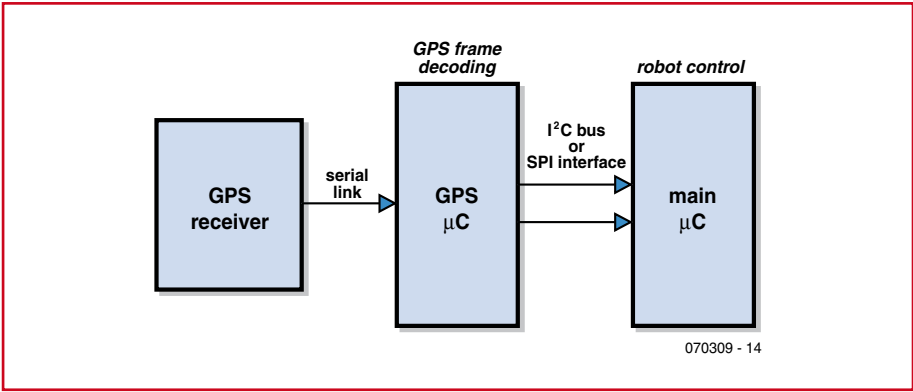


Figure 9. Block diagram for fitting a GPS receiver into a robot.

it after you've read the **inset** about the contents of NMEA frames. Note that this software decodes frames using detection of commas (the field delimiters).

Once the program has been downloaded into the CB220, the link with the PC can be disconnected for good, and the circuit then becomes stand-alone. Moreover, since you have both the source listing and the Cubloc Studio development tool, you can modify this software at your leisure if the displayed information doesn't suit your needs. In this way you might, for example, decode the end of the GGA frame to add a display of altitude, or the end of the RMC frame to display speed.

The circuit operates as soon as the program has finished loading, but if the display only shows its blinking cursor instead of the GPS information, check its I²C address is correct. This is set to 1 by the program line: Set Display 2,0,1,50, while the CLCD displays seem to be supplied with an I²C address set to 0. In that event, modify accordingly either the position of the display's DIP switches (to make its address 1), or the program line (to use a display at the I²C zero address).

A comprehensive self-contained GPS receiver

The above receiver is certainly perfectly functional and very quick to implement, but it still costs quite a bit, mainly because of the cost of the CB220 and the associated CLCD display. So now we're suggesting you really 'get your hands dirty' by building a receiver from scratch.

Just like the previous one, this has an LCD display with 4 lines of 20 characters – but a type without serial or I²C interface, and so much cheaper to buy. In addition, more and different information is provided. What's more, our receiver is totally self-contained, as it can be powered from two 1.5 V dry cells, or better still, two 1.2 V rechargeables. It is relatively compact, as it fits onto a PCB that mounts onto the back of the display board. The source listing of the software used is provided for you to download free, allowing readers to adapt it to their needs if the choices made by the author do not suit you. The receiver circuit shown in **Figure 7** is easy to follow. The heart of the circuit is IC2, a PIC18F2520 microcontrol-

ler. Using an IC from the PIC18 family allows us to have an extended instruction set and larger program and data memories than with the PIC16 family, for almost the same price. It controls a standard LCD display with parallel interface in 4-bit mode, which explains why DB0–DB3 are not connected. The presence of switch K1 means you are free to choose a backlit display – at the price of increased power consumption, of course, but more legible in low-light conditions.

The signal from the GPS receiver goes to the input of the PIC's built-in UART, but first has to be brought up to level by IC3. This is one of the criticisms we

version given here, but it's still provided for anyone who might want to add functions to this project.

To obtain a high-efficiency power supply, we've dispensed with a conventional linear regulator and used an LT1300 from Linear Technology (IC1). From an input voltage applied to power jack header K5 between +2 V and +5 V, this remarkable circuit provides a stabilized voltage of +5 V at a current of up to 400 mA in the configuration used here. So two 1.5 V dry cells or two 1.2 V rechargeables are perfect for powering this project, giving it around ten hours of operation.

The battery voltage is also applied, via

The choice of components presents no difficulty, but if you don't use the recommended type for L1, be careful to choose a choke capable of handling a current of 800 mA without saturating. If you don't, the LT1300 will work badly, or not at all.

We have provided two options for connecting the GPS receiver. If you're lucky enough to be able to get hold of a male header for K7, you'll be able to solder it in place on the top of the board. If not, as in the other two circuits, you can use 2.54 mm-pitch male pin headers and modify the receiver cable as explained above. The connections to the various switches are like-

COMPONENTS LIST

GPS/PC Adaptor

Capacitors

C1 = 470µF 25 V radial
C2 = 220nF MKT
C3 = 10µF 25 V radial
C4-C9 = 100nF ceramic

Semiconductors

D1 = 1N4004
IC1 = 78L05
IC2 = GPS receiver type EM-406A (see text)
IC3 = MAX242 (Maxim IC)

Miscellaneous

K1 = PCB mount DC adaptor socket
K2 = 6-way SIL pinheader
K3 = 9-way sub-D socket (female), PCB mount
K4 = connector type SM06B-SRSS-RB (Digikey)

K5 = 4-way SIL pinheader
JP1 = 3-way SIL pinheader with jumper
PCB copper track layout, free download # 070309-1 from www.elektor.com

Comprehensive Autonomous GPS Receiver

Resistors (0.25W / 5%)

R1 = 100Ω
R2-R5 = 10kΩ
R6 = 220Ω
R7 = 0Ω*

Capacitors

C1 = 100µF 25V radial
C2 = 47µF 25V radial
C3 = 10nF ceramic
C4,C5 = 22pF ceramic

Semiconductors

LCD1 = alphanumeric LCD, 4 lines of 20 characters
IC1 = LT1300
IC2 = PIC18F2520, programmed, Elektor SHOP # **080309-41**
IC3 = 74LS04
D1 = 1N5817 (must be Schottky)
D2 = 5.1V or 5.6V 400 mW zener diode

Miscellaneous

L1 = 22 µH, Panasonic type ELC08D (e.g. RS Components)
Qz1 = 20MHz quartz crystal
P1 = 10kΩ preset H
K1-K4 = 2-way SIL pinheader
K5 = DC adaptor socket
K6 = 4-way SIL pinheader
K7 = connector type SM06B-SRSS-TB(LF)(SN) (Digikey)
Type EM-406A GPS receiver (see text)
PCB copper track layout, free download # 070309-2 from www.elektor.com

made above of the EM-406A module: its logic High output level of 2.85 V is lower than the 4.00 V minimum High threshold of input RC7 on the PIC. So without IC3, the UART would never receive any data whatsoever.

The pushbutton connected to header K4 lets you toggle between the display screens. One shows latitude, longitude, altitude, and speed; the other, time (real, summer/winter depending on the position of switch S2), date, number of satellites being used, and battery voltage.

Switch S2 (K2) lets you choose between BST and GMT so as to display the 'real' time and not the raw UTC (Universal Time) provided by the satellite. Switch S3 (K3) is not used in the

resistor R6 and protective zener D2, to input AN2 of the PIC's analogue-to-digital converter (ADC), enabling us to display it and hence be able to judge how much operating time is left. Resistor R7 (0 Ω = it's a wire link!) is only fitted if you want to establish communication from the PIC to the GPS module and thereby be able to experiment with sending commands using the PIC.

Construction

Construction is particularly easy as there are no SMD components and the PCB is a single-sided type with a track pattern that's easy to copy, even with limited resources, as you can see from **Figure 8**. The display is mounted onto the board.

wise brought out on the same type of pin headers.

As far as the display is concerned, we fitted 2.54 mm-pitch female strip contacts to the back of it and male contacts at the same pitch on the copper side of the PCB. This is an easy way to construct an assembly that's easy to dismantle in the event of problems.

In order to simplify the PCB layout and keep it single-sided without needing too many wire links, we've not fitted an 'in-circuit' programming connector for the PIC. So it will need to be programmed using an external programmer before it's fitted into its socket. Elektor has described numerous projects of this type, and you'll also find one you can build yourself on the

author's website. The IC is also available ready-programmed via the Elektor website (see component list). The software to be programmed into the PIC is available for download from the Elektor website, as well as the author's own website, in two forms: an object file (with a .hex extension), ready to be programmed into the PIC, and the source file in Mikroelektronika Basic [7], since this is the compiler we used for this project.

Before fitting the PIC into its socket and connecting up the display and GPS receiver, connect the batteries to the circuit and check you have got +5 V on the LT1300 output. If this is OK, you can turn off the power, fit these last elements, and apply power again. The display should first indicate "Acquiring Sat." then "Invalid Data" while the receiver is not ready. However, as soon as the receiver's LED starts to blink, the information it provides should appear on the screen.

Software and incorporating into a robot

The software used for this receiver is inspired by that suggested by Marcel Durieux in the Mikroelektronika forum, with a certain number of adaptations aimed at making it work with the EM-406A receiver, not used in the original version.

While the previous receiver decoded the frames by detecting and then counting the commas (field delimiters), this one receives a complete frame and the range into an indexed variable. The advantage of this method is that it is simpler to implement. The reception of the characters sent by the EM-406A module is taken care of by the following very short function:

```
sub function ReadChr as byte
do
loop until USART_Data_Ready = 1
result=USART_Read
end sub
```

All that remains is to call it up in a loop to store the characters sent by the GPS receiver into an indexed variable. End-of-frame (EOF) detection can be achieved either by receiving the asterisk that precedes the checksum, or when the number of characters received is clearly greater than the maximum allowed by the standard. Here's an example:

```
do
GPSstr[i]=ReadChr
if GPSstr[i]="*" then
i=0
else
i=i+1
end if
loop until (i=0) or (i=75)
```

Frame decoding is then performed, according to the position of the data in the indexed variable GPSstr[i]. According to the NMEA standard, this position is fixed for a given piece of data. Unfortunately, the EM-406A receiver is a little 'creative' in terms of the length of the fields at the end of the RMC frame, requiring some adjustments in order to display the date, as you can see from a look at the BASIC listing.

We won't go right through the listing here, but have highlighted two extracts from it to help those who might want to incorporate such a receiver into a mobile robot, for example. This is actually very simple with the information in this article, but we do need to draw your attention to a couple of points.

The first concerns the accuracy of a GPS receiver, which is not unlimited, and depends heavily on the number of satellites being correctly received. In the best cases, we can hope for around 2 to 3 m with 7 or 8 satellites being received. When this number is reduced, the accuracy drops off rapidly, approaching 10 m with only 4 satellites. This is enough for route-finding in a car, but not for your robot to be able to pass between a chair and a table in your lounge, for example – unless of course you live in a castle!

The second concerns the decoding of the GPS frames, which is a time-consuming task, especially if you want 'good' accuracy, which implies constant position updating. So it must not be tasked to the robot's main processor, which would have to spend most of its time just doing this. So we recommend using the architecture given in **Figure 9**, where a microcontroller – and why not the PIC18F2520 of our previous receiver? – receives and decodes the frames. All it then has to do is provide the robot with just the required information – most usually, latitude and longitude. This can take place via its SPI port for example, or over the I²C. In this way, the robot's main processor is free to get on with its most important

primary responsibilities, and only come and collect the ready-to-use information when it actually needs it.

Conclusion

Apart from suggesting three projects we hope you'll have found interesting, we also hope this article has been able to answer some of the questions frequently found on the Internet about how to interface a GPS receiver with a microcontroller.

(070309-1)

Internet Links

- [1] Globalsat Technology Corporation:**
www.globalsat.com.tw
GPS receiver manufacturer. Product datasheet downloading.
- [2] Lextronic:**
www.lextronic.fr
Distributor for the GPS receiver and Comfile products. Downloading the datasheets and instructions for the CB220, the LCD display, Cubloc Studio and the very simple GPS receiver software.
- [3] VisualGPS LLC:**
www.visualgps.net
Downloading the VisualGPS software.
- [4] GPS Track Maker:**
www.gpsm.com
Downloading the GPS Track Maker software.
- [5] CommLinux Solutions:**
www.commlinx.com.au
Downloading the GPS Diagnostics software.
- [6] Comfile Technology:**
www.comfile.co.kr
Manufacturer of the Cublocs. Downloading the data sheets and instructions for the CB220, the LCD display, and Cubloc Studio.
- [7] Mikroelektronika:**
www.mikroe.com
Publisher of the MikroBasic BASIC compiler used for the full GPS receiver.
- [8] Author's website:**
www.tavernier-c.com
Downloading of the software for both GPS receivers.
- [9] Elektor website:**
www.elektor.com
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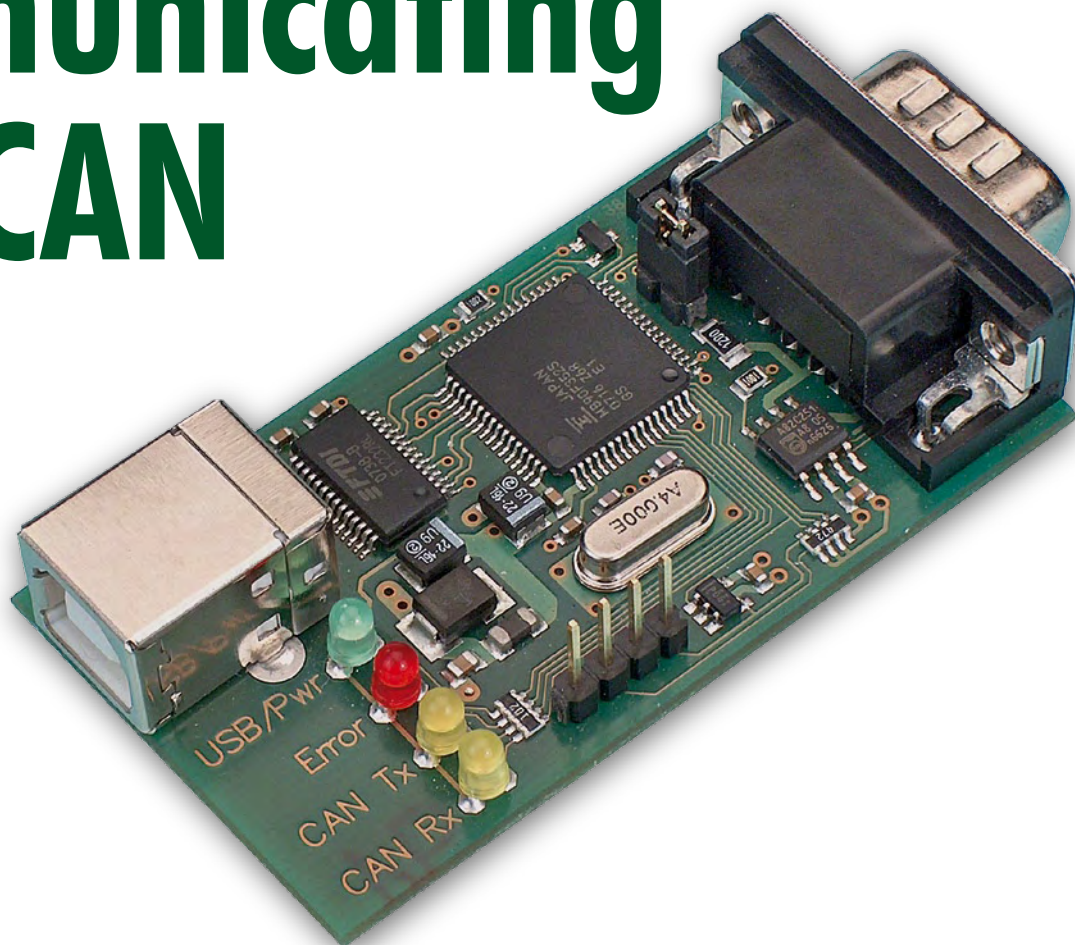
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Communicating with CAN

Compact USB-CAN Adapter

Klaus Demlehner



Despite the fact that the CAN protocol is a serial protocol, it can't just be connected to (the serial port of) a computer. The all-round USB-CAN adapter described here provides a compact and simple solution. With the help of the accompanying software you can follow all data communications taking place and carry out operations such as filtering and storage at the flick of a (mouse) switch.

The CAN (Controller Area Network) protocol was originally developed for use in the automotive sector. It is now over 20 years old, but is still frequently used these days. The protocol was invented by Bosch in order to let microcontrollers and other electronic devices communicate with each other.

It was specially designed for use in environments where you have a lot of electromagnetic interference. Because of this it was decided to use differential signalling, all of which made CAN especially suitable for use in the automotive sector.

The design

The USB-CAN adapter presented here makes it very easy to communicate

with the CAN bus. The data present on the CAN bus can be read via a USB connection, which can be found on virtually every PC these days. You can of course also transmit data. The recommended software, *Tiny CAN View*, has a handy and clearly laid out user interface for this.

Apart from the recommended software, the USB-CAN adapter can also be used with other 'third party' software such as *CANopen Device Monitor* and *CAN-REport*. After installing the device driver for the FTDI USB interface chip used in the adapter it can be easily accessed from either Windows or Linux operating systems. When a firmware update for the microcontroller is required this can also be easily done via the same USB connection.

The circuit diagram

The size of the circuit diagram (**Figure 1**) is certainly not reflected in the size of the final PCB. The microcontroller in particular is a lot smaller in real life, mainly because of its SMD packaging. The other functional blocks in the circuit diagram stand out very clearly: nearly every block represents an IC. The USB interface makes use of a USB-to-serial converter chip (IC1). This chip is the well-known FT232RL made by FTDI. It is widely supported in both the Windows and Linux operating systems. The only external component required by the FT232RL is a capacitor (C6), which is used to stabilise the internal 3.3V supply voltage. The 16-bit microcontroller made by Fujitsu (IC3) comes with integrated

Hardware highlights

- Electrically isolated
- External power supply of 9 to 48 V
- Protection circuitry for CAN and external supply, especially for automotive applications
- Hardware based transmit buffer using an interval timer, with a capacity for up to 16 CAN messages
- Microcontroller supervised by 'Hardware Watchdog'
- Firmware for the module can be updated via the USB bus.

Software highlights

- Data reception in either polled or event-driven mode (Callback function)
- Selection of received messages via filter rules
- Transmit buffer with an interval timer
- Supports saving of log files

CAN support and forms the heart of the circuit. From the controller we use the serial and CAN interfaces, and the controller also has a built-in 15-channel 10-bit A/D converter. However, the latter is not used in this circuit.

To show the status of the USB-CAN adapter we have connected four LEDs (LD1 to LD4) to the controller. With the help of **Table 1** you will be able to determine the current status of the controller.

The microcontroller (IC3) can be programmed via the USB interface. D1 is used here to protect against over-voltages. Components C1, L1, C4 and C5 make sure that any RF interference picked up by the USB cable stays out-

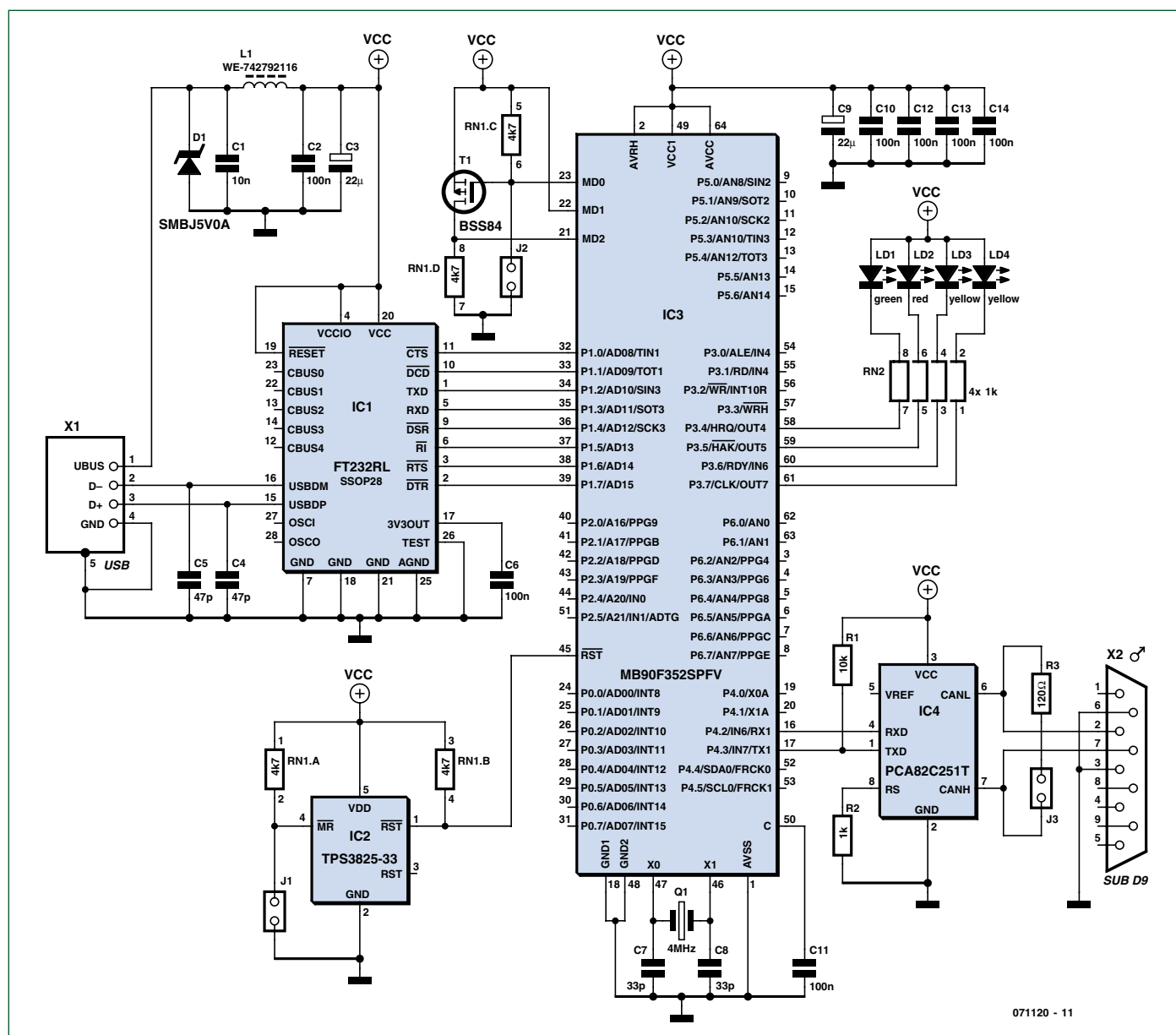


Figure 1. The circuit diagram seems much larger than the PCB. It is clear that the microcontroller made by Fujitsu (IC3) plays the main role in this circuit.

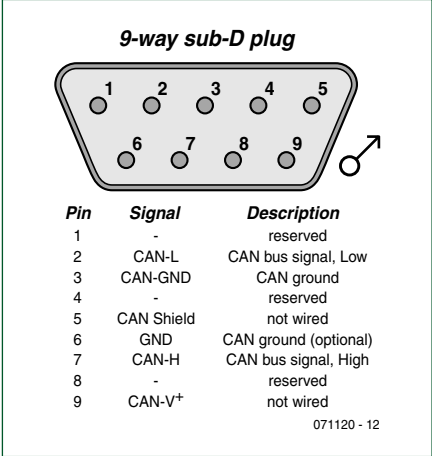
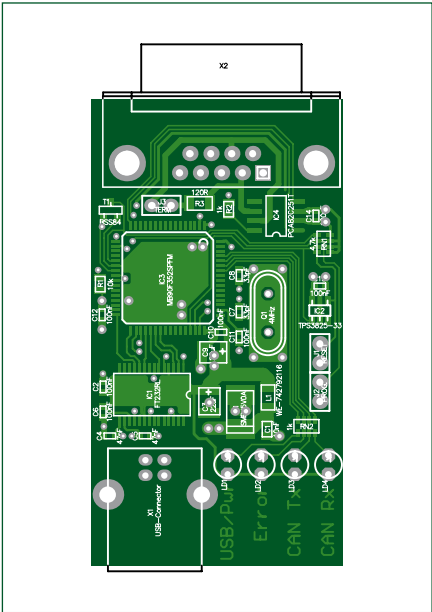


Figure 2. This shows the pinout of the 9-way sub-D plug used for connections to the CAN bus.

side the circuit. In that way they also protect IC1.

When programming jumper (J2) is not plugged in, pin 23 (MD0) is connected to the positive supply via RN1C and pin 21 is connected to ground via RN1D. The controller is then in RUN mode. With the programming jumper in place, pin 23 (MD0) is connected to ground. Transistor T1 will then conduct and present a logic High level to pin 21 (MD2). The controller is then in its programming mode.

IC2 is a reset controller, which together with jumper J1 serves as an external reset circuit for the microcontroller.



and adapted via the *Filter* sub-menu. Messages can be filtered in three different ways:

- *single*: a CAN message with a certain Id is extracted from the data stream.
- *range*: messages with an Id between two programmable values ('Id start' and 'Id stop') are displayed.
- *masked*: the Id is filtered using a mask. Only those bits that have a '1' in the mask field (see **Figure 5**) are compared. The values of the other bits in the received message are ignored.

In the transmit list the values for the CAN Id and other data can be represented in several ways. A prefix is used to show how the data is displayed: 'x' stands for hexadecimal, 'd' stands for decimal, 'b' for binary and 'c' for ASCII. To change the display method you should click on the prefix with the mouse.

Let's get started!

The module is supplied with all SMD components already mounted. Only the through-hole components need to be soldered on the board (**Figure 6**). When the USB connector has been mounted the controller can be programmed. But before you can do this, the driver for the FTDI chip (USB interface) has to be installed. Until this has happened you should **not** connect the module to the USB port. The most up-to-date driver can be downloaded from the FTDI website [1]. At the time of writing these are version 1.35r1 for Linux and version 2.04.06 for Windows, for which you can also download a 'setup executable' called *CDM 2.04.04.exe*.

To program the microcontroller you first need to plug on programming jumper J2. Only then should you connect the USB cable (please note: J2 should NEVER be plugged on or removed while the USB cable is connected!). The computer will then detect the new hardware (in the case of Windows) and show it as a USB serial port.

Download the software from the Elektor website and extract the files from the zip file. Next run the program *TCanFirst* in the folder .../Tiny-CAN/fu_down/TCanFirst. This programs the Flash Bios of the module. After a message has appeared saying the flashing has completed successfully you can unplug the USB

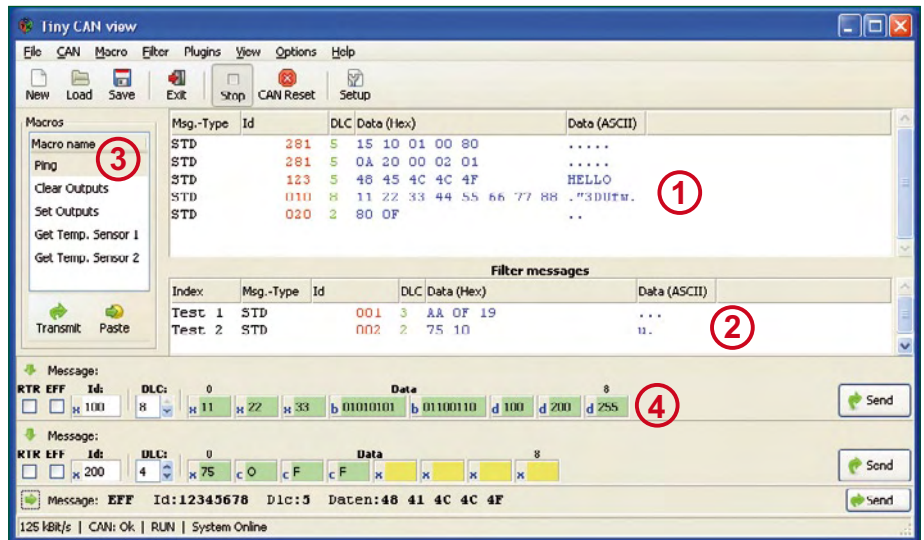


Figure 4. The relevant information is clearly laid out in the main window of the software.

cable and remove the programming jumper (J2).

After reconnecting the USB cable the red LED should light up. You are now at the stage where you can program the actual firmware. For this you need to run the program *TCanProg* that is found in the folder .../Tiny-CAN/fu_down/TCanProg. When the green LED lights up you know that everything has completed successfully. For a future firmware update you only need to carry out the last action again (run *TCanProg*). The CAN monitor program can now be started.

Tiny CAN View is a CAN monitor program available for both Windows and

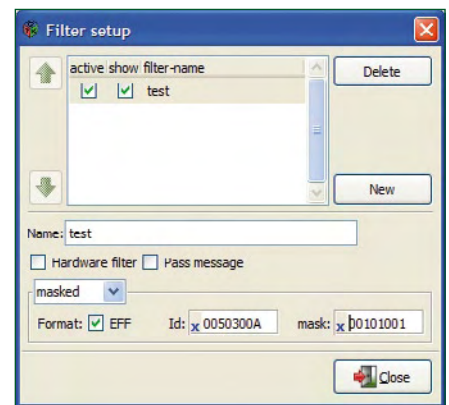


Figure 5. The filter parameters can be easily modified in the filter setup window.

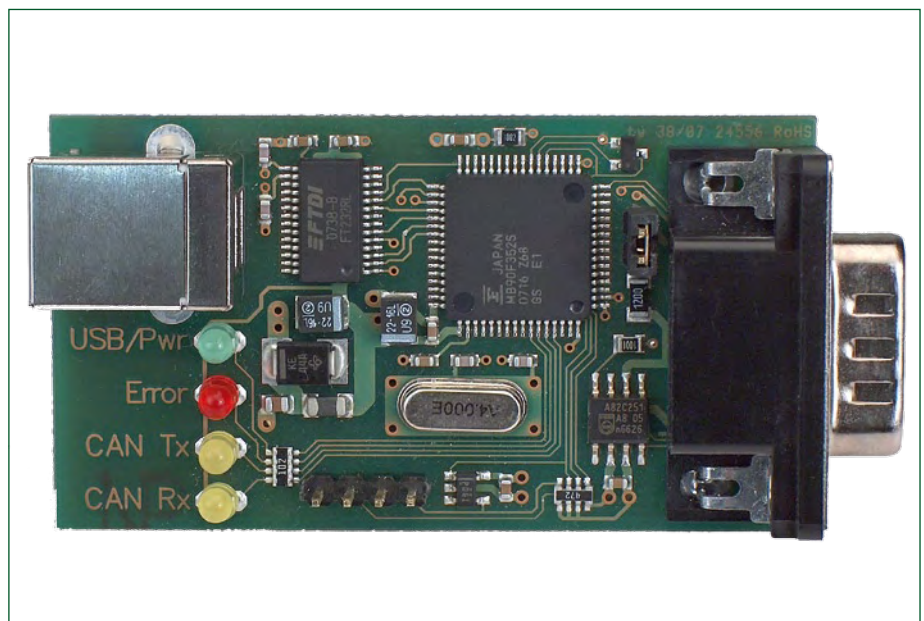


Figure 6. The module is really very compact and tidily laid out. The status LEDs show the current operational status.

Tiny-CAN View makes an automatic connection with the USB-CAN adapter when `mhstcan1.dll` is chosen as the driver. In the *CAN* tab in the setup menu you can select maximum data rate. The other tabs aren't required for the first run and can be ignored for now. As we mentioned earlier, the program makes use of filters to keep the data stream to a manageable level. The received data can also be stored in a file and CAN messages can be transmitted. Support for Standard (11-bit IDs) and Extended Frames (29-bit IDs) is built in.

All required links and programs have been grouped together on the project page for this article on the Elektor website. From there it is easy to find all the software and drivers. The PCB layout for the circuit can also be found there.

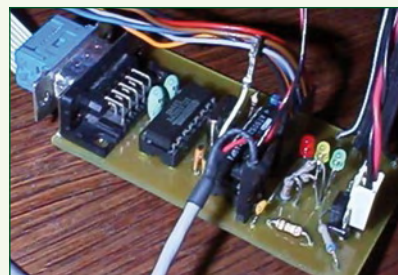
For those of you who find the SMD packages too small to solder, the module is also available as a kit of parts from the SHOP section of our website www.elektor.com. This kit consists of a board that has all SMD components already mounted. You are therefore left to solder only the through-hole ('leaded') components.

Internet Links

- [1] www.ftdichip.com
[2] <http://gladewin32.sourceforge.net>
[3] www.mhs-elektronik.de/tiny-can

Home automation

<http://caraca.sourceforge.net> — CARACA stands for CAN Remote Automation and Control with the AVR. CARACA is a home automation project based on a network of individually programmable circuits. These circuits can carry out different tasks, such as switching devices on or off, decoding signals from IR remote controls, controlling thermostats, and so on. Each node in the network can communicate with any other node via the robust CAN protocol and the status can be monitored on a PC, which in turn can be connected to the Internet.



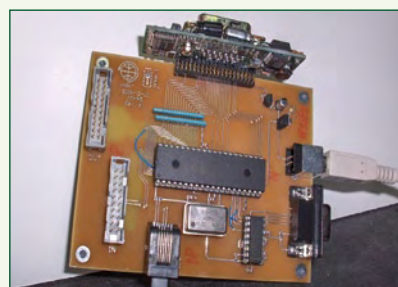
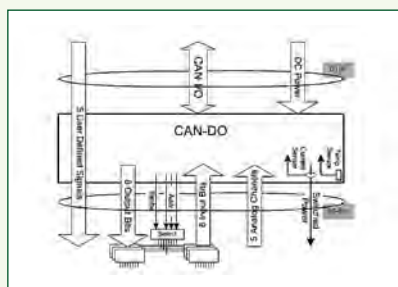
Toyota Prius

www.eaa-phev.org/wiki/Prius_PHEV_User_Interfaces — On this page the possibilities are discussed regarding the modification of the user interface and the State Of Charge Manipulation in the Toyota Prius. Such a device should be able to deal with the logic as described in the Prius PHEV Pseudo Code.



Satellite

<http://can-do.moraco.info> — CAN-Do! is a microcontroller (widget) that was designed for use as an interface to the wiring harness of a satellite and use this network to gain access to the integrated Housekeeping Unit that manages the different satellite subsystems. The primary aims are the reduction in the required amount of cabling and the simplification of the integration in a space ship.

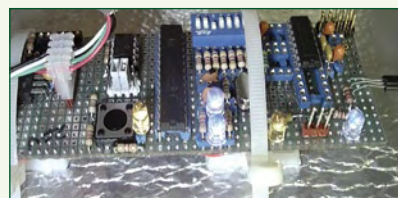



Temperature control

www.ece.usu.edu/experiences/5770_projects/zone_heating_system_sp03/index.htm

– On this site a system is described that has been developed by a group of students, and which controls the temperature in a number of separate rooms within a house. A computer program is used to set the temperature for several 'zones' and to view the current status. A dedicated controller keeps track of the status of each zone and turns on the heating or air conditioning when required.

The main controller communicates via a CAN bus with the zone controllers, which control the valves in the central heating system and which return the temperature to the main controller. The PC communicates with the main controller using a standard serial link.

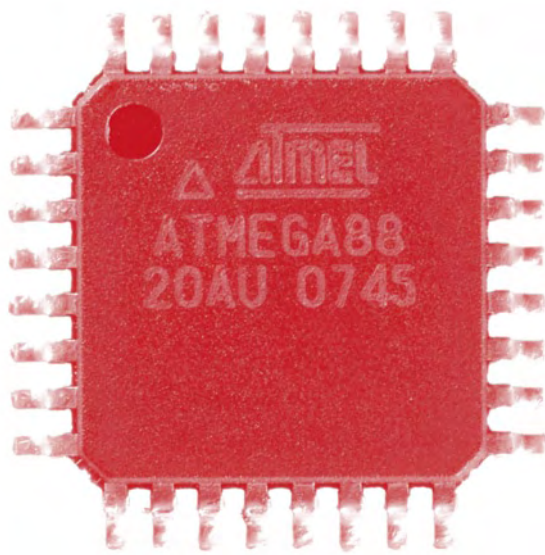


BASCOM AVR Course (2)

Using the ATmega ports

Burkhard Kainka

The port pins are the gateway between real world events and the microcontroller. The user can send out control signals and read back information. Here we give a few simple programming examples to quickly get you started inputting and outputting data.



A look at the data sheet gives some insight into the complexity of the port architecture of these microcontrollers (**Figure 1**). The ports can be configured as output or input (with or without pull-up resistors). Despite their complexity they are quite easy to use and only three important registers are needed to define the port configuration: The Data Direction Register (DDRx), the Port Output Register (PORTx) and the Port Input Register (PINx). There is also a single PUD bit

(pull-up disable) which disconnects all pull-ups. The following example programs begin by using Port B.

Reading input values

After a reset the internal Data Direction Register is reset to zero which configures all the ports as inputs. The Port Register is also reset to zero. In this condition the port pins look to the outside world like typical high impedance digital CMOS inputs (**Figure 2**). With all the inputs open-circuit the value stored in PINB is random and changes if you touch the pins with your finger (first discharge any static charge you may be carrying).

Listing 1 uses Port B as an input port. The following is an example of values you will see on the screen.

```
63
0
61
0
```

The values of PINB are changing but PORTB remains at zero, which is not surprising because we have not yet changed the port output register. PORTB is displayed in this example just to underline the difference between the PINB and PORTB registers. Experience has shown that this causes a great deal of frustration for newcomers who confuse the two register names: "how come I get a reading of zero when there is 5 V on the input pin?" The answer of course is that you should not read PORTB but PINB (read it as Port In B) to get the value of the input pin.

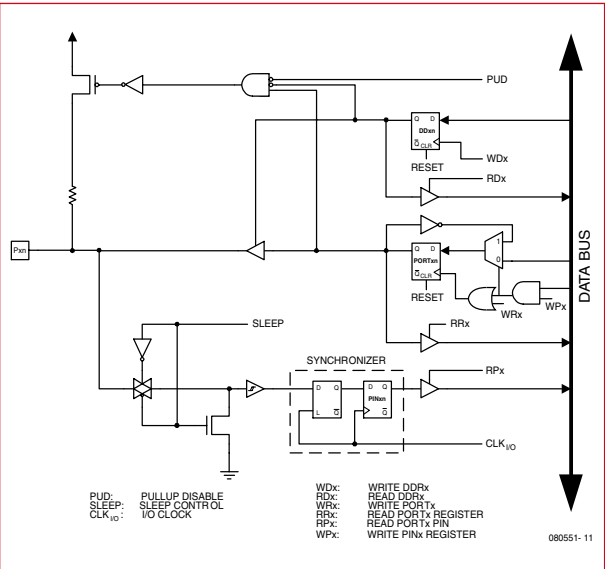


Figure 1.
The ATmega port
architecture.

Writing to an output port

The second example outputs data from Port B. It is necessary to write to the Data Direction Register to configure B as an output port. In BASCOM-AVR there are two ways this can be achieved; you can use the Register notation method (`Ddrb=255`) or the BASIC version (`Config Portb = Output`) either method has the same effect.

To run this example it's necessary to change the Goto instruction at the beginning of the program to read Goto Test2 and recompile.

To turn on alternate LEDs at the output port the decimal value 85 is written into Portb. **Listing 2** includes the hexadecimal (&H55) and binary equivalent (&B01010101) of this value, they are only included to demonstrate alternate formats. All of the LEDs on portB are switched (**Figure 3**) to produce the lighting effect (the LED boogie-woogie!).

The Mega32 has all eight port lines available for use but the Mega8 or Mega88 uses port pins PB6 and PB7 for connection of a crystal. When the fuses are configured to use an external crystal these two port pins are no longer available as I/O. The same is true for other dual purpose pins i.e if the hardware UART is used PD0 and PD1 are not available as I/O pins.

Using the pull-up resistors

When the inputs are connected to devices like switches or optocouplers (with open-collector outputs requiring a load resistor connected to VCC) it is ideal to use the built-in pull-up resistors instead of fitting additional external resistors (**Figure 4**). Writing a '0' to any of the DDRx bits configures the port pin as an input and writing a '1' to the corresponding PORTx bit connects a pull-up resistor to that pin (**Listing 3**).

With nothing connected to the inputs the program displays:

```
63
255
63
255
```

When the pull-ups are used the quiescent state of the input pin is a logic '1' so external signals must pull the input low. Connecting PBO to ground produces an PINB value of 62. With an input shorted a current of around 100 μ A flows to ground which indicates that the pull-up resistor has a value of 50 k Ω . This corresponds well with the 20 k Ω to 100 k Ω range quoted in the datasheet.

measuring Capacitance

The ATmega port architecture is very versatile and allows a very simple capacitance meter to be built. The capacitor under test (in the range 1 nF to 10 μ F) is simply connected directly to port PBO and ground (**Figure 5**). The program Test 4 (**Listing 4**) first discharges the capacitor by outputting an active low level. The internal pull-up resistor is then enabled which charges the capacitor. The program measures the time taken for the capacitor voltage to reach a logic '1' (2.5 V approximately). The value of capacitance is proportional to the charge time.

It is necessary to calibrate the unit because of the manufacturing tolerances in the values of both the pull-up resistance and the input voltage threshold. Calibrate using a close-tolerance capacitor and change the multiplication factor (0.0730) to obtain a result corresponding to the

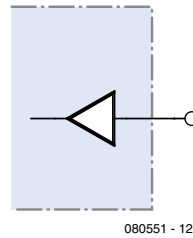


Figure 2.
A floating CMOS input.

Listing 1

Port input

```
`Bascom ATmega Ports
$regfile = "m88def.dat"
$crystal = 16000000
Baud = 9600
Goto Test1

Test1:
Dim D As Byte
Do
  D = Pinb
  Print D
  D = Portb
  Print D
  Waitms 300
Loop
```

Listing 2

Port output

```
Test2:
Config Portb = Output
`Ddrb = 255

Do
  Portb = 85
  Portb = &H55
  Portb = &B01010101
  Waitms 200
  Portb = 170
  Portb = &HAA
  Portb = &B10101010
  Waitms 200
Loop
```

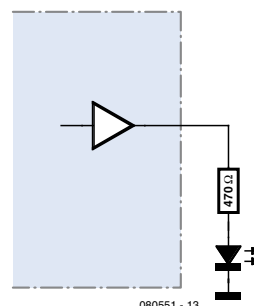


Figure 3.
Connecting an LED.

Figure 4.
The internal pull-up
resistors.

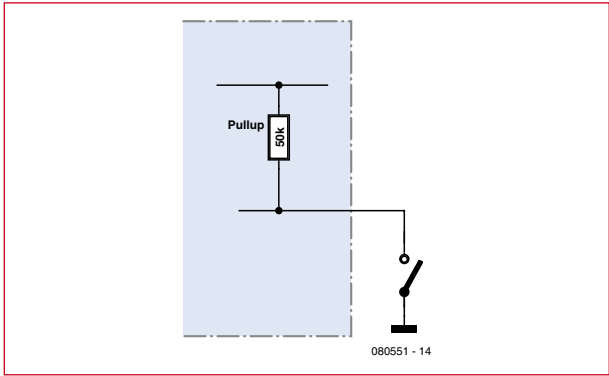
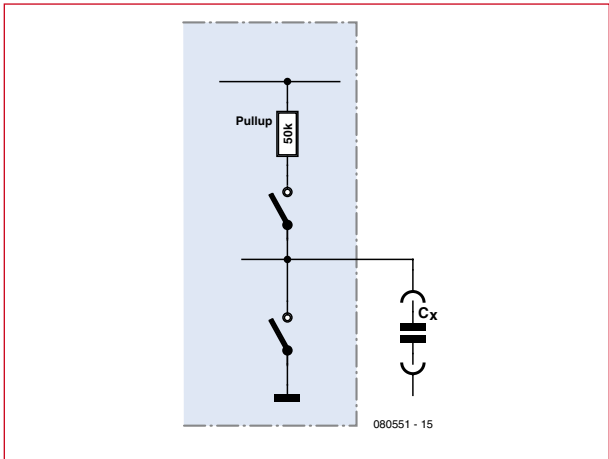


Figure 5.
The principle used for
capacitance measuring.



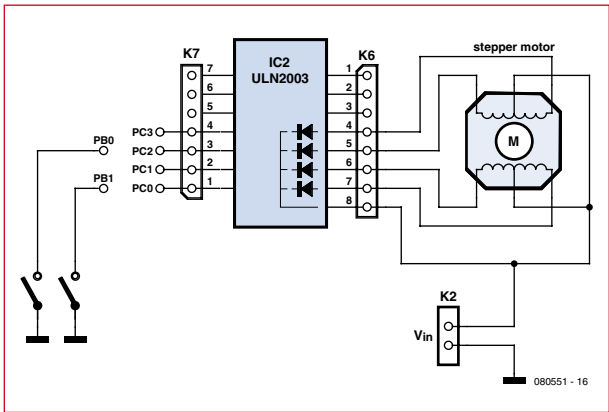
stated capacitor value. The measurements show some variation but should be accurate enough for most applications. Repeated measurements of the same capacitor gave the following spread:

- 1009 nF
- 1001 nF
- 1005 nF
- 1002 nF

Driving a stepper motor

Those of you who have a unipolar stepper motor (maybe salvaged from an old printer or 5.25-inch disk drive) may wish to experiment using this next example. Here the microcontroller uses the ULN2003 open-collector driver chip on the Elektor ATM18 test board (Figure 6). Only four outputs are required so we use pins PC0 to PC3. When this chip is

Figure 6.
Connecting a unipolar
stepper motor to the ATM18
test board.



Listing 3

Using the pull-ups

```
Test3:
Ddrb = 0
Portb = 255
`Pullups
Do
  D = Pinb
  Print D
  D = Portb
  Print D
  Waitms 300
Loop
```

required to drive inductive loads (e.g. motors or relays) it is necessary to connect the common cathode of the chip's protection diodes (pin 9 on IC2 or pin 8 on K6) to the load supply voltage pin 2 on K2 (VIN). The supply voltage on K2 depends on the type of motor used and can be in the range 6 V to 12 V.

Two pushbuttons are connected to PB0 and PB1 to provide direction control of the motor.

The BASCOM program is really simple, it just sequences through all four phases with four variables Phase(1) to Phase(4).

In the case where the motor just vibrates instead of rotating it is a simple job to swap phases in the program and saves changing the motor connections.

The programming examples Test5 to Test7 in Ports.bas (free download from www.elektor.com) contain several exercises to drive a stepper motor one of which shows how to build an analogue voltmeter where the motor controls the needle position.

(080551-1)

Listing 4

Capacitance measurement

```
Test4:
`C-meter 1 nF .. 10µF
Dim T As Word
Dim C As Single
Dim S As String * 10
Do
  T = 0
  Ddrb.0 = 1
  Portb.0 = 0
  `low Z, 0 V
  Waitms 1000
  Ddrb.0 = 0
  Portb.0 = 1
  `Pullup
  Do
    T = T + 1
  Loop Until Pinb.0 = 1
  C = T * 0.0730
  C = Round(c)
  Print C ; " nF "
Loop
```


Motor Drivers/Controllers

Here are just a few of our controller and driver modules for AC, DC, Unipolar/Bipolar stepper motors and servo motors. See website for full range and details.

Computer Controlled / Standalone Unipolar Stepper Motor Driver

Drives any 5-35Vdc 5, 6 or 8-lead unipolar stepper motor rated up to 6 Amps. Provides speed and direction control. Operates in stand-alone or PC-controlled mode for CNC use. Connect up to six 3179 driver boards to a single parallel port. Board supply: 9Vdc. PCB: 80x50mm. Kit Order Code: 3179KT - **£12.95**
Assembled Order Code: AS3179 - **£19.95**



Computer Controlled Bi-Polar Stepper Motor Driver

Drive any 5-50Vdc, 5 Amp bi-polar stepper motor using externally supplied 5V levels for STEP and DIRECTION control. Opto-isolated inputs make it ideal for CNC applications using a PC running suitable software. Board supply: 8-30Vdc. PCB: 75x85mm. Kit Order Code: 3158KT - **£17.95**
Assembled Order Code: AS3158 - **£27.95**



Bi-Directional DC Motor Controller (v2)

Controls the speed of most common DC motors (rated up to 32Vdc, 10A) in both the forward and reverse direction. The range of control is from fully OFF to fully ON in both directions. The direction and speed are controlled using a single potentiometer. Screw terminal block for connections. Kit Order Code: 3166v2KT - **£17.95**
Assembled Order Code: AS3166v2 - **£27.95**



DC Motor Speed Controller (100V/7.5A)

Control the speed of almost any common DC motor rated up to 100V/7.5A. Pulse width modulation output for maximum motor torque at all speeds. Supply: 5-15Vdc. Box supplied. Dimensions (mm): 60Wx100Lx60H. Kit Order Code: 3067KT - **£13.95**
Assembled Order Code: AS3067 - **£21.95**



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

Controllers & Loggers

Here are just a few of the controller and data acquisition and control units we have. See website for full details. Suitable PSU for all units: Order Code PSU445 £8.95

8-Ch Serial Isolated I/O Relay Module

Computer controlled 8-channel relay board. 5A mains rated relay outputs. 4 isolated digital inputs. Useful in a variety of control and sensing applications. Controlled via serial port for programming (using our new Windows interface, terminal emulator or batch files). Includes plastic case 130x100x30mm. Power Supply: 12Vdc/500mA. Kit Order Code: 3108KT - **£54.95**
Assembled Order Code: AS3108 - **£64.95**



Computer Temperature Data Logger

4-channel temperature logger for serial port. °C or °F. Continuously logs up to 4 separate sensors located 200m+ from board. Wide range of free software applications for storing/using data. PCB just 45x45mm. Powered by PC. Includes one DS1820 sensor. Kit Order Code: 3145KT - **£17.95**
Assembled Order Code: AS3145 - **£24.95**
Additional DS1820 Sensors - **£3.95 each**



Rolling Code 4-Channel UHF Remote

State-of-the-Art. High security. 4 channels. Momentary or latching relay output. Range up to 40m. Up to 15 Tx's can be learnt by one Rx (kit includes one Tx but more available separately). 4 indicator LED's. Rx: PCB 77x85mm, 12Vdc/6mA (standby). Two and Ten channel versions also available. Kit Order Code: 3180KT - **£44.95**
Assembled Order Code: AS3180 - **£54.95**



DTMF Telephone Relay Switcher

Call your phone number using a DTMF phone from anywhere in the world and remotely turn on/off any of the 4 relays as desired. User settable Security Password, Anti-Tamper, Rings to Answer, Auto Hang-up and Lockout. Includes plastic case. Not BT approved. 130x110x30mm. Power: 12Vdc. Kit Order Code: 3140KT - **£54.95**
Assembled Order Code: AS3140 - **£69.95**



Infrared RC Relay Board

Individually control 12 on-board relays with included infrared remote control unit. Toggle or momentary. 15m+ range. 112x122mm. Supply: 12Vdc/0.5A
Kit Order Code: 3142KT - **£47.95**
Assembled Order Code: AS3142 - **£59.95**



PIC & ATMEL Programmers

We have a wide range of low cost PIC and ATMEL Programmers. Complete range and documentation available from our web site.

Programmer Accessories:

40-pin Wide ZIF socket (ZIF40W) **£14.95**
18Vdc Power supply (PSU010) **£18.95**
Leads: Parallel (LDC136) **£3.95** / Serial (LDC441) **£3.95** / USB (LDC644) **£2.95**

NEW! USB & Serial Port PIC Programmer

USB/Serial connection. Header cable for ICSP. Free Windows XP software. Wide range of supported PICs - see website for complete listing. ZIF Socket/USB lead not included. Supply: 16-18Vdc. Kit Order Code: 3149EKT - **£39.95**
Assembled Order Code: AS3149E - **£49.95**



NEW! USB 'All-Flash' PIC Programmer

USB PIC programmer for all 'Flash' devices. No external power supply making it truly portable. Supplied with box and Windows Software. ZIF Socket and USB lead not included. Assembled Order Code: AS3128 - **£44.95**



"PICALL" PIC Programmer

"PICALL" will program virtually all 8 to 40 pin serial-mode AND parallel-mode (PIC16C5x family) programmed PIC micro controllers. Free fully functional software. Blank chip auto detect for super fast bulk programming. Parallel port connection. Supply: 16-18Vdc. Assembled Order Code: AS3117 - **£24.95**



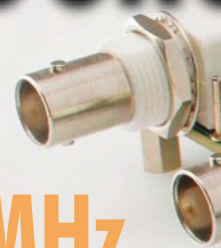
ATMEL 89xxx Programmer

Uses serial port and any standard terminal comms program. Program/ Read/ Verify Code Data, Write Fuse/Lock Bits, Erase and Blank Check. 4 LED's display the status. ZIF sockets not included. Supply: 16-18Vdc. Kit Order Code: 3123KT - **£24.95**
Assembled Order Code: AS3123 - **£34.95**



RF Sweep Frequency Gene

Measure filter response and check frequency spectrum from DC to 450 MHz



Gert Baars (The Netherlands)

The instrument described in this article combines the functions of a sweep frequency generator ('wobbulator') and a spectrum analyser. In the SFG mode, it can be used to measure the frequency characteristics of selective components or circuits at frequencies up to 450 MHz. The spectrum analyser mode can be used to measure the outputs of circuits and equipment, as well as antennas.

The measuring system described here consists of two parts: a hardware module in a separate enclosure with all the signal inputs and outputs, and software that runs on a PC under MS Windows. The measurements are displayed in graphic form on the PC monitor, and the user can configure all the variables and options as desired via the keyboard.

A major advantage relative to many commercial stand-alone instruments of this sort is the large screen area. In addition, the measured characteristics can easily be saved to disk or printed out.

Beside the two measuring modes already mentioned, the instrument can be used to generate a signal with a fixed frequency in the range of 5 kHz to 450 MHz, which means that it can be used as a test transmitter.

As the spectrum analyser is essentially a direct-conversion receiver, the instrument also includes an audio output. This allows it to be used to listen to AM or FM radio signals. A VFO (variable frequency oscillator) function is also included, which allows any desired offset frequency to be configured for the first post-mixer (IF, intermediate frequency) stage of the receiver.

The software also has an option for making measurements with a SWR bridge. An SWR (standing wave ratio)

bridge (which can be connected externally) can be used for direct measurement of the standing-wave ratio of a device such as a 50- Ω antenna.

Block diagram

The original intention was to simply make a sweep frequency generator (SFG) for frequencies extending as far as the UHF (70 cms) band. However, the idea of adding a spectrum analyser function arose quite quickly. This is only natural, since an SFG already includes a large number of the elements necessary for a spectrum analyser, such as a DDS (direct digital synthesizer) IC, a logarithmic detector, and a microcontroller with an A/D converter and UART. The main additional elements that are necessary are a mixer and some IF filters. Of course, the software must also be able to make use of both functions.

The block diagram (**Figure 1**) thus represents two different circuits that can be selected by the control function. The control function, which takes the form of a microcontroller, is connected to a PC via a serial link, and it receives commands and parameters from the PC. Based on the received commands and parameters, the microcontroller executes tasks that generate data, which is then returned to the PC where

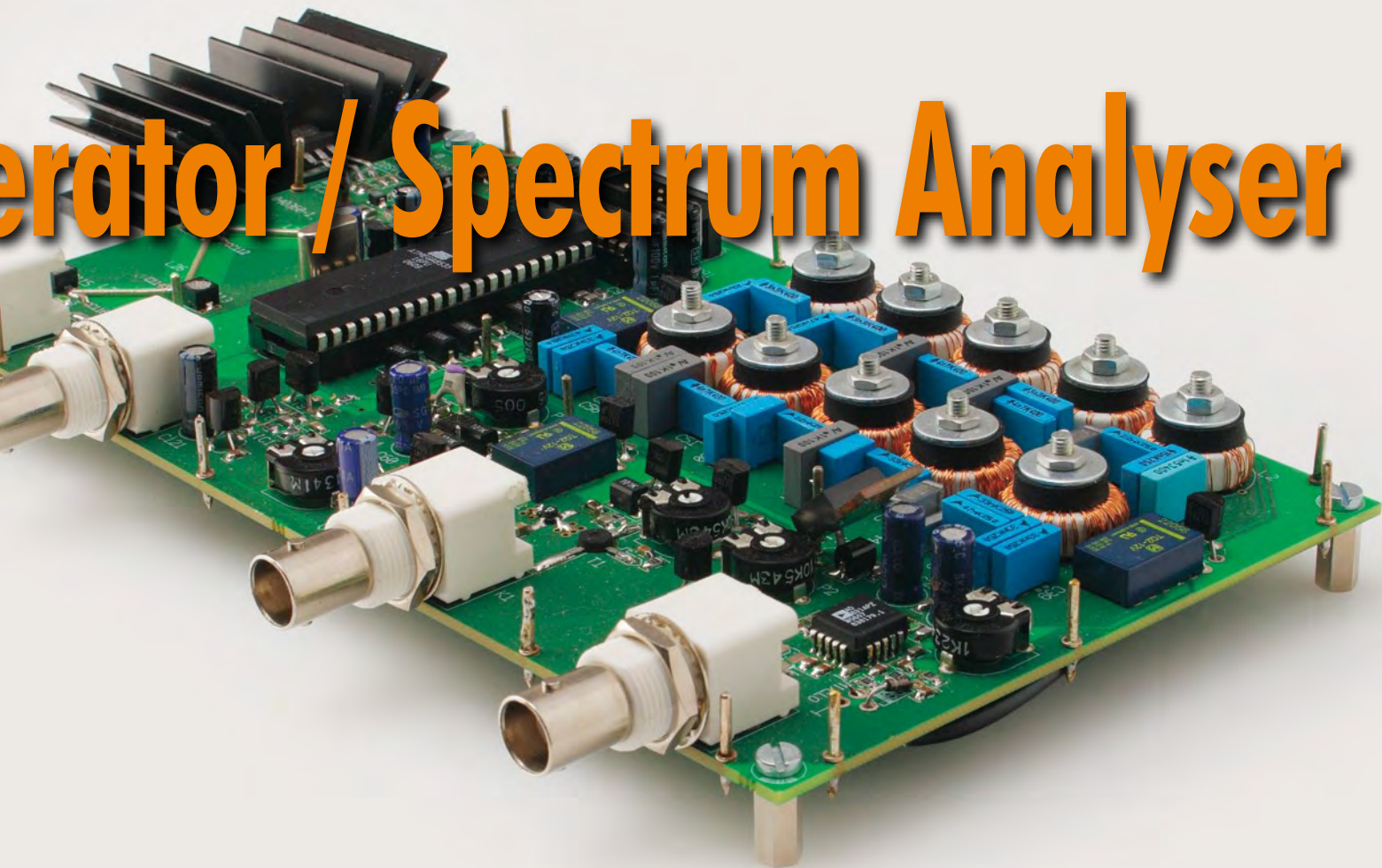
the data is processed and displayed by software running in the PC.

Thanks to this approach, the user can operate the entire system from the PC and the measured data is displayed in graphic form.

Sweep Frequency Generator portion

The sweep signal for the instrument is generated by a direct digital synthesizer (DDS). The DDS operates with a reference frequency (REFCLK) of 1000 MHz, and it can generate signals up to 450 MHz with a step size of 0.24 Hz. As the DDS provides samples at a 1000-MHz rate, the output signal can be regarded from a mathematical viewpoint as being multiplied by 1000 MHz. This generates spurious products that make output filtering necessary, and this is provided here by a 450-MHz lowpass filter. As two signals are necessary because a local oscillator (LO) signal must also be supplied to the mixer, the filter is followed by a two-way splitter with an impedance of 50 Ω . The SFG ('wobbulator') output signal from the splitter has an amplitude of approximately -8 dBm (90 mV_{eff} into 50 Ω), which makes it quite suitable for measuring the pass characteristics of a wide variety of filters. In the spectrum analyser mode, the wobbulator output is terminated in 50 Ω in order to avoid influencing

Generator / Spectrum Analyser



Technical Specifications

Sweep Frequency Generator

Horizontal:

Maximum frequency: 450 MHz

Minimum usable frequency: 5 kHz

Sweep: any desired scan between DC and 450 MHz

Resolution: 1/650 of the scan width

Sweep rate: 0.2, 0.5, 1, 2, 5, and 10 s/scan

Linear or logarithmic frequency scale

Vertical:

Range: 0 to approx. -60 dB

Resolution: 1 dB

Accuracy: approx. 2 dB

Output: 50 Ω , -8 dBm

Input: 50 Ω or active probe with 1 M Ω // 4 pF input impedance

Spectrum Analyser

Horizontal:

Maximum frequency: 450 MHz

Minimum usable frequency: 0.1 MHz

Sweep: any desired scan between DC and 450 MHz

Resolution: 1/650 of the scan width

Sweep rate depends on scan width, detection bandwidth and accuracy; range approx. 0.25 s to 30 s

Vertical:

Range: 0 to approx. -80 dBm

Resolution: 1 dB

Accuracy: Average ± 2 dBm (in part dependent on scan rate)

Detection bandwidths: 25 kHz and 100 kHz

Input impedance: 50 Ω or active probe (1 M Ω // 4 pF)

the amplitude of the LO signal for the mixer.

The SFG input (on the right in the block diagram) can be 50 Ω or an active probe with a input impedance of 1 M Ω // 4 pF, which is nice for working with filters because they often require a matching impedance much greater than 50 Ω . This way the attenuation

due to mismatching is much smaller, which means that the vertical measuring range is much larger. The probe also provides many other benefits with all sorts of measurement tasks for which low loading is desirable.

The signal on the SFG input is first preamplified. The resulting output signal closely approaches the maximum

input level (+17 dBm) of the subsequent logarithmic detector, which also increases the vertical measuring range.

The detector is followed by a low-pass filter to ensure that only the 'DC' component (in a manner of speaking) reaches the microcontroller's A/D converter.

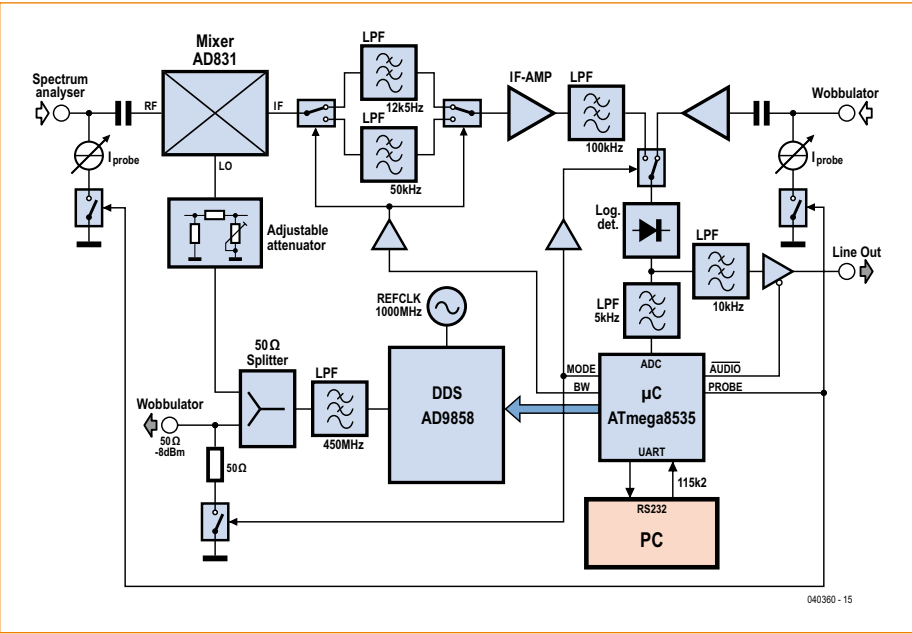


Figure 1. Block diagram of the sweep frequency generator / spectrum analyser.

Obviously, the frequency response of the device under test (DUT) can be measured by connecting the wobulator output to the DUT input and the DUT output to the SFG input and then performing a frequency scan.

Spectrum analyser portion

The spectrum analyser operates on the direct-conversion principle. This provides a number of benefits. To start with, it allows the IF filters to take the form of lowpass filters, which are easy to make as DIY filters. Another important benefit is that the image frequency is referenced to the LO frequency, which has the significant effect of making the bandwidth twice as large as that bandwidth of the post-mixer filter. This way, bandwidths of 25 kHz and 100 kHz are obtained with 25.5-kHz and 50-kHz lowpass filters. The software ensures that the right measurement data is displayed. The input of the spectrum analyser is connected directly to the mixer. The type of mixer used here is marked by very high linearity. A preamplifier ahead of the mixer would only make things worse. The post-mixer filter is followed by an amplifier, which boosts the signal amplitude to a level that matches the range of the subsequent logarithmic detector. The same detector is used for the spectrum analyser and SFG functions by switching the signal paths according to the operating mode. The remaining hardware is the same as for the SFG, with the major

difference being found in the software for the spectrum analyser and sweep frequency generator functions.

Schematic diagram

Sweep Frequency Generator input preamplifier

The input stage of the SFG consists of a broadband amplifier in the form of an ERA-5 IC (IC1) from Minicircuits [1]. This 50-Ω stripline broadband amplifier was chosen for its high IP3 and 1-dB compression point. In simplified terms, this means that the input stage has good immunity to the generation of undesired spurious products in the presence of large input signals, which could cause false measurement results, but it can still supply adequate output power. The gain of the ERA-5 is a constant 22 dB from DC to 1000 MHz, which makes it more than suitable for the desired bandwidth of 450 MHz. This MMIC also has a noise figure that is low enough for our application.

Detector

In order to achieve a large dynamic measuring range, we decided to use a logarithmic detector. The Analog Devices [2] AD8307 (IC7) used here has a bandwidth of DC to well over 500 MHz, and it outputs a DC voltage that is proportional to the level of the input signal in dBm. The input signal range of this detector is approximately -75 dBm to +17 dBm. The maximum level (+17 dBm) is somewhat on

the high side, which is why the previously mentioned ERA-5 preamplifier is included in the circuit. Another important aspect of this logarithmic detector is that it can track fast changes in the input level. This is necessary to avoid an excessively long delay for sweep generation, so the time required to perform a sweep can be kept within reasonable limits. A simple lowpass filter (R25-C83-R26-C84) after the detector prevents residual signal components from reaching the A/D converter.

A/D converter

The A/D converter is integrated in the microcontroller in the form of an ATmega8535 (IC12). This 10-bit successive-approximation A/D converter provides 10-bit conversion results with a conversion time of approximately 110 µs. It can also operate at higher conversion rates, but this comes at the cost of accuracy. The advantage of 10-bit resolution is that if desired, the vertical scale can be enlarged while still maintaining relatively high accuracy. As a result, a vertical scale of 25 dB still has the same accuracy as a vertical scale of 100 dB.

Microcontroller

The hardware is controlled by a microcontroller in the form of an Atmel type ATmega8535 [3]. This 8-bit RISC microcontroller can achieve 16 MIPS (million instructions per second) with a clock rate of 16 MHz. However, we use a 14.7456-MHz crystal here so that the baud rate of the integrated UART can be set to exactly the desired value of 115,200 baud. Among other things, this microcontroller features 8 kB of flash program memory, an 8-channel / 10-bit A/D converter, 512 bytes of RAM, and a serial UART, which make it an outstanding choice for this application. The link between the UART and the COM port requires level conversion in order to adapt the signal levels of the UART (+5 V / 0 V) to signal levels of the COM port (±12 V). A Maxim [4] MAX232 (IC11), which requires only a few external components, is used for this purpose.

DDS

The sweep signal for the SFG output and the LO signal for the spectrum analyser mixer are generated by an Analog Devices AD9858 (IC12). The outstanding feature of this particular DDS IC is its high clock speed, which extends to 1 GHz. This very advanced DDS makes it easy to generate fre-

quencies up to 450 MHz with 32-bit precision, which amounts to a step size of 0.233 Hz. In addition, this 100-pin DDS IC has extremely low phase noise (more than 145 dB below the carrier level). It can also be controlled in parallel or serial mode. Even the serial mode is more than fast enough for use as a sweep generator. Another feature of this IC, which is not used in this design, is that it can store four externally selectable frequency profiles for ultra-fast frequency hopping. Another noteworthy aspect is that the DDS chip must be powered from 3.3 V, while the maximum dissipation can be as much as 2 watts.

In addition to the DDS, the AD9858 houses a PLL and a mixer. They are also user-programmable, but they are disabled in this application by means of software initialisation and not used in the circuit in order to avoid unnecessarily increasing the power dissipation. The full-scale output current of the DDS is set by an external resistor. Here we chose a safe figure of 20 mA. According to the manufacturer, this yields the least amount of spurious products.

DDS reference clock

One thing that initially appeared to be a problem was generating a stable 1-GHz reference clock signal for the DDS. Solutions such as a crystal oscillator with multipliers or an extra PLL appeared to require an undesirable number of additional components, while a simple free-running oscillator might drift too much. Consideration was also given to using the internal PLL of the DDS IC for this.

We discovered that a 1000-MHz SAW (surface acoustic wave) resonator is available from Tai-Saw [5], with type number TC0306A. A supplementary benefit of a reference oscillator built around this sort of resonator (X2) is that it does not have to be adjusted, and any small deviations can easily be compensated in the software (a calibration feature is provided for this).

DDS output filter

As already mentioned, the digital technique used to generate DDS signals inherently causes spurious products to be generated as well. There are also residual components of the 1000-MHz clock in the output signal. A 450-MHz, seventh-order Chebyshev filter was developed to eliminate them. The inherent impedance of the filter is 50 Ω , and it has four trim capacitors that must be used to adjust it for

proper response. The chance of deviations would be too large if fixed-value components were used here. Incidentally, the adjustment is not difficult, and it can be performed directly with the aid of the sweep frequency generator, so no additional instruments are needed. A certain amount of ripple can be seen on the screen when the filter is properly adjusted, and there is some roll-off due to the reduced sensitivity of the AD8307 detector as well as the reduced amplitude of the DDS signal. However, the software has a calibration function that can be used to restore a perfectly straight-line characteristic.

The filter is followed by a simple 50- Ω splitter to yield two output signals: one for the wobulator output and the other for the LO input of the spectrum analyser mixer. As both outputs of the splitter must always see a 50- Ω load, the microcontroller connects a 50- Ω termination resistor across the wobulator output when the spectrum analyser is being used.

Mixer

Very high requirements are placed on the mixer for the direct-conversion spectrum analyser. A balanced-diode mixer is far from being good enough, due to the low isolation between the ports, and its switching behaviour is an even larger drawback. The multiplication of the LO signal with the RF signal must be as linear as possible, which is only possible with a good active mixer.

An outstanding mixer for this application is the AD831, once again from Analog Devices. This special low-distortion mixer produces very low distortion even with relatively large input signals, it has sufficient isolation, and it can be used with input and LO signals up to 500 MHz. With this mixer, the LO input is usually driven into saturation. For this purpose, it has an internal amplifier for the LO signal. However, the LO signal can be supplied via an adjustable attenuator so that the signal amplitude can be set to exactly the level that yields the least distortion. This can be done quite easily by scanning a signal in spectrum-analyser mode. If the LO signal amplitude is too high, a spike will be seen at $f/3$ of the input signal. The adjustable attenuator can be set to reduce the level of this spike until it just disappears in the noise floor. It is important to reduce it to just this level and no further, as otherwise the mixer will atten-

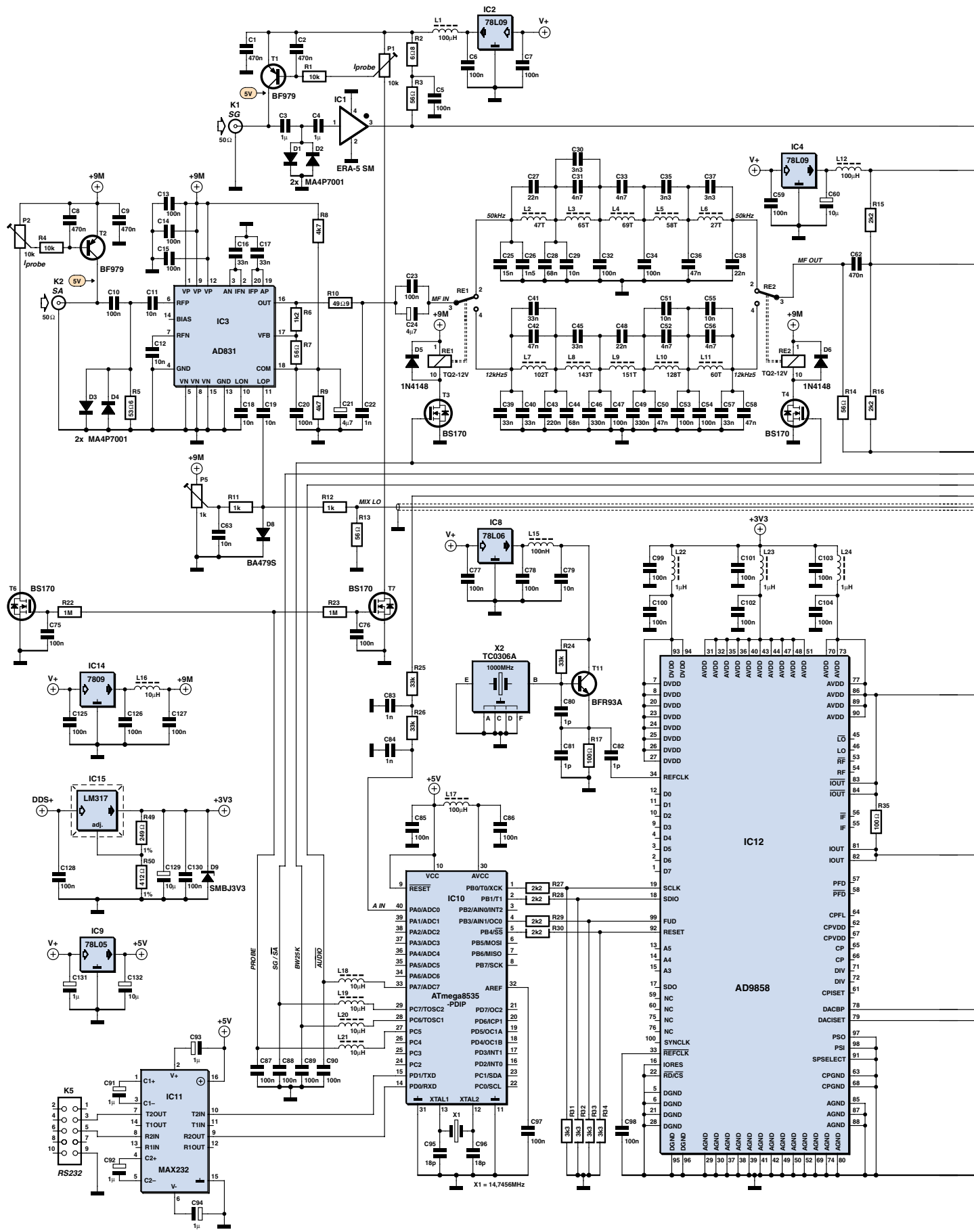
uate the signal more than necessary. The adjustable attenuator is implemented using a PIN diode so that it can be used at high frequencies.

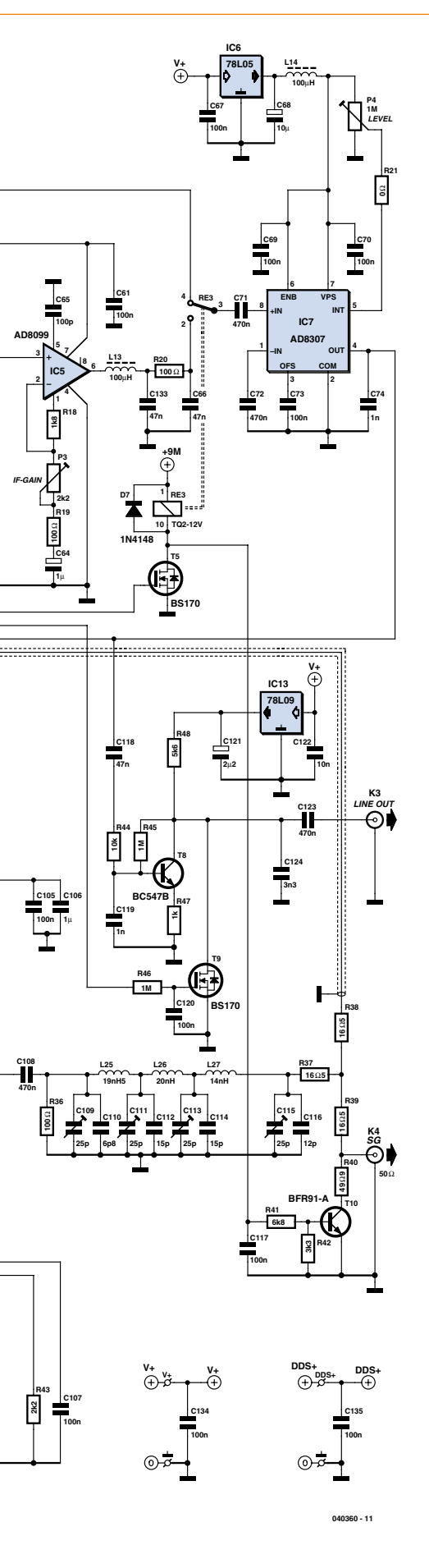
The mixer also has an internal output amplifier, which we are happy to use here because it is better to amplify the signal before the IF filter, since the noise voltage is directly proportional to the bandwidth. This allows a lower amount of IF gain to be used, which also results in less noise. In this way we manage to achieve a noise floor of approximately -80 dBm. The mixer must have an output impedance of 50 Ω in order to properly match the impedance of the IF filters. The coupling capacitors at the output determine the lowest intermediate frequency, and they must have a relatively high value. Otherwise a visible dent in frequency response will occur when the scan width is fairly small relative to the bandwidth of the IF filter, due to the direct-conversion principle. With larger scan widths, which of course will most often be used in practice, this phenomenon is compensated in software and the display shows taut, needle-shaped frequency lines.

Post-mixer filters

The filters 'behind' the mixer determine the bandwidth of the spectrum analyser. We decided to use two selectable filters with bandwidths of 12.5 kHz and 50 kHz, respectively. Due to the direct conversion principle, the bandwidth is doubled to 25 kHz and 100 kHz. These filters should be as steep as possible. The desired properties can be approximated with 11th-order elliptical filters – which means a flat amplitude characteristic up to the corner frequency, followed by a very steep skirt so that the base width is small enough for this application, even at -80 dB. We achieved this by winding our own coils on toroidal cores. The 14-mm 4C65 cores that we used have a μ_i specification of 125. This is not especially large for a toroidal core, but it must be said that toroidal cores with very large μ values are almost always made from a material with a relatively high ohmic resistance. This results in core losses, which in turn reduce the Q factor. Here we used ordinary MKT capacitors with good results. A supplementary benefit of using toroidal cores is that they are usually rather insensitive to external fields.

The two IF filters are selected by a set of TQ-2 relays operated by the micro-





controller in response to a command from the PC application.

Post-mixer amplifier

Like the mixer, the amplifier that follows it must have very good characteristics. We chose the AD8099, which is listed as an opamp with extremely low distortion and noise. This opamp – which is also affordable – is made by Analog Devices. It has an enormous bandwidth of no less than 3.8 MHz, which is not especially important for this application but certainly worth mentioning. The very low noise contribution of the IF amplifier is especially important because it keeps the noise floor of the spectrum analyser as low as possible. The noise is reduced even further by dimensioning the input section of this IC for an AC impedance of 50 Ω , which matches the impedance of the IF filters. A simple lowpass filter is located at the output of the intermediate frequency amplifier to restrict the noise spectrum.

Active probe

An active probe is included because 50 Ω would be too much of a load for many measurements. It has been kept as simple as possible and consists of only five components (**Figure 4**). It can thus be built into a small external enclosure, such as the body of a ball-point pen or felt pen.

The probe has an input impedance of 1 M Ω // 4 pF and a maximum usable frequency of about 450 MHz, and it can be used with the spectrum analyser as well as the SFG.

As the probe attenuates the signal slightly, a separate calibration button is included in the software to compensate for all the deviations. The calibration data is saved automatically in specific .ini files so it can be reused. This means that the calibration only has to be performed once. When the instrument is switched to work without the probe, the standard calibration file is automatically read from disk and used.

For convenience, the probe is powered directly from the hardware. An approach using chokes is not desirable here. Large chokes are necessary for low frequencies, and they usually have high internal and stray capacitance. A simpler and better solution

is to power the probe with a DC current. For this purpose, a switchable current source is provided at the SFG input and the spectrum analyser input, in the form of a PNP transistor (T1 or T2, respectively) with an adjustable collector current that can be switched off by the microcontroller, since a DC current could have undesirable effects when measurements are made without the probe. The 'Use Probe' command in the Options menu of the PC application switches the probe supply on or off. In principle, any transistor can be wired as a current source, but here the collector capacitance should be as small as possible. We thus selected a UHF transistor, in this case the BF979. The probe current from each transistor can be set to approximately 14 mA by adjusting the potentiometer connected to the base. At this current, the DC voltage on the collector of the transistor is approximately 5 V.

Input protection

The inputs of the spectrum analyser and SFG are protected against excessive input signals. For this purpose, two PIN diodes (type MA4P7001) are connected to each input in reverse parallel. These PIN diodes from M/A-COM [6] have a blocking capacitance of 0.7 pF and the threshold voltage of each diode is 1 V, so the input signal is limited to 2 V_{pp} . This corresponds to +10 dBm, which both inputs can handle easily. Each diode can dissipate 3 W for a relatively long time, or 10 times this much for a short time.

In practice, this means that the diodes will still do their job if (for example) the output of a 25-watt transmitter is accidentally connected directly to the spectrum analyser input. This is because relatively modern transceivers automatically and quickly reduce the output power in such situations due to the resulting low load impedance. The diodes have a very low impedance if they are overdriven, so almost all the supplied power is reflected. The author suspects that the input capacitors will fail before the diodes if too much power is applied to the input, although arguably he has not tested this. It is thus advisable to use SMA devices with a relatively small package size for the series capacitors. Then if an accident occurs, you only have to replace these capacitors.

DDS power supply and cooling

The DDS should be powered from a 3.3-V supply, and its current consumption

Figure 2. The resulting schematic diagram is rather extensive. The DDS IC occupies a central position here.

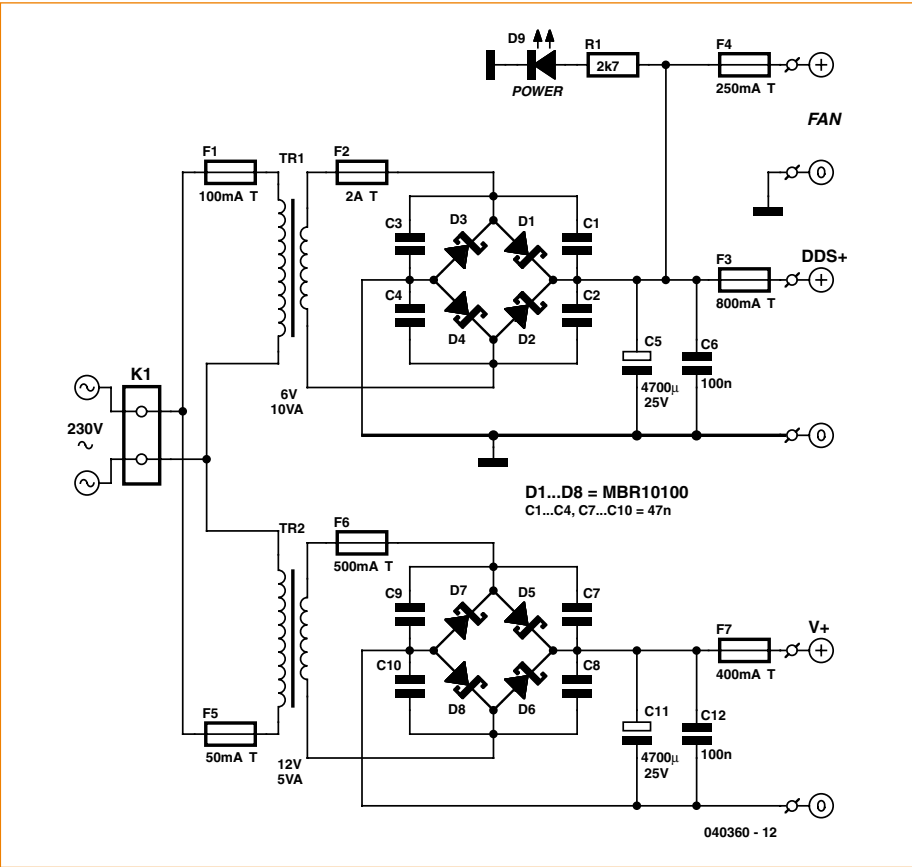


Figure 3. Two power supply transformers with rectifiers and smoothing capacitors are located on a separate power supply board.

is approximately 600 mA. This means that the IC must dissipate around 2 W of heat. For this purpose, the IC has a thermal pad on the bottom of the package, which is supposed to make contact with thermal vias in the PCB that transport the heat to the bottom of the board. The necessary vias are thus present in the PCB layout. In order to do this properly, you need a reflow soldering oven (as described in another article in this issue). The supply voltage for the DDS IC is provided by an LM317 (IC15) set to an output voltage of 3.3 V. The input voltage is approximately 7 V, so the voltage

regulator must dissipate around 2 W. It is fitted with a small heat sink for this purpose. To increase the working life of all this, the author fitted a small fan in his prototype to provide forced-air cooling. The voltage regulator and its heat sink are located close to the DDS IC so that they can both be cooled by the same fan.

Mains power supply

A separate power supply PCB has been designed for the main power supply. It holds two mains transformers along with the necessary rectifier diodes and capacitors (Figure 3). The power supply board provides supply voltages of 7 V and 12 V. A separate connector is provided for a fan if desired.

Software

The software consists of two programs: (1) firmware (i.e. object code created from assembly language) for the microcontroller in the hardware and (2) a Delphi program for the PC. Here it should be noted that the majority of the tasks are performed by the PC program. Logarithmic calculations, for example, are very cumbersome in

assembly language, so the Delphi program performs all intensive computations and only sends simplified parameters and commands to the ATmega microcontroller, whose primary task is to control the hardware.

Communication protocol

A separate protocol was created for the communication between the PC program and the firmware controlling the hardware. For each communication session, the PC sends a command to the microcontroller, which acknowledges it by returning the command (echo). After this, the PC sends a number of parameters, such as the start frequency, scan parameters, step delay, step size, and so on. The microcontroller waits for the PC to issue a 'start' command before it performs a sweep using the most recently sent parameters. The results from the A/D converter are sent to the PC during the sweep. Some parameters are always the same, such as the scan width and the two fixed IF bandwidths. These parameters are defined as constants.

In this way, specific commands and parameters are sent to the hardware after certain options or actions have been selected on the PC, and the hardware is then instructed to perform the actual measurement. The commands have been assigned simple names, such as 'hello', 'start' and 'data', and the software sees them as single-byte codes.

Assembly-language program

The assembly-language program used to build the microcontroller firmware begins in the usual manner with a reset interrupt routine. Among other things, this routine initialises the I/O ports, the A/D converter, the UART, and the DDS. This means that their parameters are set according to the desired configuration. The main program, or 'mainflow', starts after the reset routine. The only thing mainflow does is to periodically check the UART receive buffer to see whether any data has been received. If it has, the program checks to see which command is involved, which determines the subsequent course of action. The most important routines are the ones that execute a wobulator sweep or a spectrum analyser sweep and send a frequency word to the DDS. There are also several auxiliary routines, such as timer functions, starting and reading an A/D conversion, etc.

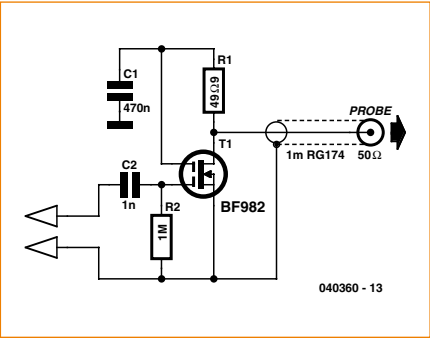


Figure 4. The active probe comprises only five components.

Delphi program

The main task of the Delphi program developed for this project (**Figure 5**) is to display the measured characteristics. Delphi provides outstanding graphics capabilities, such as procedures for drawing lines. Basically what the program does is to send commands and data to the hardware and then read in the measurement data. This data is collected in a buffer, and a graphic is generated after all the data has been received.

The program can also send the graphics to the printer or save them to disk so they are stored for examination or use in documentation later on.

The program has a menu bar with several options, such as selecting a frequency scale graduated in hertz, kilohertz or megahertz. You can set the start and end frequencies, or you can opt to set the centre frequency and scan width instead. The latter option is particularly convenient for measuring filters when the centre frequency is known.

The Options menu lets you choose the speed of the spectrum analyser scan. The choices here are Slow, Normal and Fast. You can thus choose to scan faster with somewhat lower accuracy in order to obtain a quick impression of the spectrum, such as for measuring signals received from an antenna.

You can also select a linear or logarithmic horizontal scale for the sweep frequency generator. The logarithmic scale gives a better picture of the steepness of filters, for example, while the linear scale gives a better indication of measurements with a narrow scan, such as measuring the characteristics of ceramic or crystal filters.

The Options menu also has a calibration function. You can calibrate the frequency scale, for example by scanning a signal with a known frequency. After you click the point where the centre frequency should be, the actual frequency of the DDS reference oscillator is known, and it is stored immediately in a calibration file. The vertical scale can also be calibrated with and without the probe. This also takes only a mouse click, after which the calibration data is stored for subsequent use. In principle, calibration only has to be performed once, but there is no harm in recalibrating the instrument occasionally, since component values tend to drift over the course of time.

Another option is 'Use Probe'. If you click this option, the current sources for the active probe are enabled and

the calibration file for the probe is read in and used as long as the probe is enabled. Yet another option is 'Adjust LPF'. If you tick this option, the maximum frequency is set to 500 MHz instead of the usual 450 MHz. You can use this to perform a 500-MHz scan in order to adjust the DDS output filter for 450 MHz. The details of this are described in the adjustment procedure, which is included in the supplementary documentation for this article available on the Elektor website as document 040360-W.

In addition to the graphic display and the menu bar, the Delphi program has several Edit windows. They can be used to enter numbers, such as the frequency and decibel (dB) values that determine the scale graduations for the graphic display. There are several buttons on the screen for starting and stopping scans. There are also 'radio buttons' for setting the scan rate and the bandwidth of the spectrum analyser. Most of the program's user-interface functions can be selected and used with the mouse.

When the Delphi program is closed, certain settings (including the COM port settings) are saved automatically in a file called 'Settings.ini', which is located in the folder containing the main program. These settings are automatically read and restored when the program is started again, so they do not have to be entered anew each time.

Scanning principle

The sweep frequency generator and the spectrum analyser both work with a scan width of 650 frequencies. This is not especially significant for the SFG, but in the case of a relatively broad scan with the spectrum analyser the frequency step equal to $(f_2 - f_1)/650$ may be larger than the post-mixer bandwidth.

For instance, the step size is nearly 700 kHz with a scan from 0 to 450 MHz. The problem with this is that it would be easy to miss some signals. This is solved by having the hardware perform 'sub-scanning'. This means that the hardware independently performs a scan between two successive frequency values. With a scan of 0 to 450 MHz and a detection bandwidth of 25 kHz, the hardware must execute 28 steps ($700/25$) for each X coordinate. In this case the microcontroller determines the largest measured value, which is then sent to the PC.

This method is perfectly satisfactory, but it costs a lot of time. The scan time for 450 MHz with a 25-kHz bandwidth can easily be more than 30 seconds. However, you can use the 'SASpeed' command in the Options menu to increase the scan speed. This option is intended to be used to obtain a quick impression of a spectrum by accepting lower accuracy. With this option, a scan from 0 to 450 MHz with a bandwidth of 100 kHz takes only 3 seconds. Scan rates with smaller scan widths are proportionally faster, reaching as much as several scans per second.

More information

As this is a complex project with considerable scope, we have put all the practical information (such as construction, adjustment, components list, command summary and the software user's guide) in a separate document, which can be downloaded free of charge from the Elektor website (no. 040360-W). The PCB layouts (040360-PCB) and PC software (040360-11) are also available on the website. A pre-programmed microcontroller is available for this project (no. 040360-41), and the circuit boards will be available in due course from www.ThePCBShop.com.

(040360-1)

Internet Links

[1] Minicircuits:

www.minicircuits.com

[2] Analog Devices:

www.analog.com

[3] Atmel:

www.atmel.com

[4] Maxim:

www.maxim-ic.com

[5] Tai-Saw:

www.taisaw.com

[6] Ma-Com:

www.macom.com

ATM18 Relay Board

Have it all your own way

Udo Jürss and Wolfgang Rudolph (Germany)

Since time immemorial, people have always wanted to see the effects of their deeds and shown them to others. Among electronics hobbyists and professionals, this often takes the form of wanting to make some action inside a computer visible to the outside world. Today we usually refer to this as 'regulation and control' instead of 'having things your own way'.

Now that our ATM18 project with the levitating magnet in the last issue has become truly active, we can use a relay board to implement even more external effects.

Just imagine sitting in your easy chair and using a remote control to control everything that serves your comfort and convenience: lamps, the radio, a fan, and what have you. For this to be possible, you need a few relays. Support for eight loads should be adequate in most cases, so the design described here incorporates eight relays.

Eight relays in turn require eight output lines, but this is a luxury we cannot afford here. We already kept the use of I/O lines to a minimum with the LC display, and here again we have to use them economically. For this reason, we have developed a suitable interface board, which enables the Mega88 to control the relays with only two I/O lines.

Two I/O lines is the limit

But how can you switch eight relays with only two bits? Here again, the answer is **serial data**. In other words, the bits from the test board are transmitted sequentially to an old standby: a 4094 shift register. In order to understand how the circuit works, you have to look at the data sheet for the 4094. **Figure 1** shows the internal logic of

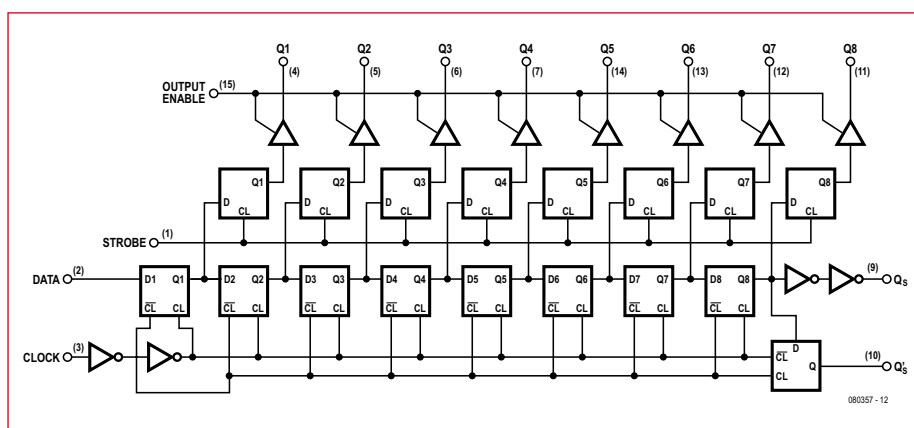


Figure 1. Internal logic of the 4094 shift register.







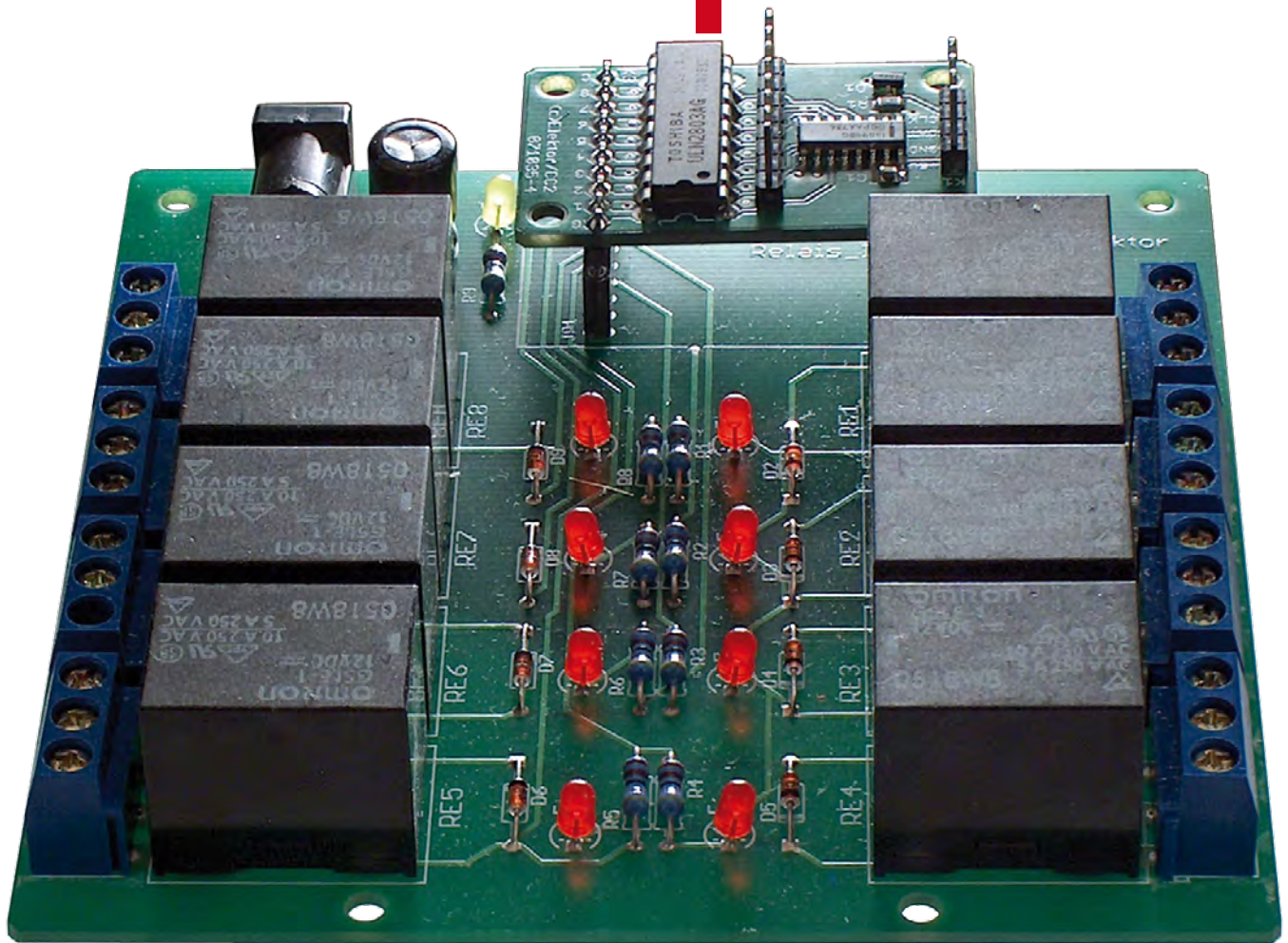
Clock	Output Enable	Strobe	Data	Parallel Outputs		Serial Outputs	
				Q1	Q _N	Q _S (Note 1)	Q' _Σ
	0	X	X	Hi-Z	Hi-Z	Q7	No Change
	0	X	X	Hi-Z	Hi-Z	No Change	Q7
	1	0	X	No Change	No Change	Q7	No Change
	1	1	0	0	Q _N -1	Q7	No Change
	1	1	1	1	Q _N -1	Q7	No Change
	1	1	1	No Change	No Change	No Change	Q7

Figure 2. The truth table from the 4094 datasheet.

and Port Expander



the IC, with eight flip-flops accompanied by eight output latches. At the Qs output (pin 9), the bits vanish into thin air after the eighth pulse on the clock input (pin 3). You could connect the data input of another shift register to this pin and use the bits for some other purpose. However, a special role is reserved here for the Q\ output (pin 10). The output of Q8 appears on this pin as well, but only on the falling edge of the clock signal. This means that it acts like a sort of ninth bit in the storage register. The truth table in the data sheet (**Figure 2**) shows this clearly. The Q\ output does not assume the state of the output of Q7 (Q8 in the block diagram) until the falling edge of the clock.

This port expander is a small, independent circuit board that can also be used without the downstream relay board. Now that you understand

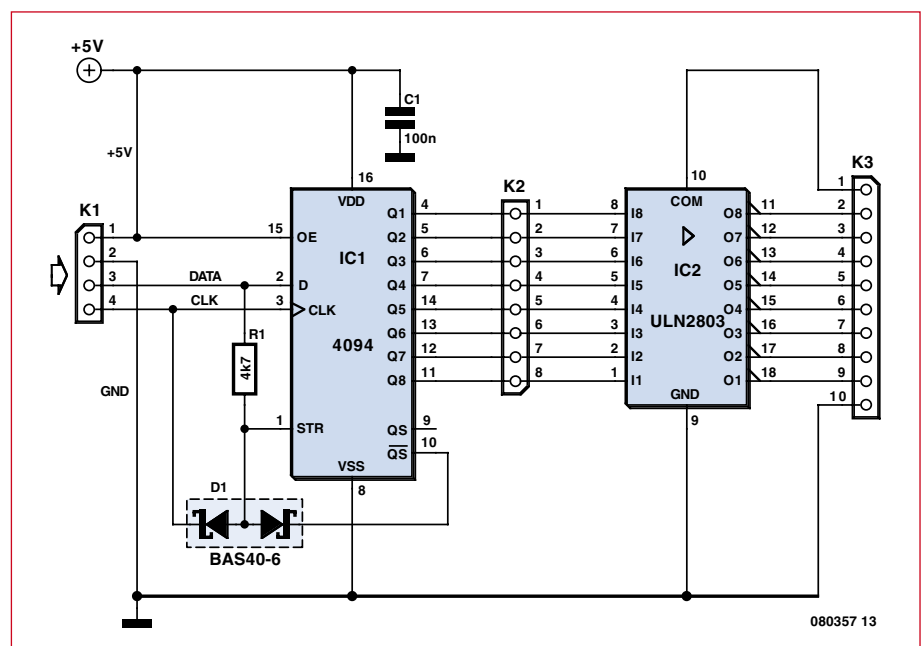


Figure 3. Schematic diagram of the port expander with the 4094 shift register and ULN2803 power driver.

how the shift register works, it's time to take a closer look at how the overall circuit works (see **Figure 3**), since we intend to support three inputs with

only two bits. The Q\ output is used to gate the strobe signal. A strobe pulse is only generated if Q\, Data and Clock are all high. The corresponding three-

input AND circuit is built using a dual Schottky diode (BAS40-6), since the necessary noise immunity could not be achieved with ordinary silicon diodes. This arrangement compels us to use the following program sequence to transfer all eight bits:

1. Eight '0' bits are loaded into the shift register. This is done by setting Data low and generating eight clock pulses. Each bit is shifted in on the rising edge of the clock signal. After this, all of the internal Q outputs are low. However, the levels on the output pins do not change because the strobe pulse is blocked by the low level of the Data signal.
2. Next, we shift a '1' bit into the 4094. It will subsequently appear at Q\ after eight clock pulses.
3. Next we transfer seven data bits, each with the desired level (high or low, corresponding to 'relay engaged' and 'relay disengaged'), and each accompanied by a clock pulse. The data bits are shifted in on the positive clock edge.
4. The eighth bit is transferred at the end in a special manner. First we set the Data line to the desired level. This time we do not generate a complete clock pulse, but instead leave the Clock line set high temporarily. This causes all eight bits to be shifted to their final positions. However, Q\ is still holding the state of the previous bit, which was set to 1 nine clock pulses earlier. Now we set the Data line high if it was not already set high for the last bit. This causes the strobe pulse to be generated via the diode/resistor network. The eight bits are thus passed to the outputs. After this the Data and Clock signals can be returned to the low level in any desired order.

This procedure is fast and reliable, and it saves an additional I/O line.

Relay board

The circuit of the relay board (**Figure 4**) is very simple. A power connector and a diode for reverse-polarity protection, as well as an LED to indicate that the supply voltage is present, are essential. There is also a 10-way pin head-

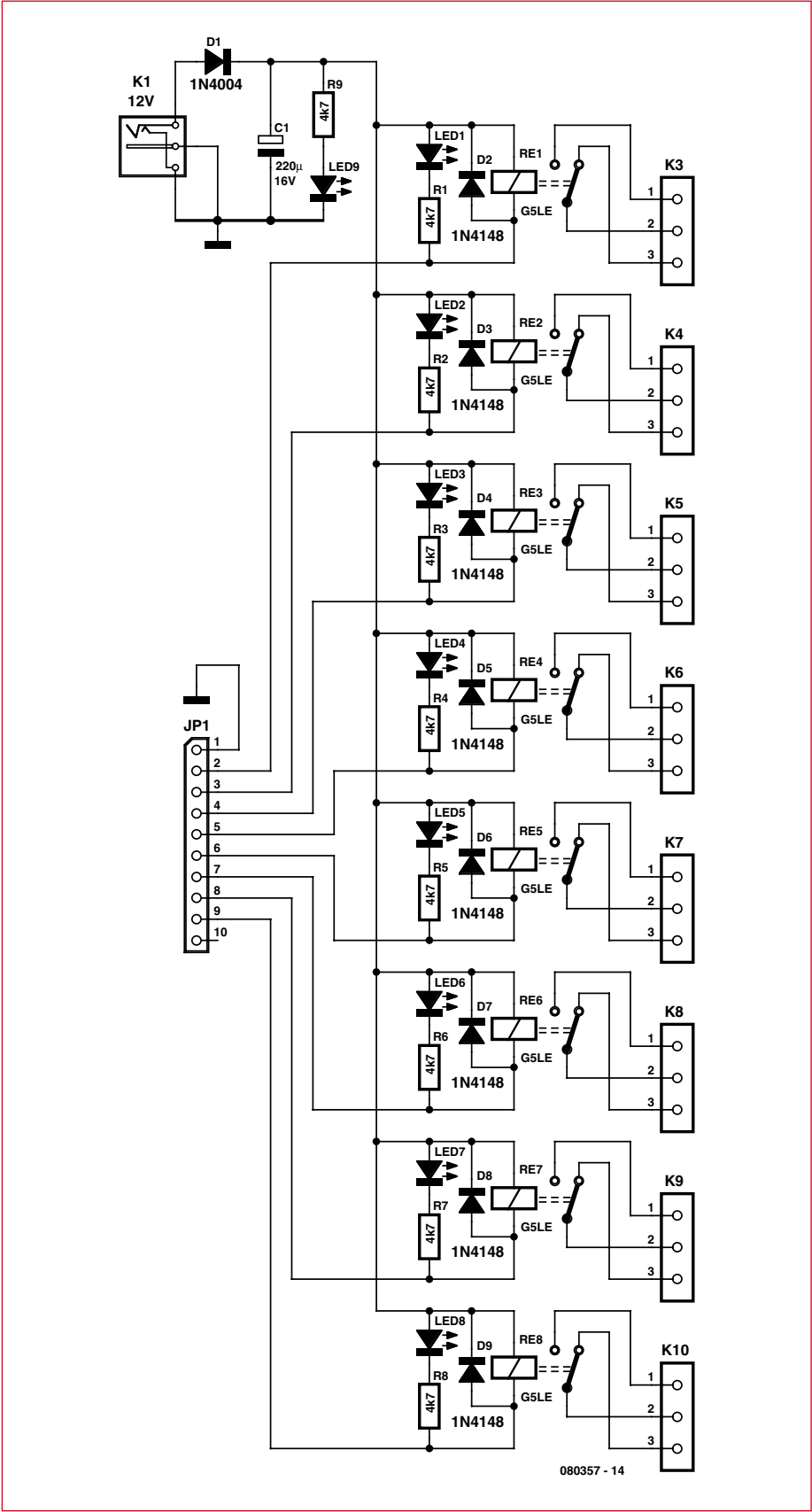


Figure 4. Schematic diagram of the relay board.

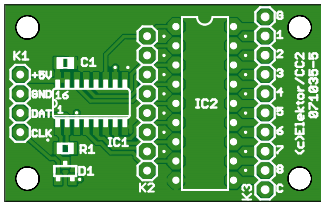


Figure 5. Port expander PCB.

COMPONENTS LIST

ATM18 Port Expansion Board # 080357-5

Passive Components

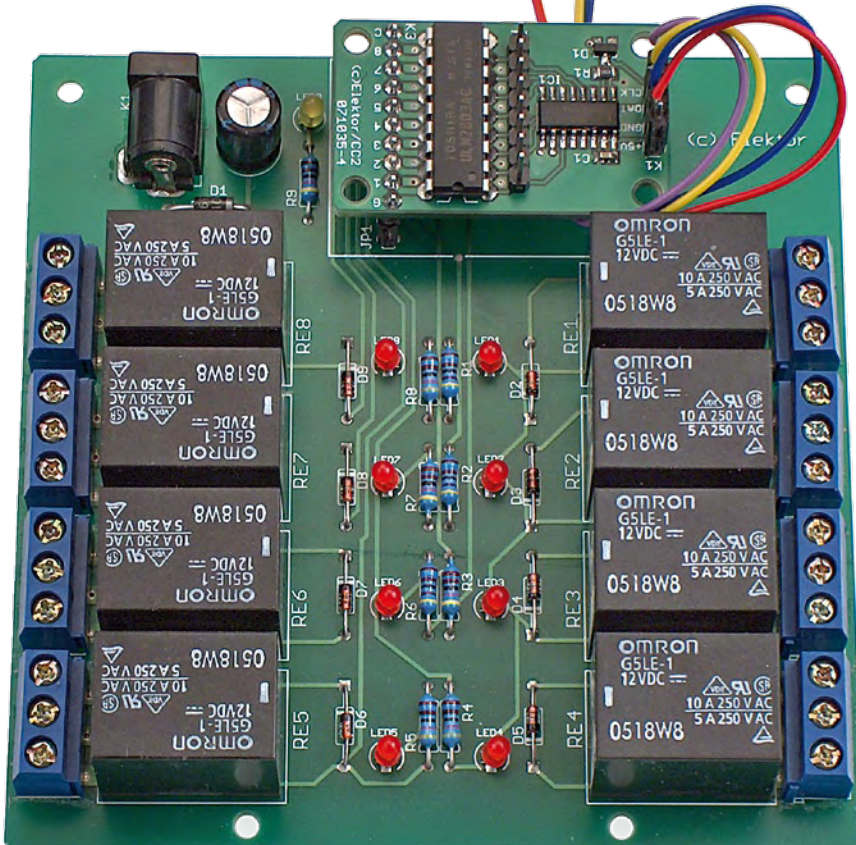
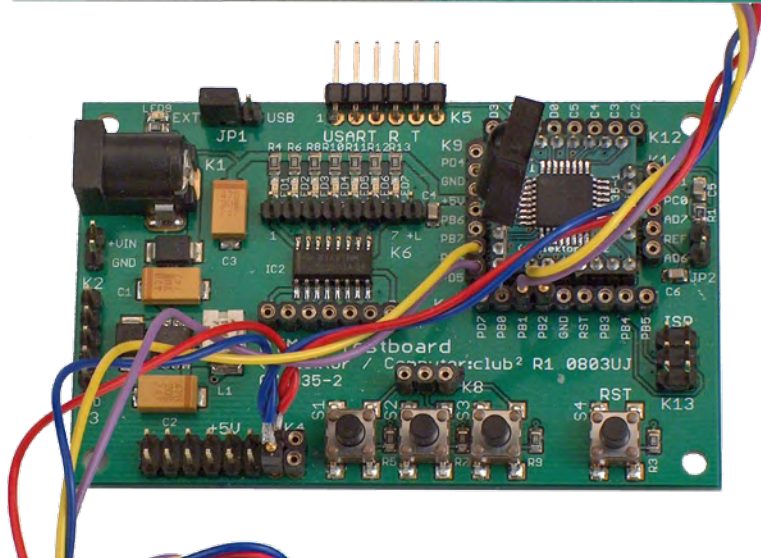
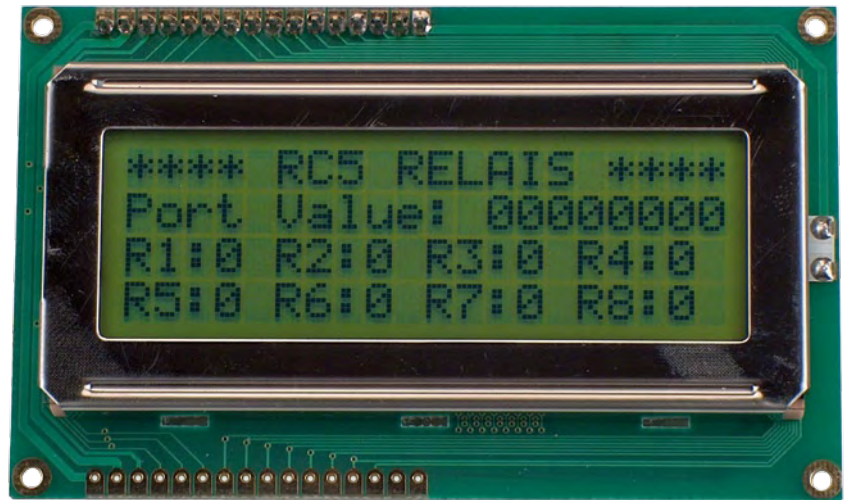
R1 = 4kΩ7 (SMD shape 0805)
C1 = 100nF (SMD shape 0805)

Semiconductors

D1 = BAS40-1 (SMD)
IC1 = 4094 (SMD SO16)
IC2 = ULN2803 (DIL16)

Miscellaneous

K1 = 4-way pinheader
K2 = 8-way pinheader
K3 = 10-way pinheader
PCB, bare, order code **071035-5**, see
Elektor SHOP
PCB with SMD parts mounted, order
code **071035-95**, see Elektor SHOP



a socket header to the port expander board (Figure 5), you can plug it on top of the relay board (Figure 6).

Of course, you can also use the relay board without the port expander board by connecting a set of leads directly from the UNL2003 outputs on the ATM18 test board (connector K6 on the test board) to it and then connecting the ULN inputs (on connector K7 of the test board) to the pins of the microcontroller I/O port. However, this is not as elegant as our two-wire solution.

Diodes connected in parallel across the relay coils (freewheel diodes) must always be fitted to limit the high voltages that result from the coil inductance when the relay is de-energised. LEDs with series resistors are also useful for helping you recognise the states of the relays.

The relays used here are rated for currents up to 5 A, and the circuit board tracks can also handle this current

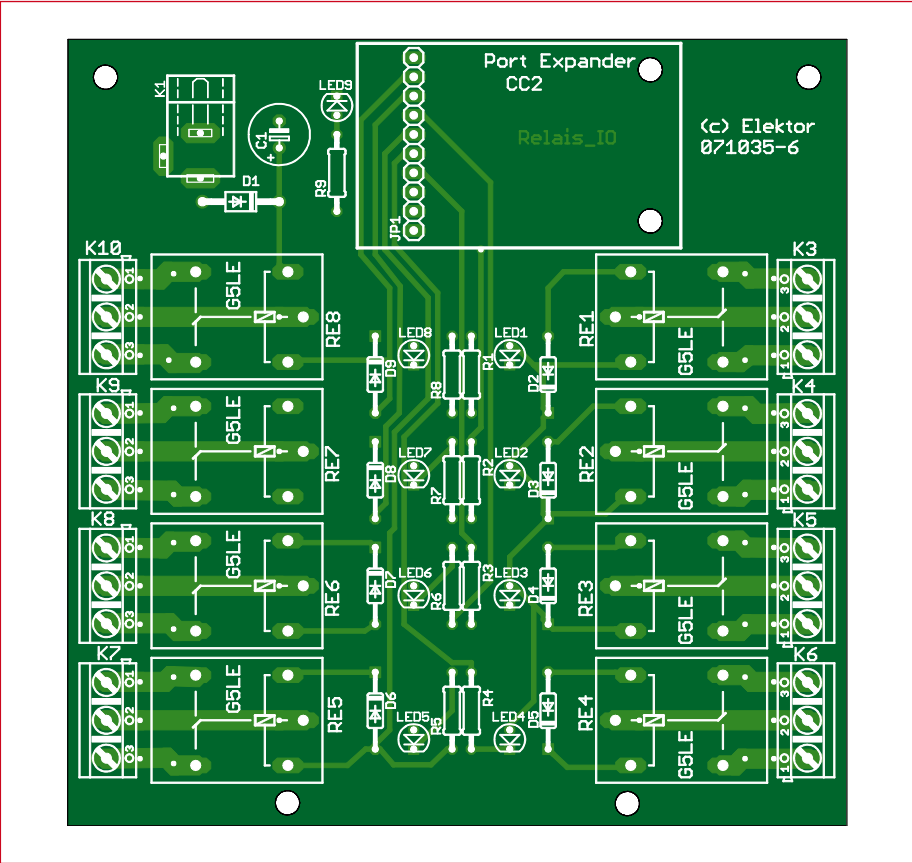


Figure 6. Relay board component layout.

level. In theory, they could be used to switch the mains voltage (110 V or 230 V) – the track spacing is adequate for this – but hobby electricians (such as the author) are well advised to avoid this temptation. If the board were used

this way, it would have to be fitted in a suitable enclosure and it could only be used to switch devices with suitable protection against contact with potentially live parts (because the relay switches only one side of the circuit).

COMPONENTS LIST

ATM18 Relay board
080357-6

Resistors
R1-R9 = 4kΩ7

Capacitors
C1 = 220µF 16V

Semiconductors
D1 = 1N4004
D2-D9 = 1N4148
LED1-LED9 = LED, 3mm diam.

Miscellaneous
JP1 = 10-way box header
K1 = DC adapter socket, PCB mount
K3-K10 = 3-way PCB terminal block, lead pitch 5mm
Re1-Re8 = Omron G5LE
PCB, bare, order code **071035-6**, see Elektor SHOP
Kit of parts (PCB and all components), order code 071035-72, see Elektor SHOP

The message is thus: stay away from 110 V or 230 V if you aren't a qualified electrician.

As the port expander is built using SMD ICs, the board is available pre-assembled. By contrast, a parts kit with a bare PCB is available for the relay board with its relatively large, easily soldered components.

C code

As usual, an example program written in C is available for downloading from the Elektor website. This program (ATM18-RC5_Relay) uses the relay board for convenient control of all eight outputs via an RC5 remote control. The decision regarding which two I/O lines to use to control the port expander depends on which other hardware functions are needed. The C program is written for an application with an LCD module connected via a two-wire interface. In this configuration, the display shows the current state of the relays. It occupies I/O lines PB1 and PB2 (see the May 2008 issue of *Elektor*). The RC5 receiver is connected to PB0 (see the June 2008 issue of *Elektor*). The PD5 and PD6 pins can then be used for

Listing 1

Excerpt from main.c

```
RC-5 button assignment:
1..8: Switch corresponding relay on/off
0   : Switch off all relays
9   : Switch on all relays

Test board wiring for ATM18_LCD application

COMPONENT                ATM18 PIN
*** LCD 2-wire interface
CLOCK                     PB1 (can be changed in "application.h")
DATA                      PB2 (can be changed in "application.h")

*** Port expander 2-wire interface
CLOCK                     PD5 (can be changed in "application.h")
DATA                      PD6 (can be changed in "application.h")

*** IR receiver ***
Receiver supply +/-       K4 (watch out for proper polarity!)
Receiver output           PB0_ICP1
```

the Clock and Data lines, respectively. If necessary, you can easily assign other pins. Everything you need to use the circuit successfully is contained in main.c (**Listing 1**).

One important point is that the remote control unit that you use must use device code '0' (video recorder). With this arrangement, you can use buttons 1 through 8 to independently switch each relay on or off. The 0 button clears all the outputs, so it is a sort of 'closing time' button: everything off!

BASCOM example

For beginners, the BASCOM example

program PortExpander1.bas is probably easier to understand. It uses the same pin assignments for the port expander but omits the LCD. Instead, data is output via the serial interface for test purposes. In this way, you can see which data is sent by the RC5 remote control.

The listing shows the data transfer to the shift register in the procedure Sub Pe_write_byte. I/O line D6 is the data output, while D5 supplies the clock signal. The main routine reads data from the RC5 receiver and uses it in exactly the same way as the C program. This means that you can use buttons 1 through 8 to switch individual relays on and off, while button 0

clears all the outputs.

Experience with infrared control units has shown that the only real difficulty is finding a suitable remote control unit. If you have found one that generates RC5 signals, it may turn out to use the wrong device address. For this reason, the Basic program intentionally accepts all device addresses. This means that it does not matter whether the remote control belongs to a video recorder, a television set, or some other device. The device address and the command byte are output each time via the serial interface. This is useful for troubleshooting,

(080357-1)

Listing 2

PortExpander1.bas

```
'ATM18 Port expander, Relays, RC5
'Clock = PD5, Data = PD6

$regfile = "m88def.dat"
$crystal = 16000000
Baud = 9600

Dim Address As Byte , Command As Byte
Dim Mask As Byte
Dim N As Byte
Dim State As Byte
Dim Relay As Byte
Dim Ctrl As Byte , Ctrl_old As Byte

Pe_clock Alias Portd.5
Pe_data Alias Portd.6
Config Portd = &B01100000
Config Rc5 = Pinb.0
Declare Sub Pe_write_byte(d As Byte)
Enable Interrupts

Print "Port Expander"
Relay = 0
Pe_write_byte Relay

Do
  Getrc5(address , Command)
  If Address < 255 Then
    Ctrl = Command And &B10000000
    If Ctrl <> Ctrl_old Then
      Print Address
      Print Command
      Command = Command And &B01111111
      If Command = 1 Then Toggle Relay.0
      If Command = 2 Then Toggle Relay.1
      If Command = 3 Then Toggle Relay.2
      If Command = 4 Then Toggle Relay.3
      If Command = 5 Then Toggle Relay.4
      If Command = 6 Then Toggle Relay.5
      If Command = 7 Then Toggle Relay.6
      If Command = 8 Then Toggle Relay.7
      If Command = 0 Then Relay = 0
      Pe_write_byte Relay
    End If
    Ctrl_old = Ctrl
  End If
```

```
End If
Loop

Sub Pe_write_byte(d As Byte)
  'Write Byte To Port Expander
  Mask = 1
  Pe_clock = 0
  'Clear data signal
  Pe_data = 0
  'Clear all stages of shift register
  For N = 1 To 8
    Pe_clock = 1
    Waitus 5
    Pe_clock = 0
  Next N
  'Set High Level For Qs
  Pe_data = 1
  'Cock in QS
  Pe_clock = 1
  Waitus 5
  Pe_clock = 0
  'Do this for 7 databits
  For N = 1 To 7
    State = D And Mask
    If State = 0 Then
      Pe_data = 0
    Else
      Pe_data = 1
    End If
    Pe_clock = 1
    'Clock in data with rising edge
    Waitus 5
    Pe_clock = 0
    Shift Mask , Left
  Next N
  'last bit
  Pe_data = 0
  State = D And Mask
  State = State / Mask
  If State = 1 Then Pe_data = 1
  'Set Strobe
  Pe_clock = 1
  'Clock in data
  Pe_data = 1
  Waitus 5
  Pe_data = 0
  Pe_clock = 0
End Sub
End
```


Two Low Cost Scopes

Economy digital oscilloscopes from the Far East

Dr. Thomas Scherer (Germany)

The cathode ray tube (CRT) has made way for the LCD and digital has replaced analogue technology. This trend is also evident in the design of oscilloscopes. Prices are falling: a good specification DSO from China can now be found for € 600 (£ 450) or less. One of our freelance contributors Thomas Scherer got the chance to put two economy scopes through their paces.

Sitting on my workbench for the past 20 years or more has been my faithful friend, a single channel Hameg 103 oscilloscope (**Figure 1**). In more recent years my often repeated motto: '10 MHz is bandwidth enough' has started to sound a little unconvincing and anyway it would at least be nice to have a scope with a second channel. With these thoughts in mind I had recently been searching the Internet for a suitable replacement for my old oscilloscope. It was something of a coincidence when I got a call from the Elektor office asking me to try out two low-cost scopes from the Far East. This would be an excellent opportunity to get my hands on these machines and find out if they really could take the place of my old Hameg. What follows is a subjective assessment of just two models and may be of some help to those of you in the similar position who are considering investing in some test equipment.

Manufacturers

There is certainly no shortage of digital oscilloscopes available today but most models are aimed at the professional

user with prices that reflect their specification. The cost of many of the higher-spec models from the established test equipment manufacturers is equivalent to what you would expect to pay for a decent family car. Trawling the Net for oscilloscopes costing less than 1000 euros (approx. 750) however does not generate too many hits. Two companies who are producing relatively low-cost test equipment are Rigol and Owon. Both manufacturers are based in China and are typical of the many new companies that have sprung up over the last ten years, fuelling the country's massive economic growth.

In addition to the standard digital 'scopes they also produce variants with integrated logic analyser functions. Although the sampling clock rate is way too low to be of any use on modern PC systems with their gigahertz clock speeds they can perform a useful role debugging the majority of modern-day microcontroller designs. It was two of these combination scopes that I had available for this test. For my own needs the additional analyser functions are not so interesting so for this report I confined my comparisons to the oscilloscope functions only.



Figure 1.
The 22 year old Hameg 103 oscilloscope on the author's workbench.

Owon MSO5022

The offering from Owon (**Figure 2**) is the lighter (1 kg) of the two scopes on test despite it being the bigger of the two models. The larger case 350 x 155 x 120 mm (WxHxD) is necessary to accommodate the impressive 7.8" colour display. This screen size is big enough to display full 640 x 480 pixel VGA resolution images. Although the screen gets full marks for its size this type of LCD uses low cost STN technology and consequently does not have such a good viewing angle as the more expensive types of LCD. The colours assigned to functions and displayed waveforms cannot be changed (at least I couldn't work out how to change them!). The MSO5022 comes with the range of accessories shown in **Figure 3**.



On the positive side the large display is impressive and individual selector switches are used to select the vertical amplification for each channel. Control knobs can adjust the vertical position of each waveform. At the rear of the unit is a compartment for an optional rechargeable battery pack allowing the scope to be used independently of the mains. The scope takes around 10.5 W (measured) which should allow a few hours operation on batteries. There is no fan fitted. The menu is quite easy to navigate and did not require reference to the handbook. The quoted bandwidth of 25 MHz is sufficient for my needs as is the memory depth of 5,000 samples. The A/D converter has an 8-bit resolution.

Now to look at some of the features that were less impressive: The vertical sensitivity is adjustable up to only 5 mV/div. and while gain steps of 1, 2.5, 5 are well spaced there is something important missing here: fine adjustment. My old Hameg has a variable gain knob which can be used to increase the vertical magnification up to 1.7 mV/div. The time base is adjustable in steps from 5 ns to 5 s/div. but again the lack of a manual time base expansion control is frustrating. The larger screen dictates that this unit takes up a little more space on the workbench than the Rigol.

To make good quality screenshots the scope can be connected to a PC using either a USB or serial port. The software necessary to run a virtual oscilloscope program on the PC is included on a CD. Despite successfully installing the driver on my PC running Windows XP the computer failed to recognise the scope on the end of the USB cable. Okay, I thought, no problem, I will use the serial port but attempts at communication over this port were also unsuccessful. By this time I had convinced myself that there was probably a conflict with some previously installed software. With this in mind I attempted to install the USB software on my laptop which has a relatively new installation of XP and very few additional programs. The result was rather disappointingly the same. After a few hours of tinkering and despite

my conviction that the software must have worked at least once in Beijing I decided to throw the towel in. When all else fails a memory stick can be used to store and

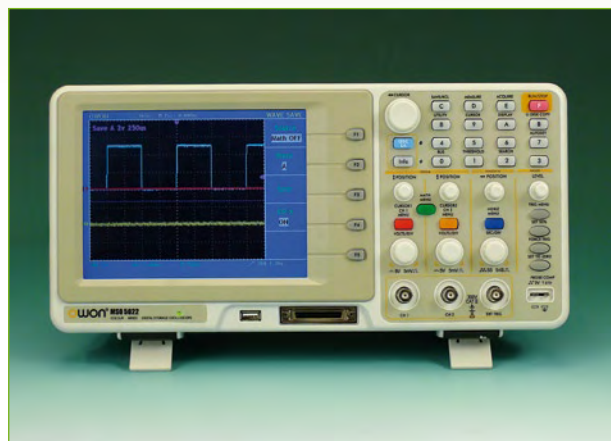


Figure 2.
The two-channel MSO5022 digital scope from Owon with built-in logic analyser.



Figure 3.
The package from Owon includes: Software-CD, manual, logic analyser clips, two 1:10 switchable scope probes with spares and a USB cable.



Figure 4.
The two-channel DS1102C
digital scope from Rigol
with built-in logic analyser.



Figure 5.
The package from Rigol
includes: Software-CD,
manual, logic analyser
clips, two 1:10 switchable
scope probes with spares
and a USB cable.

transfer files from the USB socket on the front of the scope to a PC using the Owon software.

Rigol DS1102C

The most obvious difference from the Owon is size, at 303 × 154 × 133 mm (W×H×D) the Rigol is a little more compact and is fitted with a 5.7" display (**Figure 4**). The Rigol again does not use the best technology PVA/MVA or IPS type LCD, and with its smaller screen can only manage 320 × 234 pixels. Weighing in at 2.4 kg the Rigol is more than twice as heavy as the Owon. The scope comes with a set of accessories similar to the Owon (**Figure 5**). The DS1102C does not have space for a battery power pack but with a power consumption of 26 W the batteries would not last too long between charges anyway. The scope runs warm and is fitted with a fan. The Rigol scope also comes with its own handy tote bag allowing the scope, pods, probes and accessories to be neatly stowed for transporta-



Figure 6.
The Rigol virtual
oscilloscope.

tion while providing protection from the worst knocks. The wider analogue bandwidth (100 MHz) of this model is not really an issue here, the company also makes lower cost 25 MHz and 40 MHz scopes comparable to the specification of the Owon. The Rigol certainly has more useful features and the whole concept seems better 'thought through'. In use the Rigol also has a better feel; the knobs operate smoothly and you are left with the general impression of a better build quality. Fine adjustment of the vertical amplification is available by pushing and rotating the vertical scale knob. The timebase also features delay and fine position control. Use of the cursor is quite intuitive. The measurement ranges go from 2 mV to 10 V/div. vertical and 2 ns to 50 s/div. horizontal. The memory depth is 8,000 samples in standard mode and can be expanded to 512 k samples. The greater number of settings and adjustments available on the Rigol scope give it more flexibility and make it a more useful tool on the test bench than the competitor. The trigger function alone has 15 different modes and the user interface has a choice of ten languages.

After the frustrating experience trying to connect the Owon to a PC I was not looking forward to attempting the same with the Rigol. I need not have worried; the drivers and software were installed without any problem and as soon as I connected the PC and scope with a USB cable the new hardware was recognised and ready for use. The screenshot in **Figure 6** shows that practically all of the scopes front panel controls are represented on the PC screen. Waveforms appear on the screen after a very slight delay. One negative aspect of the PC display is the representation of the scope's knobs. These are drawn as very simple push buttons for incrementing and decrementing the setting and are a little clumsy to use. More annoying is that once communication with the PC is established it is only possible to control the scope functions from the PC. So if you want to quickly change the settings on the scope's real knobs it is first necessary to disconnect the USB cable. This feature is a little impractical.

A Personal choice

In terms of features, build quality and after-sales support both of these offerings still have a long way to go before they can be favourably compared to similar machines designed by the more established European or North American manufacturers.

Both machines have a significant price advantage however; the Rigol model on test retails at over 1,000 euros (approx. £ 750) whereas the Owon will set you back just over 600 euros (approx. £ 450). Both companies also offer several other versions without the logic analyser function and with bandwidths of 25, 40 and 60 MHz. For my needs the lowest spec model would be sufficient.

To get the best of both worlds we would need to take the innards from the Rigol and marry them up with the display from the Owon but that is not a viable option. The day will no doubt come when the electron beam makes its final journey across the graticule of my Hameg and the chances are that on that day it will be replaced by a Rigol machine despite the shortcomings of its display.

(080411-1)

Internet Links

- [1] www.owon.com.cn/eng
- [2] www.rigolna.com

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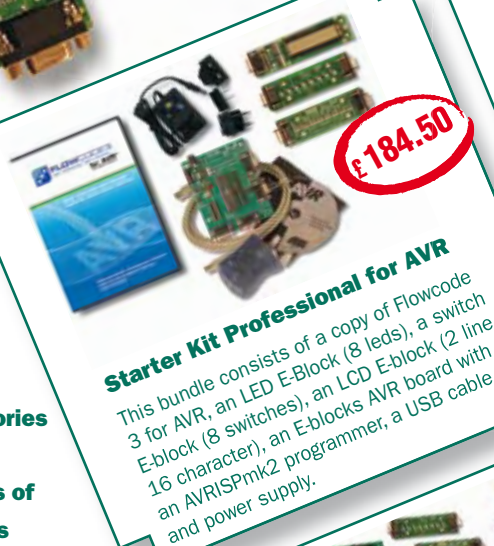
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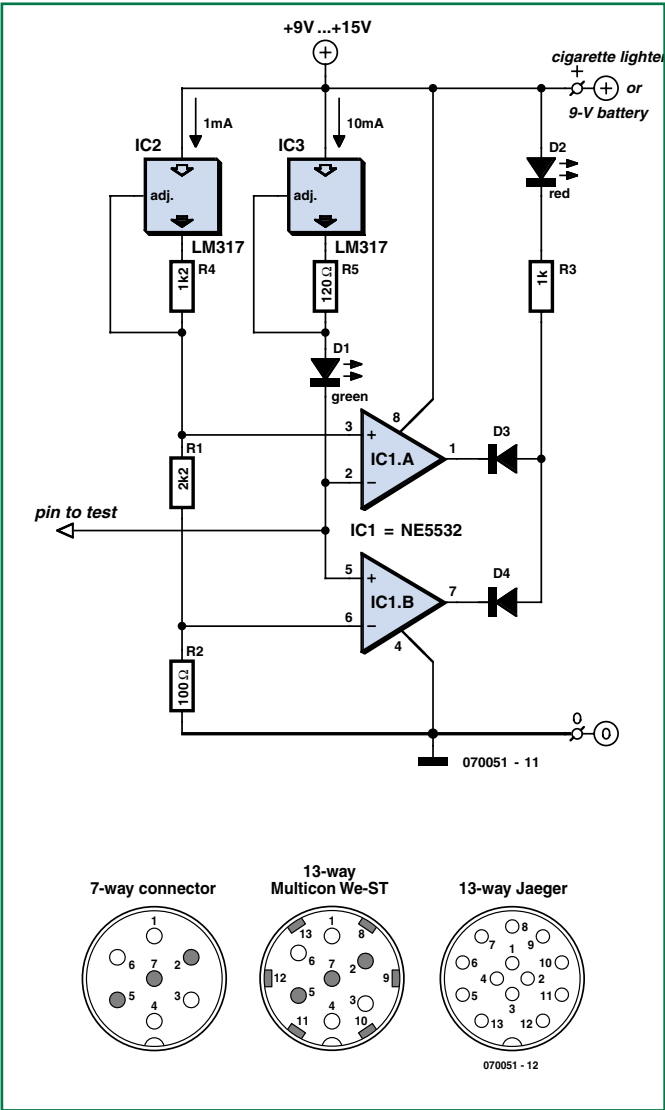


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£243.70

Testing trailer connectors



Erwin Deumens

For testing the lighting of trailers or caravans you really need two people: one to operate the switches and pedals, the other to check that the lights work. This has been the most practical way until now. When you use the circuit from this design tip you can do the testing on your own.

The circuit isn't complicated. The pin of the trailer that is tested is connected to two opamps (configured as comparators) and compared to two reference voltages. We have specified an NE5532 for the opamps, but any other opamp that can operate at about 14 V (such as a 741) can also be used. The reference voltages are obtained by passing a constant current of 1 mA through two resistors (R1 and R2). This creates a voltage of 100 mV at pin 6 and 2.3 V at pin 3 of IC1.

When the pin being tested (i.e. the lamp) works correctly, the voltage on the pin will be between 100 mV and 2.3 V (for example: a 12V/5W lamp has a resistance of about 30 Ω). At a current of 10 mA this cre-

ates a potential difference of 300 mV). A current of 10 mA will then flow through LED D1, which causes it to light up. The outputs of IC1A and IC1B are both high and D2 stays off. If there is a short to ground somewhere, the output of IC1B will become low and both D1 and D2 will light up. When the lamp has burnt out the voltage at the pin will be equal to the supply voltage of the circuit. In that case there is no current flow through D1. The output of IC1A is then low, which causes D2 to light up.

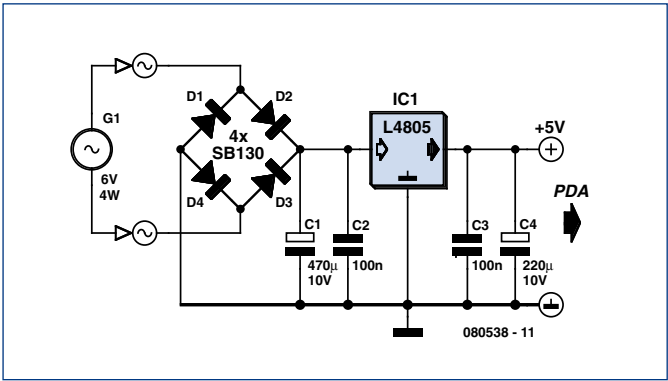
The ground of the circuit should of course be connected to the ground of the trailer or caravan. In the diagrams for some of the most common connectors you can see which pin is connected to which lamp, so you can easily find out where the problem is. It is of course also possible to build the circuit 7 or even 13 times, so you can test all lamps in one go, but it works just as well with a single circuit.

(070051-1)

PeDAI power

Jan Visser

Even if there are cycle tracks and special maps, some cyclists will stubbornly try to find their own way – these die-hards can be recognized not only by the latest GPS or PDA kit fitted to handle bars, but sadly also by the desperate looks and moaning as result of flat batteries experienced 'by the roadside'. According to Elektor's cycling expert Jan Visser, two hours of continuous use is about the most you can from a GPS-running PDA fitted on a bicycle. This Design Tip should lengthen the useable period to about five hours increasing the cyclist's



chances of reaching the destination hopefully with meaningful GPS guidance.

The circuit shows that the alternating voltage supplied by the (hub or wheel) dynamo is recti-

fied by Schottky diodes. These exhibit a forward drop of just 0.3 V and so allow some more headroom for the L4805 voltage regulator. The USB cable connections allow the charging voltage to be fed directly to the PDA. The result is some charging of the battery while cycling and longer use of the GPS function on your bike.

(080538-1)

Hexadoku

Puzzle with an electronics touch

Here's another Hexadoku puzzle to exercise the odd brain cell. Get out a pencil and enter hexadecimal numbers 0 through F in the boxes in such a way they occur once only in each row, column and 4x4 area. Send us your solution and enter a prize draw for an E-blocks Starter Kit Professional and three Elektor Shop vouchers..

The instructions for this puzzle are straightforward.

In the diagram composed of 16 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.

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PARTICIPATE!

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

editor@elektor.com - **Subject: hexadoku 10-2008** (please copy exactly).

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

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

The closing date is **1 November 2008.**

PRIZE WINNERS

The solution of the July/August 2008 AlphaSudoku is: **HKCEAO.**

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

Andie Elizabeth French (UK).

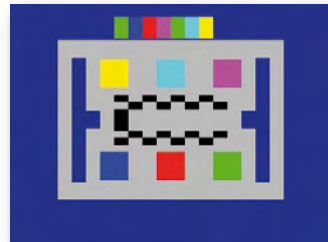
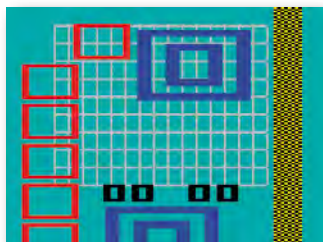
An **Elektor SHOP voucher worth £40.00** goes to: Mike Parker (UK); Tuomo Hyrönmäki (FIN); Gerard Schouw (SA).

Congratulations everybody!

F	3	6	B			C	8			E	D				
8						A			5		3				E
	1				D			2		4	F	8			6
	D	E	A			4				B					5
	F		4	2	3			A	8		B	7			5
	9	D	6			1			7	0	3	2	4	F	
2						7			5		C			0	
0				C				1		D		6			A
	2	8				5		F		1					
A			C	F	2	E	4		0				8		
3				D	8	9	7		4						A
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Elektor TV Games Computer (1979)

James Jacobs (Australia)

Next year will mark the thirtieth anniversary of the Elektor TV Games Computer (TVGC), which first appeared in the April 1979 issue of Elektor. The TVGC project was 'adopted' by various advertisers in later issues of the magazine, selling in kit form for £ 200-300.

This innovative machine, designed by Elektor and Philips, was based around hardware from Signetics, a US subsidiary of Philips: most importantly, the Signetics 2650A CPU and the Signetics 2636 Programmable Video Interface (PVI). A regular PAL television set was used to display output.

A Philips 2 k 'monitor' ROM served as BIOS and operating system, allowing programs to be loaded and saved via the cassette interface, the machine to be programmed, and debugging performed. Interactive, open-platform computing 30 years ago!

The PVI supported 16-colour graphics, reusable scalable sprites, score display and limited background graphics. A 28-key keyboard and a pair of analogue joysticks were used for input.

The total RAM was 2 k in the basic machine and 5 k in the expanded machine; this was shared between the monitor ROM software and user games.

This computer was in a functional sense a rough superset of the professionally manufactured games consoles of its day. For example, the 'Hobby Module' cartridge for the Radofin

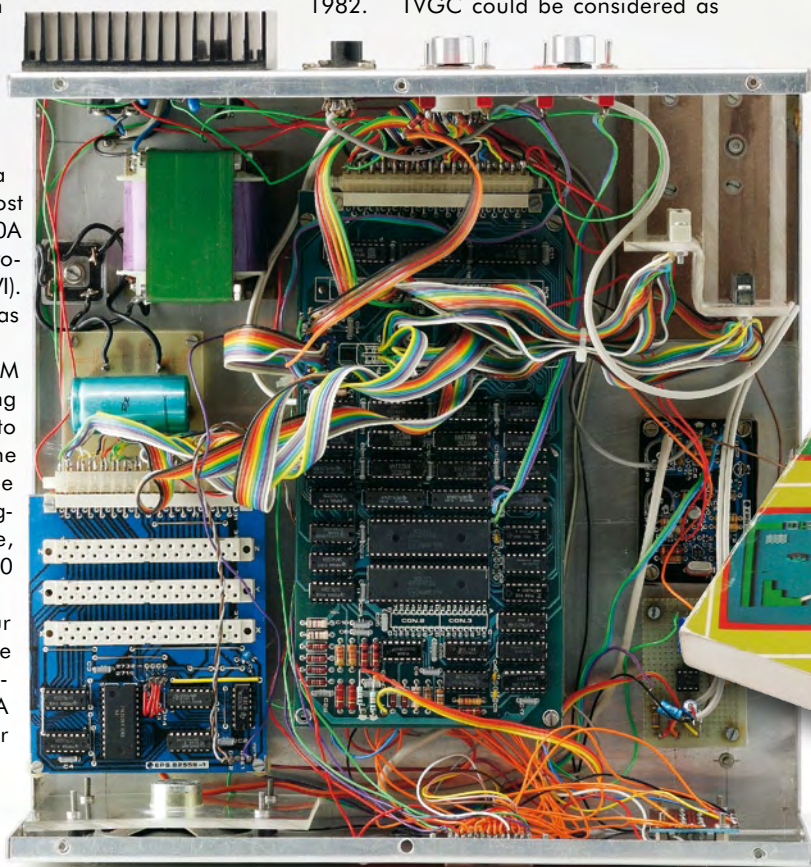
console contained the monitor ROM, RAM and a DIN socket for a cassette recorder; use of this effectively transformed the console into a basic TVGC.

A variety of expansions for the system were designed and published in Elektor magazine from

1979 to

1982.

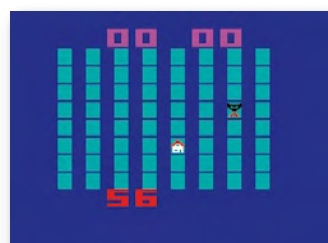
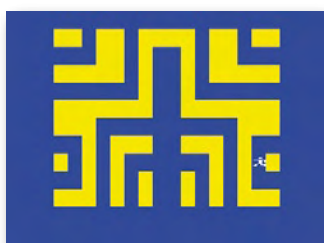
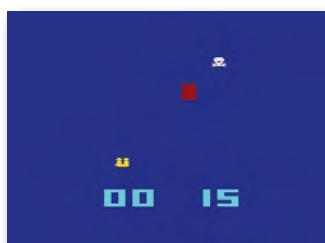
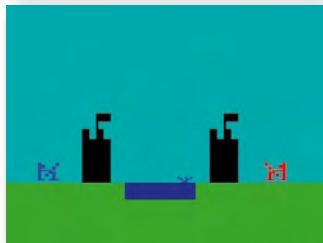
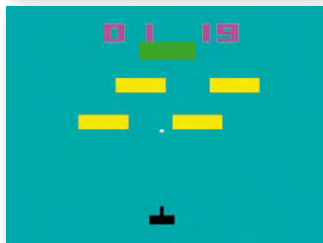
TVGC was a pair of expansion slots, designed to accept commercial game cartridges for the consumer Interton VC 4000 and Radofin 1292 Advanced Programmable Video System consoles, which were likewise based on the Signetics 2650A and 2636 chips. Effectively the TVGC could be considered as

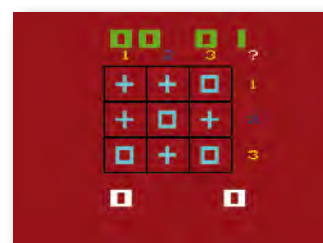
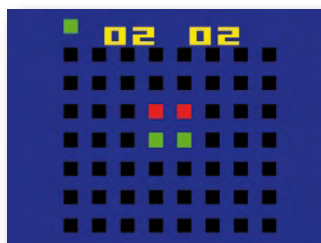
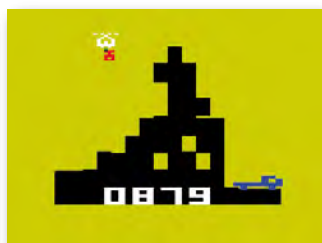


Although the basic machine already had a square wave generator, the expanded version featured a pair of General Instrument AY-3-8910 Programmable Sound Generators (PSGs) (later computers such as the 16-bit 1985 Atari ST had to make do with just one of these!).

An interesting option on the

a development system for such consoles; certainly there were many games which were released both as TVGC cassettes and console cartridges. Which were the originals and which were the derivatives is not always easy to ascertain. Also, a 'Rapid Loading Games' project, enabling the use of





EPROMs instead of cassettes for program storage, and a plug-in EPROM programmer, essentially gave the system a primitive form of Flash memory. A hardware-based random number generator (RNG) was another project. Various software written by enthusiastic readers was available through the then fledgling Elektor Software Service, not only on cassette but also on 45 rpm vinyl records! Third-party software was provided on cassette

by, among others, Hoc-

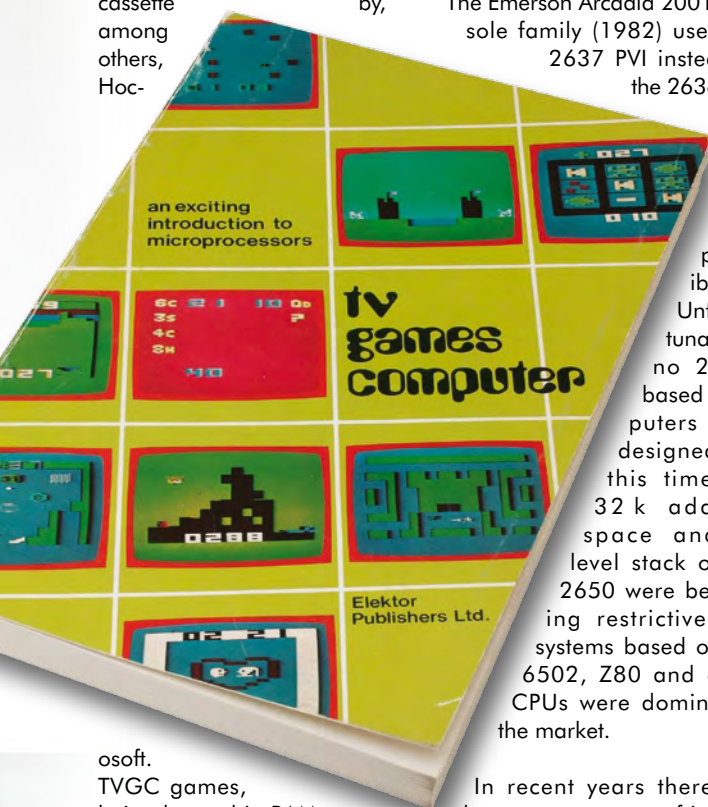
The Emerson Arcadia 2001 console family (1982) used the 2637 PVI instead of the 2636 and

were not possible on the real hardware, such as gameplay recording and playback, turning off the collision detection to cheat in the games, setting data watchpoints, and so on. There is also a friendly community of enthusiasts to this day [2].

Being rare and treasured items, these machines command a premium in the market. Each is effectively a hand-crafted piece; for example, extensive calibration routines were required to compensate for the variety of joysticks that were in use.

The TVGC main unit pictured here is in careful storage in the Retronics cabinet at Elektor House. It has a Perspex case and cover (here removed) for 'look but do not touch' display and demonstrations at shows and exhibitions where visitors would marvel at all the high tech innards. Sadly, none of the game cartridges, keyboard, extension boards and joysticks have survived the Elektor's company moves or *space reallocations for vintage projects* (mostly equating to: "into the skip"). If these bits were available to fire up the TVGC (say on the Retronics workbench in the Elektor lab) your next issue would be in serious danger of not appearing in time.

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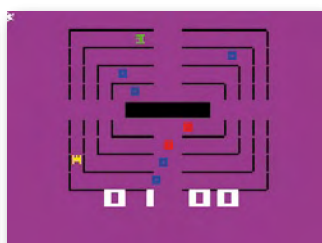
osoft. TVGC games, being located in RAM, could and did use self-modifying code extensively and also leveraged routines in the monitor ROM. Unsurprisingly, they were also typically highly timing-dependent. There were dozens of games

In recent years there has been a resurgence of interest in the Elektor TVGC. It now possible to emulate these systems under Windows with the open-source WinArcadia emulator [1]. (Amiga versions are also available). It has been extended to accommodate features that

Web Links

- [1] amigan.classicgaming.gamespy.com
- [2] tech.groups.yahoo.com/arcadia2001consoles

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



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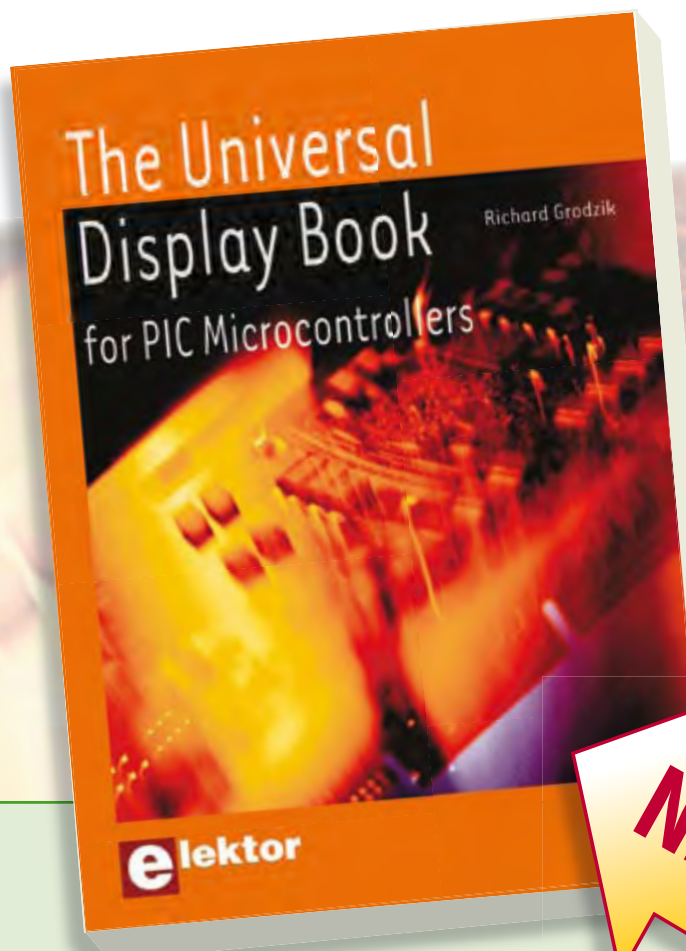
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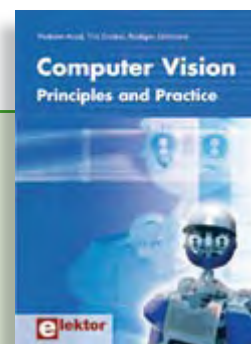
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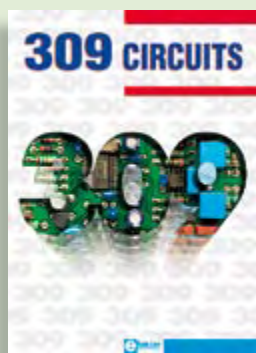


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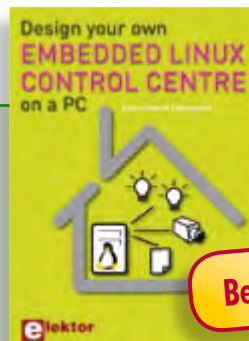


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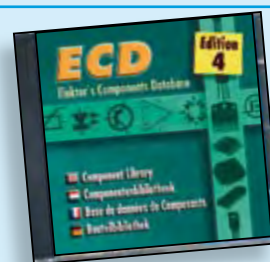


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DCC Command Station

(September 2008)

Electronics is making more and more inroads into the domain of model trains. Trains are now controlled with digital codes, and in many cases the entire system can be operated from a computer. Elektor presents a design for the device that forms the heart of a digitally controlled model railway: the DCC Command Station. The computing power in this design is provided by a highperformance ARM7 processor.

Kit of parts incl. programmed ARM module

Art. # 070989-71 • £88.50 • US\$ 177.00



SAPS-400

(May 2008)

The linear supply. With the SAPS-400 we offer a powerful, adjustable symmetrical supply that's ideal for lightweight audio power amplifiers and happily sits in less than a quarter of the space taken by a comparable supply of conventional design.

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DigiButler

(May & April 2008)

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

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

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BUILD YOUR OWN ELECTRIC BIKE

Next month we show how to build an electric bicycle from a kit of parts of (no wonder!) Chinese origin. For little money we got an electromotor, a drive unit, a 'throttle', two brake handles and a sensor. The motorised wheel replaces the existing front wheel on your bike. The kit was taken through its paces in the Elektor labs to see if it's any good and the results are published next month.



REMOTE CONTROLLED VOLUME POT

Remote control is now common for all sorts of equipment in and around the home. With most quality audio gear it's also great to be able to adjust the volume remotely. However, home made and high-end amplifiers however often lack the functionality and that's why we describe a remote volume control that employs a premium Alps potentiometer with motor drive. The electronics involved allows the pot to be controlled with just about any RC5 compatible remote you may have lying around.

CELLPHONE REMOTE SWITCHER

Many situations exist where it would be useful to be able to switch electrical equipment (such as a heating system) on and off from large distances. The circuit published in next month's Elektor enables this to be achieved with an ordinary cellphone (a.k.a. 'mobile' or GSM). Three switching outputs are available for mains-powered equipment. The Text (SMS) message returned by the circuit tells you the current status of each of these outputs. If a GPS receiver is connected up, it is even possible to have the unit send you map coordinates of the remote circuit.

The November 2008 issue comes on sale on Thursday 23 October 2008 (UK distribution only). Article titles and magazine contents subject to change, please check 'Magazine' on www.elektor.com UK mainland subscribers will receive the issue between 17 and 20 October 2008.

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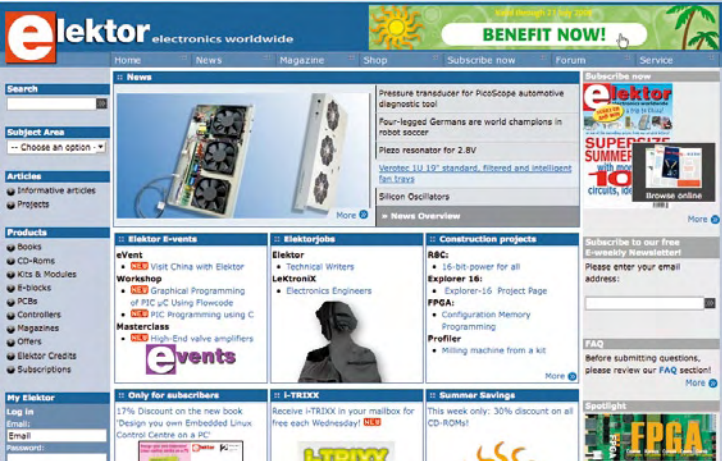
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