[Microcont... Analog • Audio • Digital • Test & Measurement]

October 2010

32x NE5532 = top-notch amp

+ S-FSK Powerline Communication

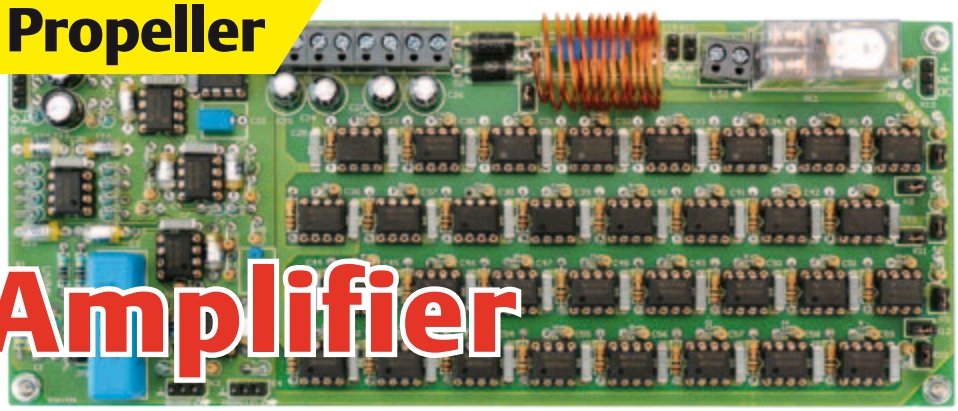
elektor

+ Quartus/Altera FPGA Design Simulation

+ 80 Candles for the Pentode

+ Satnav with Propeller

5532 Power Amplifier



20 AC/DC clamp meters on the test bench



US $ 7.95 - Canada $ 7.95

10

0 74470 24965 8

Making Your Devices Smart & Simple!

Internet Connectivity Wizard

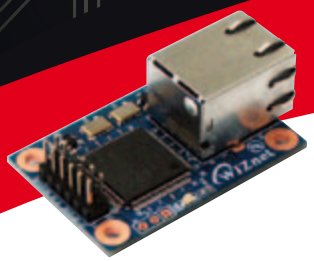
WIZnet's uniquely patented Hardware TCP/IP technology has proven effective in millions of network-enabled devices around the world, allowing users to easily add internet to the devices with greater stability to ensure faster product releases out to the market.

Hardware TCP/IP Offload Technology

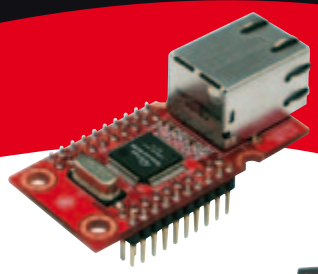
- Offloading Protocol Processing from a System MCU
- Stable Hardwired TCP/IP Logic
- Silicon-proven IP for SoC and ASSP
- High Performance & Low Cost Platform
- No Booting Time
- Simple System Composition
- Best-fits OS-less Device

Applications

- Smart Grid and Smart Meter
- Medical Device Management
- Industrial Control
- Robot Control
- Security System



Serial-to-Ethernet Module



Drop-in Network Module



Wireless LAN Module



External Device Server



Hardware TCP/IP Chip

Get more information at www.wiznettechnology.com

3003 North First Street, San Jose, CA 408-232-5415
sales@wiznettechnology.com

WIZnet TECHNOLOGY

NXP mbed DESIGN CHALLENGE

What TECHNOLOGY can you SET FREE?



The mbed Microcontroller, based on the NXP LPC1768, lets you work with an ARM Cortex-M3 in a 0.1" DIP form-factor. Combined with the http://mbed.org website, featuring the mbed "Cloud" Compiler, it is an ideal platform for rapid prototyping with microcontrollers.

NXP and ARM/mbed challenge you to revolutionize the way people build prototypes! Build a reusable library, component interface, reference design or product prototype that can be shared on http://mbed.org to help others build their prototypes even faster, and you could be walking away with part of a prize pool worth $10,000! **Deadline for entries is February 28, 2011.**

Join the Challenge by registering at

www.circuitcellar.com/nxpmbeddesignchallenge!

Apply for a free NXP sponsored mbed Microcontroller kit while supplies last.*

NXP mbed Design Challenge empowered by:

elektor CIRCUIT CELLAR® NXP mbed

*No purchase necessary. See website for details.

The reader/advertiser promise

If you are not in the electronics industry, or without a formal qualification in the field, it may be good to realize that electronics as a pastime would be non-existent without the wide diversity of manufacturers, distributors and suppliers of equipment, tools, components and CAD software — the friendly ones of course.

Although some readers have expressed a desire to see a version of Elektor without any advertising pages, short discussions on the phone or by email are usually sufficient to agree that their wish is unrealistic. For one thing, our advertisers make up for a good part of our income, the other main pillars being subscribers, newsstand sales and product sales. On the other hand, from a reader viewpoint, advertisers are the gateway to services and products (including components and tools) that are essential to enjoy electronics as a pastime, or pursue it at any level in education.

Sure, old hands with a fully loaded electronics workshop may object to seeing basically the same advertisers for years on end. But then, when I was learning about electronics at a young age, I believe I got as much information and fun out of browsing adverts, comparing component prices and seeing the big names in industry, than from actually reading articles, trying to understand it all and building circuits in front of me.

I am happy to say that Elektor is attracting an increasing number of companies, big and small, advertiser or not, wishing to run projects with us. Recently, 'projects' has taken on a wider meaning in also covering reader offers and contests. Together with our American colleagues at Circuit Cellar, we're officially launching the *NXP mbed Design Challenge* at Embedded Systems Conference in Boston MA, September 20–23. Invariably, reader offers and contests take a lot of time and effort to arrange exclusively for you — or should I say "for your pleasure". More is in the pipeline.

Jan Buiting, Editor
(and celebrating 25 years with Elektor this month)

elektor

6 **Colophon**
Who's who at Elektor magazine.

8 **News & New Products**
A monthly roundup of all the latest in electronics land.

14 **The 5532 OpAmplifier (1)**
The NE5532 is a great audio opamp — been there, done that! But if you connect enough of them in parallel you suddenly have high-end power amplifier. Here we discuss the technicalities of doing just that.

20 **LabView Embedded for ARM µCs**
If you think that LabVIEW can only be used for producing attractive man/machine interfaces for esoteric applications, then this article is for you.

22 **Measure that Current!**
Ask an electronics enthusiast whether he or she has a clamp meter, and you'll hear that they're more suitable for electrical installers and service technicians. Nevertheless, in many cases a clamp meter can be just as useful as a multimeter.

30 **FPGA Design Simulation**
A primer on using Quartus Web Edition and ModelSim Altera Edition.

36 **CL-3 Digital Rotary Combination Lock**
A long time ago the CL-3 was a piece of 'black box' electronics. Today it's been redesigned as an open source project.

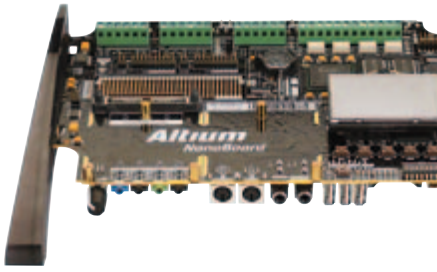
40 **One-button Data Entry**
Here's how to double the function of a pushbutton in a user interface.

43 **Discover the STM32!**
Development kits are a wonderful way to get started with microcontrollers, and cheap too!

44 **Electrolytic capacitors in audio circuits**
Things to keep in mind when designing electrolytics into audio signal paths.









CONTENTS

Volume 2
October 2010
no. 22



14 The 5532 OpAmplifier (1)

The (NE)5532 is audio's most popular dual opamp in the world. An interesting power amplifier can be made by connecting enough 5532s in parallel, how about 32 for a start? This may sound like a radical course of action, but it actually results in a very simple amplifier with high-end performance.



22 Measure that Current!

As opposed to multimeters, current clamp meters aren't limited to currents of a few amperes. They also don't need to cost much more than a multimeter. Here we examine the features of twenty clamp meters suitable for measuring AC and DC current, in price classes from a few tens of dollars to several hundred dollars.



30 FPGA Design Simulation

As soon as you add complex digital logic to give your circuit a bit of intelligence, most conventional simulators are no longer up to the task. In such cases, it's necessary to use an emulator to mimic the behavior of the logic system.



48 GPS ft. Propeller

A more versatile GPS receiver for in-car use and radio-control model applications was the spur to designing this project, with capturing motion speed and presenting this in both digital and analog form a primary requirement. With eight CPUs onboard working in parallel, the Propeller microcontroller from Parallax manages these demanding graphic applications with ease.

46 **A pocket projector**
There's no end to the degree of miniaturization achieved in consumer products by the electronics industry.

48 **GPS ft. Propeller**
Whenever there's a lot to do at the same time, like GPS processing and user-interfacing, the Parallax Propeller is the processor of choice.

54 **ZigBee Today & Tomorrow**
The outlook of ZigBee is simply brilliant. Zigbee is tightly structured however, and here we look at it as a platform.

58 **Tux and ATmega**
Our ATM18 has great potential in the Linux area, too, and here we show the ease of using the board with Linux tools only. Food for programmers!

64 **Powerline Communications & the Chip Issue**
PLC communication is a virtual arena where a format war is imminent. We look at S-FSK, generally considered one of the strongest contenders.

68 **Booster for Audio Signals**
Weak bass and dull treble are things of the past with this circuit.

72 **Design Tips**
From microphone to line input

73 **Gerard's Columns**
Accidents Happen

74 **Retronics: 80 Candles for the Pentode**
Regular feature on electronics 'odd & ancient'. Series Editor: Jan Buiting

77 **Hexadoku**
Our monthly puzzle with an electronics touch

84 **Coming Attractions**
Next month in Elektor magazine.

elektor | international media bv

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



No. 22, OCTOBER 2010 ISSN 1947-3753

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

Elektor (ISSN 1947-3753) is published monthly (except for one issue in July/August) at $39.95 per year, Canada add $11.00 per year;
by Elektor International Media LLC,
4 Park Street, Vernon, CT 06066, USA.
Phone: 860-875-2199, Fax: 860-871-0411.
www.elektor.com

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

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

Editor: Jan Buiting (editor@elektor.com)

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

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

Graphic design / DTP: Giel Dols, Mart Schroijen

Publisher: Hugo Van haecke
(h.vanhaecke@elektor.com)

Marketing: Carlo van Nistelrooy

Customer Services: sales@elektor.com

Subscriptions:
Elektor US, 4 Park Street, Vernon, CT 06066, USA.
Phone: 860-875-2199, Fax: 860-871-0411
Internet: www.elektor.com
E-mail: subscriptionsus@elektor.com

Elektor Personal Organizer 2011

NEW!

Contents refill available separately

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



The Organizer 2011 at a glance:

- 2011 calendar (two pages per week)
- Appointments calendar (with corner perforations) in six languages
- 60 pages of technical information on electronics
- Seven sections, separated by tab sheets
- Alphabetic address and telephone book
- Handy monthly planner
- Lined pages for your notes
- Five credit-card pockets and a pocket for business cards
- Push-button closure
- Six-ring binder mechanism
- Luxurious grey imitation-leather binding
- Free pen and SMD Tool (with complete package only)

Contents refill 2011

If you purchased the Elektor Organizer last year, the content refill for 2011 can be ordered separately for $23.90.

ISBN 978-90-5381-259-4 • $40.20

elektor SHOP

Limited Period Offer for Subscribers!
16% DISCOUNT
www.elektor.com/october

Further information and ordering at
www.elektor.com/organizer

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

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

Copyright Notice
The circuits described in this magazine are for domestic use only. All drawings, photographs, printed circuit board layouts, programmed integrated circuits, disks, CD-ROMs, DVDs, software carriers and article texts published in our books and magazines (other than third-party advertisements) are copyright Elektor International Media b.v. and may not be reproduced or transmitted in any form or by any means, including photocopying, scanning an recording, in whole or in part without prior written permission from the Publisher. Such written permission must also be obtained before any part of this publication is stored in a retrieval system of any nature. Patent protection may exist in respect of circuits, devices, components etc. described in this magazine. The Publisher does not accept responsibility for failing to identify such patent(s) or other protection. The submission of designs or articles implies permission to the Publisher to alter the text and design, and to use the contents in other Elektor International Media publications and activities. The Publisher cannot guarantee to return any material submitted.

Disclaimer
Prices and descriptions of publication-related items subject to change. Errors and omissions excluded.

© Elektor International Media b.v. 2010 Printed in the USA

The $129 Full-Feature Nano-10 Ethernet PLC


Nano-10

The Nano-10 PLC from Triangle Research Int'l, Inc. only has 10 I/Os, but is a full-function programmable logic controller with many of the features found only in bigger and much more expensive PLCs. Measuring only 3.3" by 2.8" and weighing in at 2.6 oz, this $129 nano class controller packs a big punch and stands out with the inclusion of a built-in Ethernet port which supports MODBUS TCP/IP Server and Client connections. In addition, an RS485 connection which supports native host link commands protocol as well as MODBUS RTU and MODBUS ASCII, makes it possible not only to communicate with other Triangle Research PLCs, but also to work with a whole range of other devices that support the same industry standards.
Designed to be Internet-savvy, the Nano-10 allows machine OEMs or integrators to easily create a web page that allows them to control the equipment without writing a single line of Internet program. This is cleverly done by simply defining a background image and modifying a few variables that define the I/O labels and their locations on a browser screen.
Programming of the Nano-10 is done using the highly acclaimed and very efficient iTrilogiC "Ladder+BASIC" language. The PLC has four digital inputs which support high speed counter and interrupt functions. The 4 digital outputs (two of which are voltage-free relays) are capable of supplying 2 channels of PWM current, or control pulse and direction for a stepper motor. Other features of this PLC include a fast CPU processing speed of 4 µs per step, counters/internal relays/sequencers, PID computation engine, real time clock plus an optional module for battery back-up.
The pricing of the Nano-10 brings a whole new level of PLC sophistication to smaller and lower end automated machines. The Nano-10 is ideal in applications which require a small I/O count but which have the same demand for capabilities and networking as larger and more complex systems.
Special feature of the Nano-10 PLC is a "User Quick Setup of a PLC Control Web Page". The Nano-10 PLC allows users to easily create their own graphic web page for remote interaction with the controlled equipment without the need to write any Internet program. A user is only required to define a background image and modify relevant variables that define the I/O labels and their locations on a browser screen for a quick set-up his/her own custom-made control web page.

http://www.tri-plc.com
(100640-I)

Stomp boxes enclosures tickle the fancy of electric guitarists everywhere

Hammond Manufacturing's 1590 STOMP die-cast aluminum enclosures are the housings of choice for leading stomp box manufacturers. As the name suggests, stomp boxes, also known as guitar effect pedals, are foot-operated equipment used by electric guitarists to produce preset effects such as distortion, wah-wah, delay, chorus and phasing. Many will have a collection of as many as 20 stomp boxes, each providing a different effect.
The 1590 STOMP boxes are rugged, die-cast aluminum enclosures that are easy to machine and can easily cope with the demanding on-stage environment in which they will be used. Available in two sizes, 4.39 x 2.34 x 1.06 in. (112 x 60 x 27 mm) and 4.67 x 3.68 x 1.18 in. (19 x 94 x 34 mm), they are finished with a smooth gloss polyester powder coating, which does not chip after machining and provides a good surface for labels and silk screening.
As you might expect, the standard colors are strong and vibrant. Cobalt Blue (RAL 5013) Green (RAL 6024) Light Gray (RAL 7035) Orange (RAL 2009) and Red (RAL 3011) are available from stock; the enclosures can also be factory finished in other colors to suit corporate styles. A lap joint seals the units to IP54, protecting against the ingress of dust and water, and the finish coating is applied only to the external surfaces, maintaining RFI integrity.



All enclosures can be supplied factory modified with machining and silk screening to the user's specification. AutoCAD and PDF dimensioned drawings can be downloaded from the Hammond website.

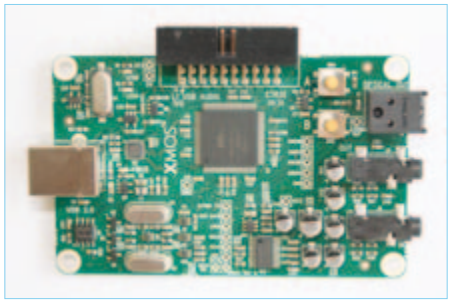
www.hammondmfg.com
(100555-VI)

USB Audio 2.0 reference design supports high channel counts

XMOS has announced the industry's first USB Audio Class 2.0 reference design for high channel count computer audio interfaces, DJ and live sound mixers, musical instruments and digital effects devices.
The new reference design builds on the

XMOS L1 USB Audio 2.0 reference design for low channel count (stereo) applications. It is implemented entirely in software using the dual core XS1-L2 XMOS processor. The design supports high-speed USB Audio 2.0 (480 Mbps) and up to 18 audio inputs and outputs with 24-bit resolution and a 192 kHz sample rate. Key factors in the design's reproduction of high quality audio are operation in asynchronous mode and a precise, low-jitter local clock. The reference design also achieves round trip latency below 3 ms, making it ideal for live recording applications.

The reference design's software-defined workflow enables users to readily adapt and customize the design to handle specific interface requirements, DSP algorithms for audio enhancements, and custom front panel peripherals. To reduce development time, a ready-made library of software components is available, including I²S, S/PDIF, and many other interfaces.



The reference utilizes the specific features of XMOS processors, including event-driven multi-threaded processing for integrating audio DSP capability, flexible I/O interfaces, real-time control processing, and a USB 2.0 high speed interface that supports high audio channel counts with 24-bit resolution at 192 kHz sample rate with extremely low latency and support for MIDI and S/PDIF in/out.

The design is Audio Class 2.0 compliant for plug-and-play operation with Audio Class 2.0 enabled computers and Audio Class 1.0 compliant for backwards compatibility, and it boasts native Mac OS X and Windows support. Native USB Audio 2.0 driver support is available in Apple Mac OSX 10.6.4 and higher, and a version of the XS1-L2 with a bundled Audio Class 2.0 Windows driver for Windows XP, Windows Vista and Windows 7 is available.

Asynchronous clocking enables complete control of the audio master clock, resulting in minimized jitter and highest quality digital audio. Standard-compliant device firmware update (DFU) loader support enables in-field software updates to deployed devices. Additional features will become available later in the year, including digital audio mixing and ADAT with no hardware upgrade necessary.

www.xmos.com
(100555-X)

Microchip and Cymbet offer energy harvesting development kit

Microchip Technology and Cymbet have joined hands to offer the XLP 16-bit Energy Harvesting Development Kit, a customizable energy-harvesting application development kit with a modular development board

Microchip's contribution to the kit is the PIC24F16KA102 micro-

Advertisement

Introducing Pololu's new
Maestro USB Servo Controllers

Conduct a symphony of servos.



Pololu's 6-channel Micro Maestro and new 12-, 18-, and 24-channel Mini Maestros take serial servo controllers to the next level by incorporating native USB control for easy connection to a PC and programmability via a simple scripting language for self-contained, host controller-free applications. Whether you want the best servo controller available or a versatile, general-purpose I/O control board, these compact devices will deliver.

#1350
Micro Maestro
6-Channel
$19.95

#1352
Mini Maestro
12-Channel
$29.95

#1354
Mini Maestro
18-Channel
$39.95

#1356
Mini Maestro
24-Channel
$49.95

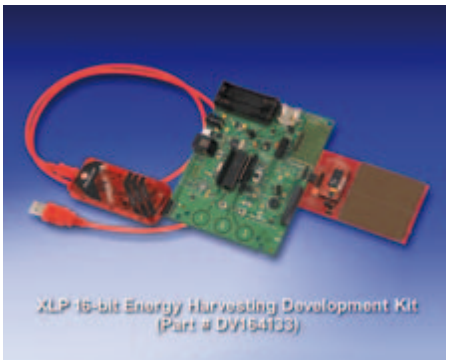
- Three control methods: USB, TTL serial, and internal scripting
- Free configuration and control application with motion sequencer
- Channels can be used for digital I/O or up to 12 analog inputs
- Individual servo speed and acceleration control for each channel
- Up to 8 KB of internal scripting memory (~3000 servo positions)
- 0.25 us servo pulse resolution with pulse rate up to 333 Hz



more information at
www.pololu.com/maestro

Pololu
Robotics & Electronics

controller, featuring eXtreme low power technology, along with support for PICtail daughter boards for rapid evaluation of a wide variety of system functions, including ZigBee, proprietary wireless connectivity and SD memory cards.



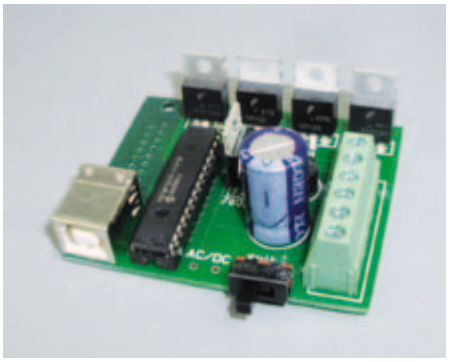
Cymbet contributes its EnerChip EH Eval-08 energy harvesting board, which harvests indoor or outdoor light energy and stores it in solid-state, thin-film EnerChip rechargeable energy storage devices. The EnerChips supply power to the XLP development board when light is not available.
The development board portion of the kit features the PIC24F16KA102 XLP MCU, onboard temperature sensors, data EEPROM, a potentiometer, watch crystal, LEDs, and an expansion connector for PICtail modules. Supported PICtails include RF, SD/MMC cards, speech playback and more.

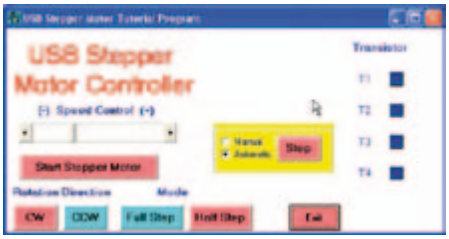
Power condition and capacity are monitored by the PIC24F using Energy Aware software algorithms developed by Microchip and Cymbet. The monitored information can be reported to the PC user interface over a USB connection. This allows users to experiment with balancing energy collection versus energy use and maximize the benefits of energy harvesting.

http://www.microchip.com
(100555-XI)

USB stepper motor controller kit runs under Windows

A USB stepper motor controller kit from Images Scientific Instruments Inc. (Staten Island, New York) enables users to control a 5-volt or 12-volt unipolar stepper motor from a Windows environment.





The exclusive Windows user interface is designed to teach the fundamentals of stepper motor control. Automatic and manual control of the stepper motor are possible with the Windows user interface. The control functions available on the interface include speed (steps per second), direction (clockwise (CW) or counterclockwise (CCW)), full-step and half-step mode, and manual stepping.

A tutorial booklet explaining all basic functions of the unipolar stepper motors is included. The kit price is $49.95.

www.imagesco.com/catalog/motors/stepper.html
(100555-XIV)

2.4 GHz reference design targets remote control racing toys

Nordic Semiconductor has released nRFready R/C Racing, a complete reference design for advanced remote controlled racing toys that operates at 2.4 GHz and supports game play features previously impossible with conventional 27 MHz and 49 MHz remote control systems. These features include racing with multiple friends, using waypoints to define free-form racetracks, feeling crashes through controller vibration, and the ability to collect, see and share racing data.
The nRFready R/C Racing reference design includes two cars, two controllers, four waypoints, a USB dongle, the nRFready Racing Studio PC application, and all necessary source code and hardware design files. The cars, controllers and waypoints are based on Nordic's single-chip nRF24LE1 2.4 GHz transceiver, which provides a flexible development platform with flash memory as well as a smooth migration path to Nordic's lower-cost one time programmable variants for mass production.
The cars in the nRFready R/C Racing reference design feature continuous steering and throttle control and crash sensors, as well as blinker lights and headlights that can be switched on and off from the controller. The controllers include LEDs for car battery status and force (vibration) feedback to indicate crashes. The cars can also detect when they are in close proximity to a waypoint and wirelessly send race statistics such as lap times, speed and number

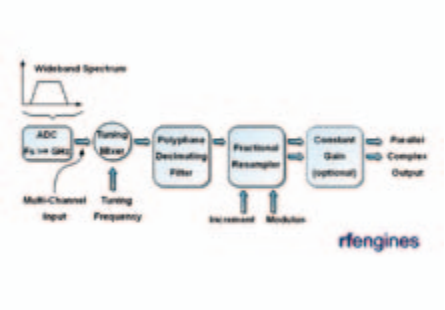


of crashes to the nRFready Racing Studio PC application through the supplied USB dongle.

http://www.nordicsemi.com
(100555-XII)

Digital down converter handles 1 GHz bandwidth

RF Engines Limited (RFEL) has extended the range of its digital down converter (DDC) technology to process up to 1 GHz of input bandwidth (2 Gsps ADC rate) and provide an output signal with a narrower bandwidth. This technology can operate with fixed frequencies and bandwidths or be fully flexible as required.
One of the main application areas is elec-



tronic surveillance in military digital receivers, where a DDC allows a desired signal band to be extracted from a wide slice of the spectrum so that further analysis of the signal content can be carried out. For example, a radar warning receiver may spot the signal signature of an incoming missile or other threat, and the down converter extracts the specific signal and measures its parameters. In scientific applications, for example in advanced radio telescopes, this approach allows very wide sections of the spectrum to be monitored at the same time in order to acquire weak or hidden signals.
The RFEL wideband DDC core is highly optimized for size and speed on a range of Xilinx and Altera FPGA devices. With unique options such as fractional resampling for arbitrary output bandwidth selection and the ability to implement designs in either logic-rich or DSP-rich FPGA architectures, the RFEL wideband DDC can meet the needs of a wide variety of applications in the shortest possible time.

www.rfel.com
(100555-XIII)

Advertisement

$51 For 3 PCBs
FREE Layout Software!
FREE Schematic Software!



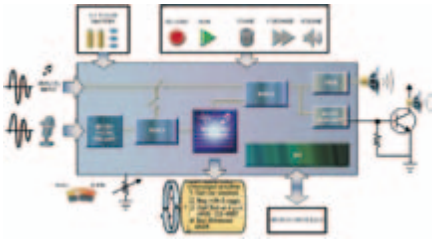
01 DOWNLOAD our free CAD software
02 DESIGN your two or four layer PC board
03 SEND us your design with just a click
04 RECEIVE top quality boards in just days

expresspcb.com

Nonvolatile voice/audio IC boasts integrated phone functions

Nuvoton Technology Corp. has introduced the ChipCorder ISD61S00, a nonvolatile voice/audio IC optimized for telephony systems. The device provides a digital audio interface, audio storage interface, macro scripting ability and programmability, allowing designers to develop telephony-based systems with audio prompting, multi-language options, and fast, address-free recording and playback with a capacity of up to 64 minutes.
The ISD61S00 can perform communications functions such as detection and generation of DTMF signaling and FSK for Bell 103, Bell 202 or V.23 modems. It additionally offers a PSTN interface, customer alert signal detector, call progress tone detection, and ring detection. Other features include echo cancellation, a PCM/I²S digital audio interface, and 16 general-purpose I/O pins accessible via the device's SPI ports. Technical specifications include sampling rates up to 16 kHz, 90 dB SNR (typical), 0.5 W maximum dissipation, and an operating voltage range of 2.7 to 3.6 V.
The ISD51S00 is designed to offer high-quality single-chip voice record/playback solutions for embedded applications. Typical applications include voice prompting, alerts, interactive menus, and voice memos for consumer, industrial and security products. Pre-recording services make it easy to add voice to system designs.
The ISD61S00 is packaged in a 48-pin LQFP and is sampling now, with production scheduled for the third quarter.

www.nuvoton.com
(100555-XV)



A MUST ATTEND!

Fully Immerse Yourself
In the Latest ARM Technology

2010 ARM TECHNOLOGY CONFERENCE
The Core Of Your Future

NOVEMBER 9-11, 2010
The Santa Clara Convention Center
Santa Clara, CA

Attend the only conference dedicated to the ARM architecture where you can become fully immersed in the latest strategies, methodologies, applications, tools and technologies for designing with ARM IP.

Combining classroom sessions, tutorials, industry panels, product demos and exhibits this three day event enables system designers, software developers and silicon manufacturers to increase their design expertise with the most pervasive embedded architecture in the industry—ARM®.

Classroom & Workshop Tracks Include:

- Buses and Communication Channels
- Build Your Own ARM-based System
- Designing with Open Source
- Embedded Internet
- Low-Power Design and Performance Optimization
- MCUs, MPUs, DSPs
- Multicore and Virtualization
- Networking and Connectivity
- Operating Systems Selections
- SoC Architecture & Design … and more

ALL NEW Conference Format

NOVEMBER 9
Chip Design

Centered on ARM-Chip based design, software and enabling tools. Content explores both the high-performance and low-power ends of the spectrum, as well as the places where these two areas could potentially converge. Conference tracks will cover SoC architecture and design (product definition, design implementation and tools, IP, and DFM); SoC verification and silicon validation (design verification and tools, DFT, prototyping, test, and characterization); and SoC manufacturability and reliability challenges.

NOVEMBER 10-11
Software & Systems Design

Geared towards board and systems designers… those interested in building ARM-based modules, boards, and systems. Conference tracks will cover buses and communication channels; open-source software; embedded Internet; low-power design; safety and security; and debugging tools and techniques.

REGISTER NOW for best rates

For more information or to register: **www.eetimes.com/armconference** • email:arm@ubm.com
For sponsorship opportunities contact Sean Raman at **415.947.6622** or sean.raman@ubm.com.

AP CIRCUITS
PCB Fabrication Since 1984

As low as...
$9.95 each!

Two Boards
Two Layers
Two Masks
One Legend

Unmasked boards ship next day!

www.apcircuits.com

VISA MasterCard PayPal IPC MEMBER ASSOCIATION CONNECTING ELECTRONICS INDUSTRIES BBB

USB Add USB to your next project. It's easier than you might think!

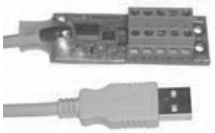
DLP-USB1232H: USB 2.0 UART/FIFO

HIGH-SPEED 480Mb/s



- Multipurpose: 7 interfaces
- Royalty-free, robust USB drivers
- No in-depth knowledge of USB required
- Standard 18-pin DIP interface; 0.6x1.26-inch footprint

DLP-IO8-G
8-Channel Data Acquisition



Only $29.95!

- 8 I/Os: Digital I/O
  Analog In
  Temperature
- USB Port Powered
- Single-Byte Commands

DLP-IOR4
4-Channel Relay Cable

DLP-TH1b
Temp/Humidity Cable

DLP-RFID1
HF RFID Reader/Writer

DLP-FPGA
USB-to-Xilinx FPGA Module

DLP Design

www.dlpdesign.com

Back-to-school discounts on basic kits at paia.com

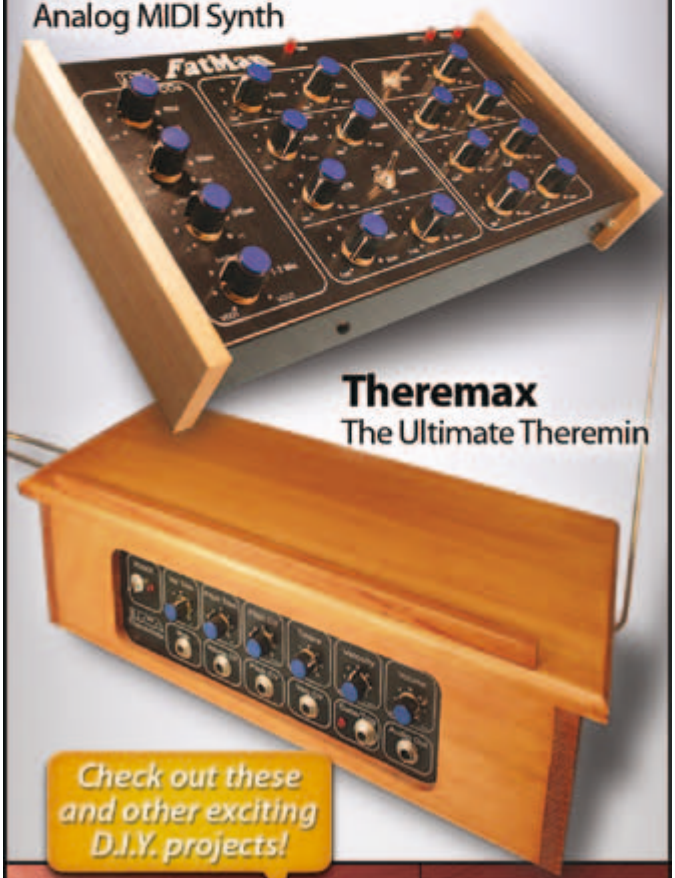
PAiA
Electronic Kits for Enthusiasts

BUILD YOUR OWN!

PAiA 9700s
Modular Synthesizer



FatMan
Analog MIDI Synth



Theremax
The Ultimate Theremin

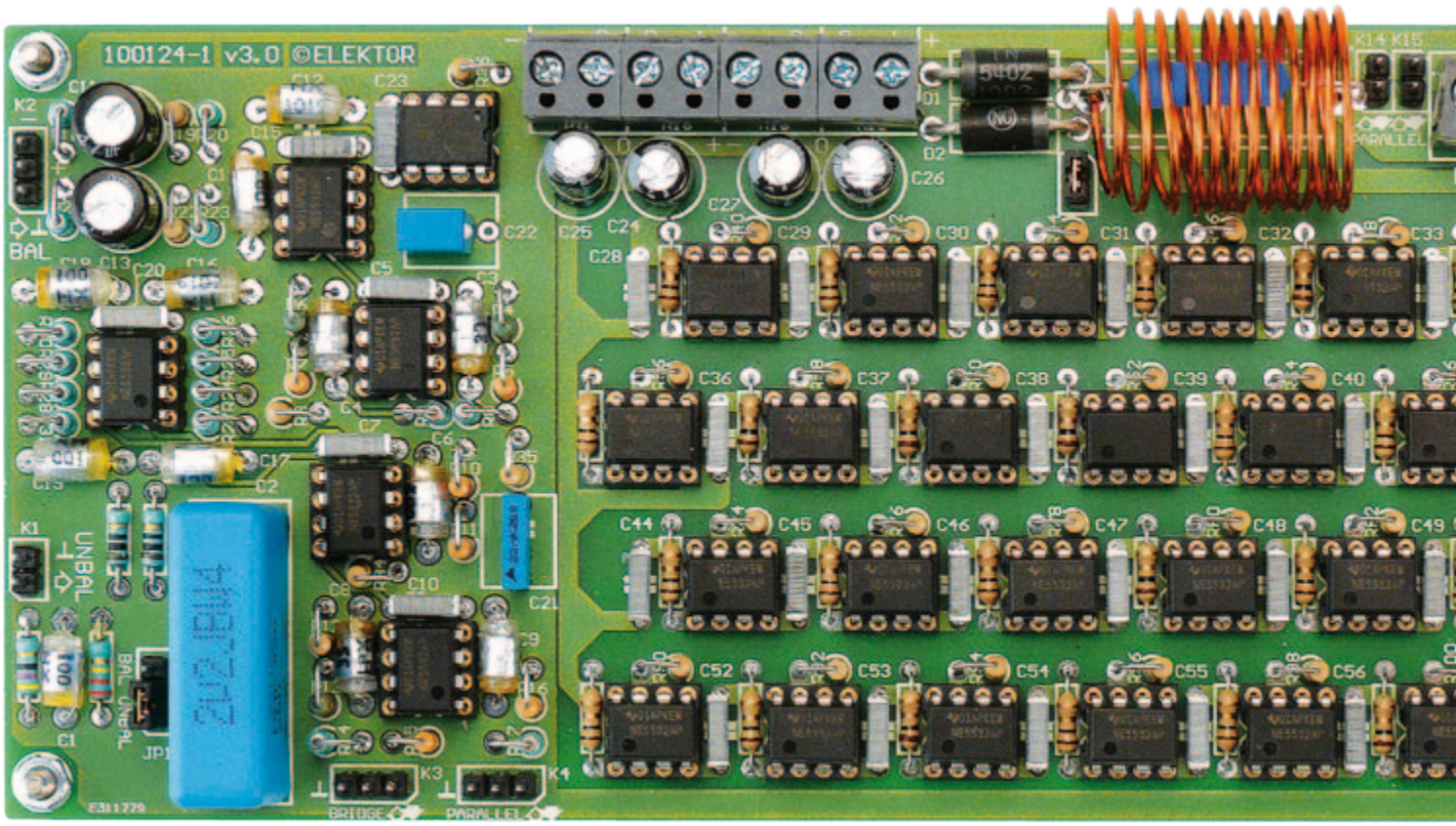
Check out these and other exciting D.I.Y. projects!

PAiA paia.com

Music/Tutorials/Kits
Guitar Effects
Tube Electronics
Studio Gear

The 5532 OpAmplifier

Part 1: design philosophy and schematics



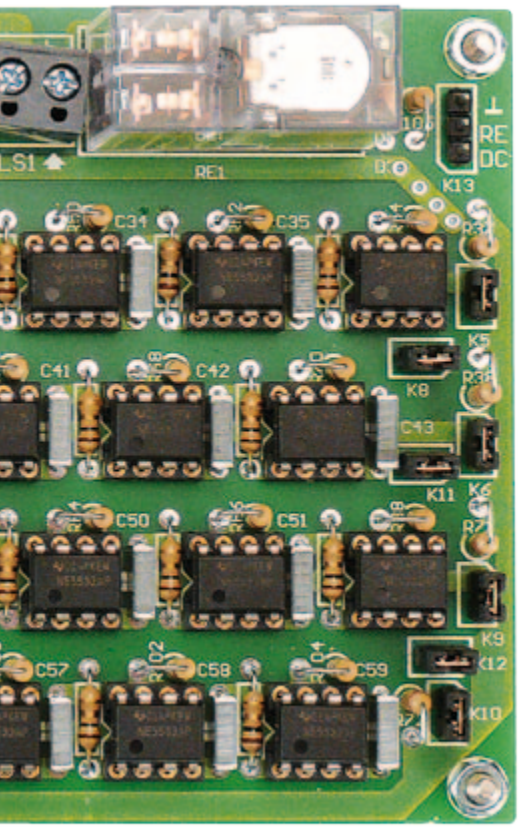
By Douglas Self (UK)

The most popular dual opamp in the world of audio is the (NE)5532. An interesting power amplifier can be made by connecting enough 5532s in parallel, how about 32 for a start? This may sound like a radical course of action, but it actually works very well, making it possible to build a very simple amplifier that retains not only the excellent linearity but also the power-supply rejection and the inbuilt overload protection of the 5532, which reduces the external circuitry required to a minimum.

While not exactly a brand-new design, the type (NE)5532 dual operational amplifier (opamp) is a very capable device giving low distortion with good load-driving capabilities, and a remarkably good noise performance. It is only quite recently that better opamps for audio work have become available. While these can give truly outstanding results, the cheapest of them costs ten times more than the 5532, which is available at a remarkably low price — in fact it is one of the cheapest opamps, because it is so widely used in audio applications.

It should be mentioned at once that the obvious limitation with using opamps to drive loudspeakers is that the output voltage swing is limited compared with a conventional power amplifier, and using a single-ended array of 5532s will give about 15 W_{rms} into 8 Ω. This output can be greatly extended by using two such amplifiers in bridge mode; one amplifier is driven with an inverted input signal so the voltage difference between the two amplifier outputs will be doubled, and the power output is quadrupled to about 60 W_{rms} into 8 Ω. This should be enough for most domestic hifi situations.

The other unalterable limit set by the opamps is the maximum output current, set by the internal overload protection. A single 5532 section (one half of the dual package)



Specification — per channel, 8 ohm load

Supply voltage	±18.3 V	
Input sensitivity	- unbalanced	840 mV (16 W, 1 % THD)
	- balanced	833 mV (16 W, 1 % THD)
Input impedance	- unbalanced	38.8 kΩ
	- balanced	93.6 kΩ
Output power, sinewave	- 0.1 % THD	16 W
	- 1 % THD	16.8 W
Output power bandwidth		1.5 Hz – 275 kHz
Slew rate		5 V/µs
Rise time		4 µs
Signal/noise ratio	(1 W ref.)	110 dBA
	- 108 dB (B = 22 Hz – 22 kHz linear/unweighted)	
Harmonic distortion + noise	- 0.0005% (B = 22 kHz, 1 kHz, 1 W)	
	- 0.0009% (B = 80 kHz, 1 kHz, 1 W)	
	- 0.0004% (B = 22 kHz, 1 kHz, 8 W)	
	- 0.0005% (B = 80 kHz, 1 kHz, 8 W)	
	- 0.003 % (B = 80 kHz, 20 kHz, 8 W)	
Intermodulation distortion	- 0.0012% (1 W)	
	- (50 Hz : 7 kHz = 4 : 1) 0.0015% (8 W)	
Dynamic IM distortion	- 0.0011% (1 W)	
	- (3.15 kHz square wave + 15 kHz sine wave)	0.0035% (8 W)
Damping factor	- 194 (1 kHz)	
	- 111 (20 kHz)	
DC-protection	±1.5 V	
Quiescent current	300 mA	

will drive 500 Ω to the full voltage output, though it is advisable to keep the loading lighter than this to maintain low distortion at high levels. If 4 Ω operation is required, twice as many opamps must be used to supply the doubled current demand. This also applies to bridged operation into 8 Ω.
The system is designed so that either single-ended or bridged operation can be used; the basic design described here gives a working stereo amplifier with just three PCBs. The amplifier cards can be paralleled without problems, and facilities are provided to connect more PCBs in parallel for driving low-impedance speakers.
Overload protection is inherent in the opamps, but output relays are used for on/off muting and to protect loudspeakers against a DC fault.

A tour of the design

The schematic in **Figure 1** shows one channel of the complete amplifier, which consists of unbalanced and balanced line inputs, and the power amplifier itself, which is divided into a +22.7 dB gain stage and an array of paralleled output opamps configured as voltage-followers, giving the maximum amount of negative feedback around them to minimise distortion. Let's have a look at the various sections of the circuit.

The unbalanced input

This consists simply of RF filter R1, C1 and DC-drain R2, which are directly connected to the gain stage when JP1 is in the 'unbalanced' position.

The balanced input

This amplifier is an innovative design that gives very low noise. The conventional balanced input stage built with four 10 kΩ resistors and a 5532 opamp has a far worse noise performance than a simple unbalanced input, and is also much noisier than most power amplifiers; output noise is approximately –104 dBu. This balanced amplifier here solves this problem partly by the use of a dual balanced stage (IC5A, IC5B) amplifier that partially cancels the uncorrelated noise from each amplifier, giving a 3 dB noise reduction, and in a similar way improves the CMRR; it also uses much lower resistor values than usual (820 Ω instead of 10 kΩ) which produces less Johnson noise in the first place. This is only possible because it is driven by unity-gain buffers IC4A, IC4B, which also allow the input impedances to be much higher than usual, preventing loading of external equipment and further improving the CMRR. The noise output is less than –112 dBu, an 8 dB improvement over conventional technology.

The gain stage

The main input amplifier is another innovative design that achieves very low distortion by spreading the gain required over three stages. +22.7 dB could easily be obtained with one opamp but 5532s are not

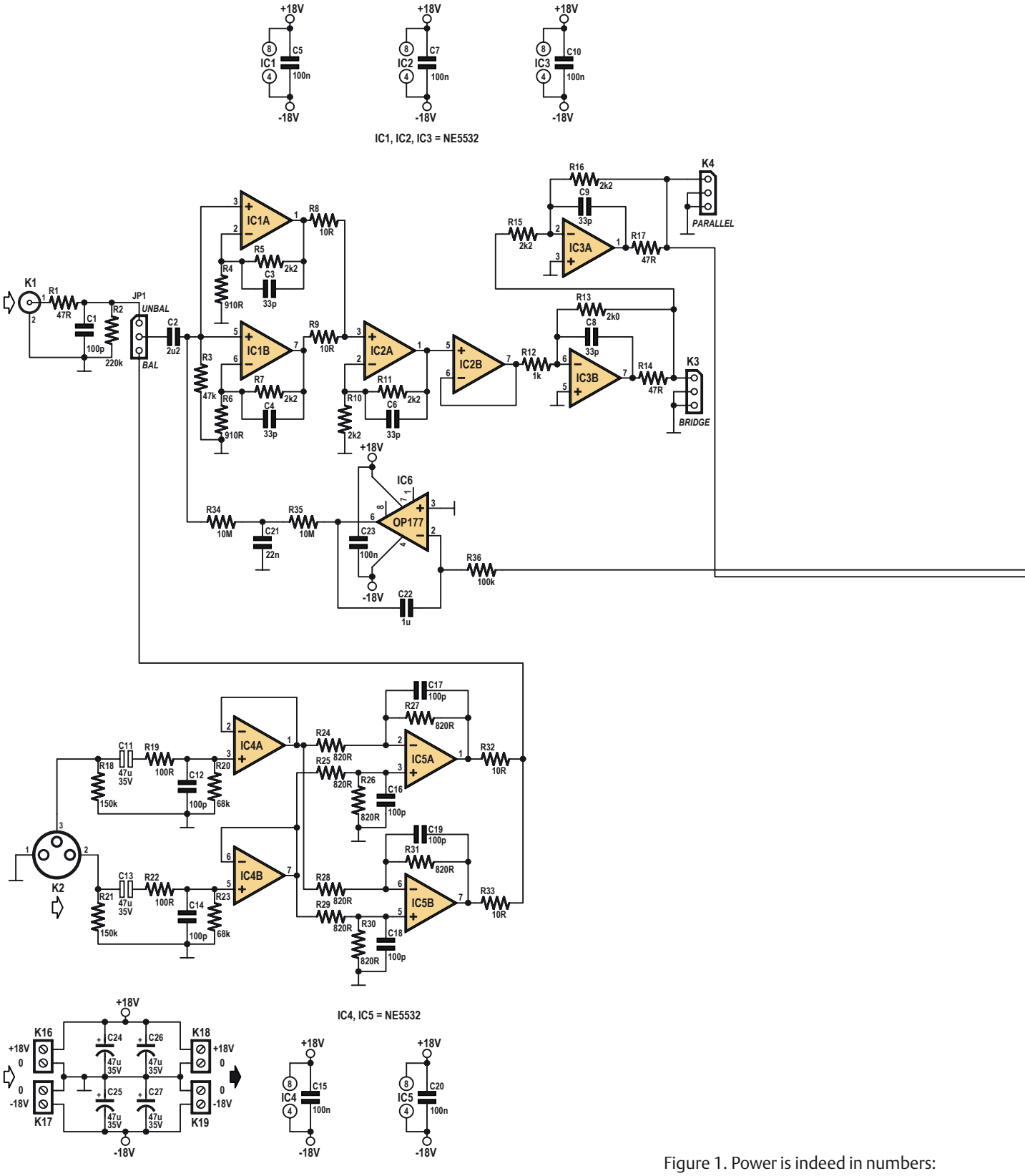
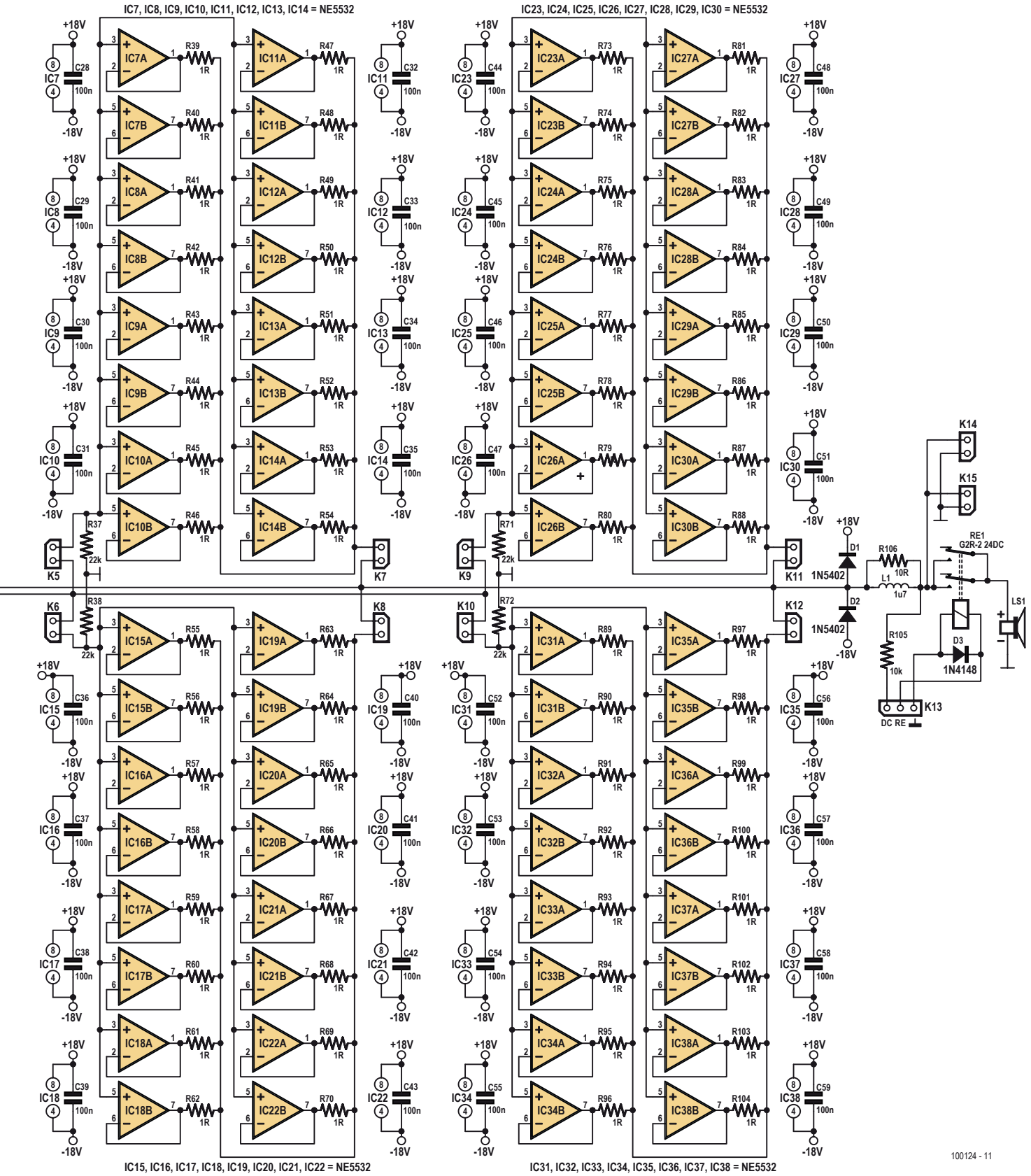


Figure 1. Power is indeed in numbers: circuit diagram of the basic NE5532 audio amplifier (one channel shown).


IC7, IC8, IC9, IC10, IC11, IC12, IC13, IC14 = NE5532
IC23, IC24, IC25, IC26, IC27, IC28, IC29, IC30 = NE5532
IC15, IC16, IC17, IC18, IC19, IC20, IC21, IC22 = NE5532
IC31, IC32, IC33, IC34, IC35, IC36, IC37, IC38 = NE5532
+18V
-18V
K5
K6
K7
K8
K9
K10
K11
K12
K13
K14
K15
R37
R38
R71
R72
22k
D1
D2
1N5402
R106
10R
L1
1u7
RE1
G2R-2 24DC
DC RE
R105
10k
D3
1N4148
LS1
100124 - 11

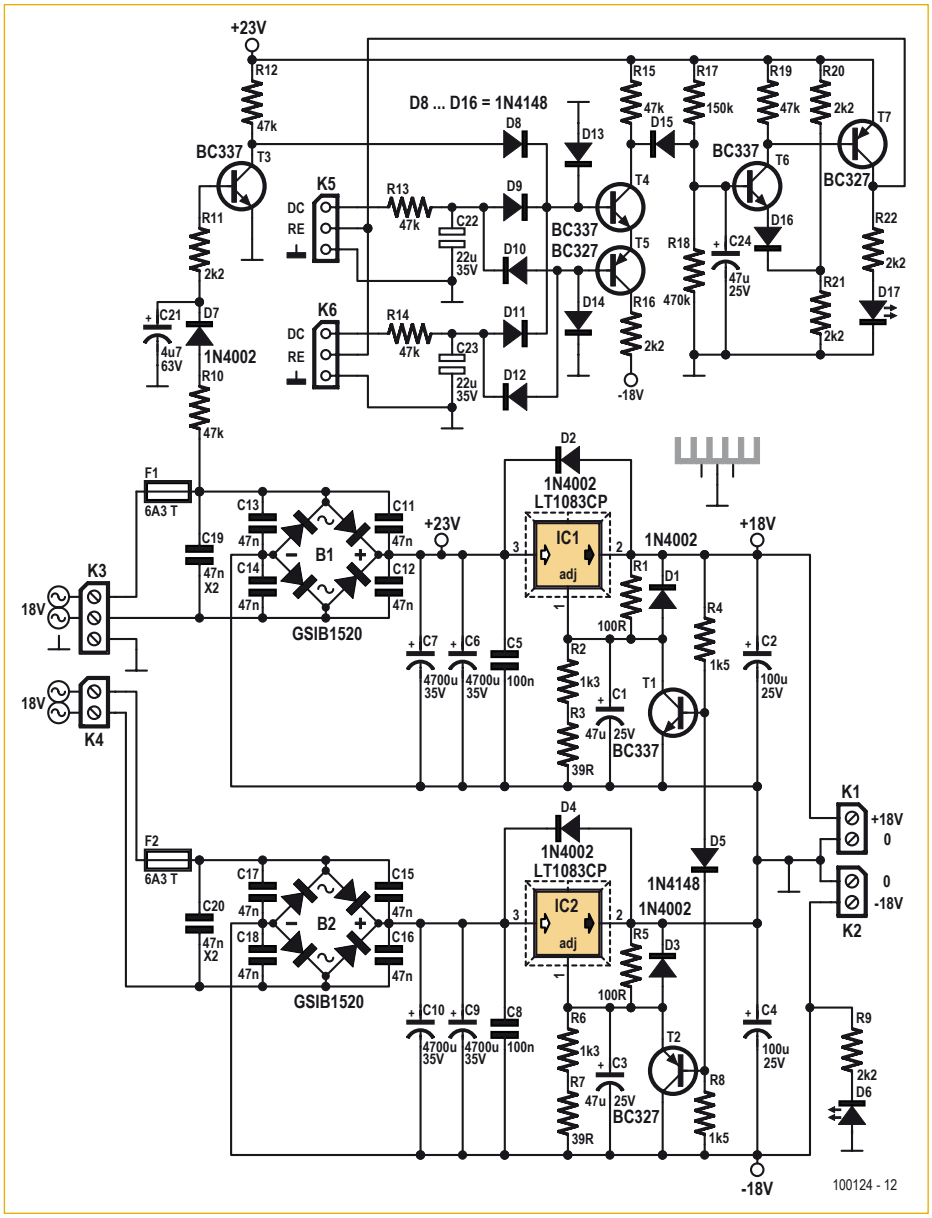


Figure 2. The symmetrical power supply is dimensioned for the 2x15-watt, 8 ohm basic version of the amplifier.

completely distortion-free, and the THD would be significant.

The first stage (IC1A, IC1B) gives +10.7 dB of gain; the two outputs are combined by R8, R9 to give a 3 dB noise advantage, as in the balanced amplifier. The second stage IC2A gives +6 dB of gain. The gain is less to maximise negative feedback because the signal level is now higher. IC2B is a unity-gain buffer which prevents the 1 kΩ input impedance of final gain stage IC3B from loading the output of IC2A and causing distortion. IC2B is less vulnerable to loading because it has maximal negative-feedback. IC3B gives the final +6 dB of gain; it is used in shunt-feedback mode to avoid the common-mode distortion which would otherwise result from the high signal levels here. It has a 'zero-impedance' output, with HF feedback via C8 but LF feedback via R13, so crosstalk is kept to a minimum while maintaining stability with load capacitance. The output at K3 is phase-inverted and can be used for bridging.

IC3A is a unity-gain inverting stage which corrects the signal phase. The output is also of the 'zero-impedance' type.

The power amplifier

The power amplifier consists of thirty-two 5532 dual opamps (i.e. 64 opamp sections) working as voltage-followers, with their outputs joined by 1 Ω current-sharing resistors. These combining resistors are outside the 5532 negative-feedback loops, and you might wonder what effect they will have on the output impedance of the amplifier. A low output impedance is always a good thing, but not because of the so-called 'damping factor' which is largely meaningless as the speaker coil resistance always dominates the circuit resistance. 'Damping factor' is defined as load impedance divided by output impedance; we have 64 times 1 Ω resistors in parallel, giving an overall output impedance of 0.0156 Ω. This gives a theoretical damping factor of 8 / 0.0156 = 512, very good by any standards. The wiring to the loudspeaker sockets will have more resistance than this!

The output opamps may be directly soldered into the board to save cost and give better conduction of heat from the opamp package to the copper tracks. However, on the prototype built in the Elektor labs, high quality sockets were used. Having a lot of opamps in parallel could make fault-finding difficult — if there is one bad opamp out of 32 then you are likely to have to do a lot of unsoldering (or IC unplugging) to find it. The opamp array is therefore split up into four sections of eight opamps, which are joined together by jumpers K5–K12, so on average you would only need to unsolder (or pull out) four opamps to find a defective one. In my many years of experience with it the 5532 has proven a very reliable opamp, and I think such failures will be very rare indeed.

There is an output choke L1 for stability into capacitive loads, and catching diodes D1–D2 to prevent damage from voltage transients when current-limiting into reactive loads.

The output relay and its control

The output mute relay RE1 protects the loudspeakers against a DC offset fault and gives a slow-on, fast-off action so no transients are passed to the loudspeakers at power-up or power-down. The relay is controlled from the power supply board. With reference to **Figure 2**, at power-up R17 charges C24 slowly to give a turn-on delay. In operation C21 is charged and

T3 is on; when the AC power is removed C21 discharges rapidly, T3 turns off, and D8 turns on T4–T5, which discharge C24 and cause the output relay contacts to be opened immediately. Even a brief AC power interruption gives the full turn-on delay.
Normally T4 and T5 are off and D15 non-conducting, but if a DC offset fault applies either a positive or negative voltage via R13 or R14, T4–T5 turn on and the relays are opened at once to protect the loudspeakers.

Power supply

Again referring to the circuit diagram of the power supply unit in Figure 2, the ±18 V symmetrical supply is regulated by two type LT1083 TO3-P positive regulators. When a 5532 sees one supply rail disappear, this opamp can get into an abnormal state in which it draws excessive current. This could obviously be catastrophic with this design, so the PSU incorporates a mutual-shutdown facility which shuts off each supply rail if the other has collapsed due to short-circuiting or any other cause. If the positive rail collapses, T2 turns on and disables the negative supply. If the negative rail collapses, T1 turns on and disables the positive supply.

Cost

This project uses quite a lot of 5532s; 37 in each channel, but that does not mean the cost is excessive. In the USA, NE5532s can be obtained from mail order companies like Mouser at around $0.50 each at 100-off order quantity. This means that the cost of all the opamps in the project would be about $37.00.

To be continued

Next month's closing installment will cover approaches to constructing the amplifier on circuit boards, some performance figures obtained from our high-end test equipment, and an outline of challenges to those of you wishing to modify the amplifier for higher output powers and/or lower output impedance. Meanwhile this month's *E-Labs Inside* section has a page or so on issues with electrolytic capacitors encountered while the first prototype of the amplifier was tested.

(100124)

Internet Link

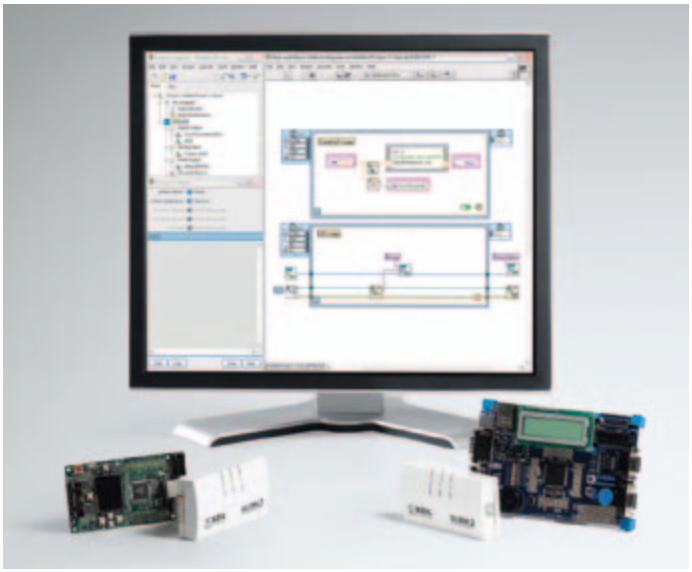
1. www.rapidonline.com

Advertisement



LabVIEW Embedded for ARM µCs

By Clemens Valens (Elektor France Editorial)



If you think LabVIEW can only be used for producing attractive man/machine interfaces for esoteric applications, then this article is for you. If you are interested in easy programming for powerful microcontrollers, then you should read on too. And even if you haven't the least idea what LabVIEW is, don't just turn the page, for it's well worth taking a look at this tool.

LabVIEW is flagship product from National Instruments. Originally designed as a tool for driving measuring benches and displaying data, LabVIEW has evolved a great deal in twenty-odd years and has become a powerful, unique graphic programming language. It's the only tool on the market that makes it possible to develop an application on a computer, FPGA, or microcontroller using the same language and the same programming methods. It's what is known as a multiplatform language.

A program 'written' in LabVIEW Embedded for ARM looks just like any other application written in LabVIEW, with a user interface and a diagram. In the case of an embedded application, the front panel may represent the board's peripherals, like a switch or an LED, but also debugging elements like variables. In LabVIEW Embedded, the user interface is only used for simulating and debugging the application.

To give you an idea just what a LabVIEW for ARM program looks like, take a look at the screen snapshots illustrating this article. It's a very simple application that compares twice the voltage (coming from the potentiometer on the board) with a threshold value. If the value is above this threshold, an LED lights up. The doubled voltage is also sent to the analog output (don't forget to remove the loudspeaker jumper).

The magenta blocks (**Figure 1**) are the elementary I/Os corresponding to one pin of the microcontroller. LabVIEW offers a number of predefined ones, like the LEDs, but you can add your own — for example, for a relay. The green LED in the diagram is an element that appears on the front panel (**Figure 2**). It mirrors LED1 on the board. On the front panel there are also the 'threshold' and 'output' boxes. These are program variables that are not accessible on the board, but which can be modified or displayed during debugging. The '2' and '100' boxes are constants, and the triangles are mathematical or logic operations.

The large gray rectangle represents a loop (note the arrow at the bottom right-hand corner). Everything within the rectangle is

What's in the kit?

- DVD-ROM with LabVIEW and the LabVIEW Embedded for ARM module: these are NI tools that let you program an ARM microcontroller board in a graphical fashion.
- Keil µVision RealView microcontroller development kit: this is a standard integrated development environment (IDE) for programming a microcontroller in C/C++, assembler, etc. The IDE is called µVision, the toolchain is RealView.
- ULINK2 USB-JTAG adaptor for programming the microcontroller and debugging the application.
- ARM microcontroller evaluation board. There are two models: the MCB2370U from Keil based on the LPC2378 (ARM7TDMI-S) from NXP, and the EK-LM3S8962 (Cortex-M3), a Texas Instruments thoroughbred.
- Instructions and two USB cables.

Price of the kit as shown: €8,999

For more details: www.ni.com/arm

LabVIEW Embedded also exists for PSD and for 32-bit microprocessors.

LabVIEW, µVision & RTM

µVision RealView can be implemented without LabVIEW and makes it possible to develop applications for other boards or your own hardware using an ARM µC in the 'traditional' way. At the time of writing, RealView supported over 260 processors with ARM7, ARM9, or Cortex-M3 cores. The kit includes a time-unlimited licence with one year's technical support from Keil (renewable).

LabVIEW Embedded for ARM, on the other hand, requires use of µVision (supplied with the kit), except in simulation mode. The link between LabVIEW for ARM and µVision is RTM from Keil, a real-time operating system for microcontrollers. The program in LabVIEW is translated into a program in C which relies heavily on RTM. This is the program that is compiled by RealView into an executable for the microcontroller. Without the RTM libraries (or compatible ones, all you have to do is write them…), it won't work. Note that the source codes for your LabVIEW program translated into C are accessible for inspection.

repeated until the loop is ended. Here the loop never ends, since the stop condition (the red hexagon) is closed by the green box containing the value 'False', where a value of 'True' is needed to exit the loop. The loop is clocked by the little metronome, which operates in such a way that it is run every 100 ms.
LabVIEW is multitasking, which explains why the real-time operating system from Keil (see box) is needed to produce the executable for the microcontroller. To illustrate this multitasking aspect, a second loop has been added which continually interrogates the board's push-button and which lights LED2 when the button is pressed. The two loops run independently of each other.
Compiling this simple application takes an astonishingly long time — over a minute on the test computer (even though it's a fairly recent laptop: Intel Pentium T4200 @ 2 GHz, 4 GB RAM, Windows XP Pro SP3). This is due to the C compiler, which has a large number of files to process. The executable produced is in ELF format. The 'arm-elf-size' tool (part of the GNU toolchain for ARM, not LabVIEW) gives a size of just over 34 KB. An application consisting of just an empty infinite loop produces a 14 KB executable and the compilation time is just as long.

Of course, LabVIEW Embedded's real interest is for more complex applications. A large number of functions (PSD, TCP/IP, serial port, maths, etc.) are available and ready to use. If you're short of a function, you can create it yourself or import it via a third-party DLL (your own, for example). LabVIEW Embedded can be adapted to your hardware; the evaluation board included in the kit is just one example. Once you've mastered LabVIEW Embedded, you have an extremely powerful tool at your disposal. However, do make sure you use a powerful computer, otherwise the time you've saved in programming will be wasted waiting for it to compile.

(100337)

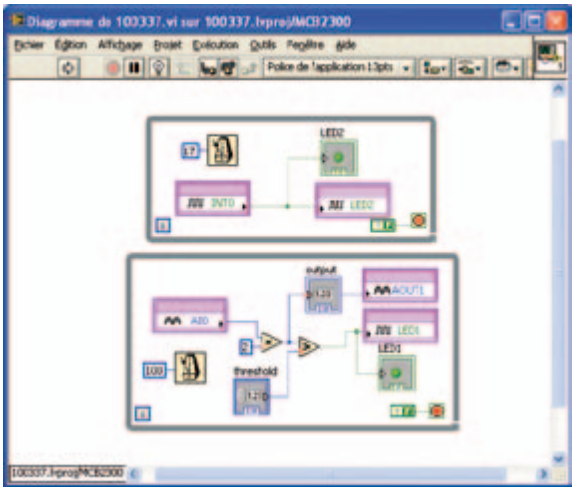


Figure 1. Diagram for the test application.



Figure 2. The test application user interface during debugging.

Remember the right-click!

The fact that LabVIEW is a graphical programming language doesn't mean it is child's play, even though NI has gone to great lengths to explain everything properly. So do make sure you read the short instructions supplied in the kit, and don't forget that a right-click can be helpful at all times.

Measure That Current!



Twenty AC/DC clamp meters on the test bench

By Harry Baggen (Elektor Netherlands Editorial)

Everyone who has anything to do with electronics has at least a multimeter at home and on the work table. But what about a clamp meter? These instruments are often just as versatile as multimeters, and they aren't limited to currents of a few amperes. They also don't need to cost much more than a multimeter. Here we examine the features of twenty clamp meters suitable for measuring AC and DC current, in price classes from a few dozen dollars to several hundred dollars.

If you ask an electronics enthusiast whether he or she has a clamp meter, the usual response is that they're more suitable for electrical installers and service technicians. Nevertheless, in many cases a clamp meter can be just as useful as a multimeter — and often even more useful. The current measuring range of most multimeters is limited to 10 A, which means you need to be careful that you don't exceed the maximum current rating and blow the fuse for the 10-A range or burn out the sense resistor. At the same time, we see more and more circuits that draw hefty currents, and this involves more than just measuring the input currents of household appliances or other devices connected to the AC grid. Modern clamp meters, which are also able to measure DC currents, open up a wealth of new possibilities. For example, you can measure the starter motor current in a car, measure how much current an electric motor in a model aeroplane draws from the battery, or measure how much current the CPU on the

motherboard of your computer guzzles. A multimeter is not really designed to handle any of these tasks, but a clamp meter simply takes them in stride.

Available products

While looking through the catalogs of instrument suppliers, we quickly noticed that an enormous variety of clamp meters is available. Some manufacturers have more clamp meters than multimeters in their catalogues. This suggests that there is a large demand for these meters, the majority of which are most likely used in the electrical industry. However, as we already mentioned, modern clamp meters are so versatile that they are also very attractive for all sorts of electronics applications. For instance, many modern clamp meters can measure DC current in addition to AC current, and most of them can also make many other types of measurements. For example, the group of meters we examined includes models that can measure capacitance, frequency and temperature as well as voltage and resistance. This makes them full-fledged substitutes for a multimeter. The main advantage is that they allow you to measure much larger currents, ranging from 100 to 1000 A, so you don't have to be constantly afraid of blowing a fuse or burning out a resistor in your meter.

We did our best to select meters in various price classes from the enormous variety of available instruments. All of the selected meters can measure AC and DC current, and they are also suitable for measuring relatively small currents in the low ampere range. We also included a few clamp-on current probes (also with combined AC/DC capability), which do not have their own display but can be connected to an existing multimeter or to an oscilloscope.

Operation

The mechanical construction of a clamp meter is very similar to that of a power transformer. The jaws or yoke of the meter usually consist of a laminated metal core with a circular or elliptical shape, which is divided into two parts so the jaws can be opened and the conductor to be measured can be positioned inside the core. When a current flows through the conductor, it induces a magnetic field, and the laminated core conveys this field to a small measuring coil (with several turns) that is wound on the core (see **Figure 1a**). The strength of the current flowing through this secondary winding can be read from a meter connected to the measuring coil. The amount of current flowing through the primary conductor can be determined from the winding ratio of the two coils.

In most modern clamp meters, the measuring coil is replaced by a Hall sensor (a semiconductor device that is sensitive to magnetic fields). Depending on the design and the accuracy of the meter, one or two Hall sensors are placed in the air gaps between the two parts of the laminated core (**Figure 1b**). The voltage generated by the Hall sensor is directly proportional to the strength of the magnetic field produced by the current in the measured conductor.

In this way, clamp meters provide a simple and safe means to measure relatively large currents. Furthermore, meters that use Hall sensors are able to measure both AC and DC currents, and the latter capability is especially interesting for electronics enthusiasts.

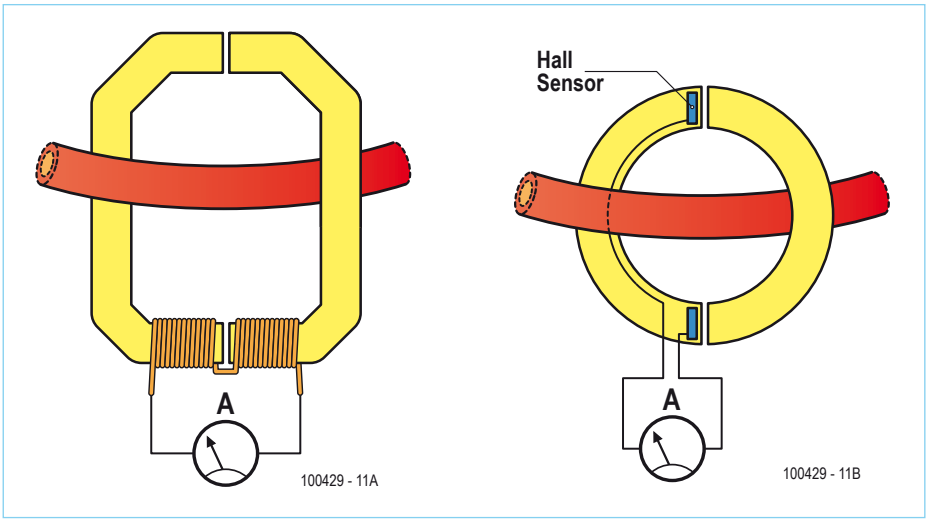


Figure 1. Operating principle of a clamp meter: a transformer with primary and secondary windings (a). In most modern meters, the secondary winding is replaced by one or two Hall sensors (b).



Figure 2. A pair of Hall sensors are clearly visible in the air gaps between the jaws of this Fluke clamp meter.



Figure 4. Clamp meters are complex instruments with many adjustment points. We counted around 15 trimpots in this model.

Agilent U1213A



A large, professional clamp meter with jaws big enough for 2-inch cables. Many extra features, including frequency and duty cycle measurement, as well as simultaneous read-out of AC and DC current or voltage on the dual display, which also has a bar scale. Many basic settings can be configured in a separate menu. Includes case and probes.

Appa 30R



Handy, robustly built small clamp meter with all the basic functions but no extras. Suitable for conductors up to around 20 mm. The Peak/Hold button function must be selected before switch-on, which isn't very convenient. The 'True RMS' designation on the device does not match the description in the user guide. Includes carrying case and probes.

Benning CM2



Dark red, handy, robustly built small clamp meter with all the basic functions, but no extra functions other than voltage and resistance. The Peak/Hold button function must be selected before switch-on, which isn't very convenient. Clearly written multilingual user guide. Supplied with carrying case and probes.

ELV ST-9700T



Small clamp meter with relatively large jaws. With regard to the mechanical construction, we noticed that the display window can be pressed in quite easily. The only clamp meter in the group without autoranging or auto shut-off. Separate on/off switch. Supplied with a temperature sensor, carrying case and probes.

Extech EX613



Hefty, bright orange meter with capped inputs. Many extra features, including capacitance measurement, frequency measurement up to 100 MHz, and separate inputs for two type K thermocouples (included). Built-in voltage detector for AC power voltage. Probes and carrying case included.

Fluke 355



This heavy-duty clamp meter, suitable for currents up to 2000 A, is the benchmark device for this survey. The large dual display can show the frequency of the measured signal at the same time as the measured value. Built-in low-pass filter to eliminate HF interference. Extensive calibration report, case and probes included.

HT9021



Hefty, robustly built clamp meter with large jaws, from the Italian make HT. Clear display with a supplementary bar scale for monitoring voltage trends. Many measuring options plus a built-in contactless voltage detector. Suitable for voltages up to 1000 V. Temperature sensor, carrying case and probes included.

Kyoritsu 2300R



Handy, small clamp meter designed exclusively for measuring currents up to 100 A. A special feature of this clamp meter is the open jaws, which allow it to be easily fitted over a conductor (up to 1 cm diameter). Built-in contactless voltage detector for locating live power grid wiring. With carrying case.

Kyoritsu 2046R



Sturdy professional clamp meter with large jaws and many functions, including voltage, resistance, capacitance, frequency and duty cycle. Large, clear display with a bar scale. Built-in contactless voltage detector for AC grid voltage. Supplied with carrying case and probes.

Mastech MS2102



Handy meter with fairly large jaws fitted to a well finished and sturdy housing (relative to the low price). The display is fairly small but easy to read, and it has a bar scale for monitoring voltage trends. Pity that it doesn't have a Peak button. Carrying case and probes included.

Megger DCM340



Sturdy meter with large jaws, fits nicely in the hand. Clear display with digital indicator and analog scale. Unlike most of the other meters, this one has separate buttons for the extra functions, which is particularly convenient. Very succinct user guide. Supplied with case and probes.

Metrix MX675



Hefty, robust professional meter with large jaws, suitable for thick conductors. Large dual display, which can show current and voltage, frequency and voltage, or current and frequency at the same time. Simultaneous temperature display in °C and °F. Temperature sensor, carrying case and probes included.

Multimetrix CM 605



Simple, handy meter with fairly small jaws (1.2 cm maximum), suitable for measuring relatively low currents up to 100 A. The lowest range is 10 A, so even low currents can be measured reasonably well. Analog voltage output for displaying AC and DC current signals on an oscilloscope. Probes and carrying case included.

Peaktech 1615



Hefty clamp meter with large display and substantial jaws with enough room for relatively large conductors. Many extra functions, including frequency, duty cycle and capacitance measurement. Autoranging can be disabled. Unfortunately, there is no button for peak readings. Temperature sensor, carrying case and probes included.

Peaktech 1645



Handy, small clamp meter with reasonably large jaws for conductors up to approximately 0.6 inch. Operation somewhat clumsy with rotary knob and button. Supplementary bar scale on display for monitoring signal variations. Built-in pocket torch and voltage detector for AC power voltages. Supplied with probes and carrying case.

Velleman DCM268N



Hefty clamp meter with large display and substantial jaws suitable for conductors up to 1.2 inch. Various extra functions, including frequency and capacitance measurement. Clear display with a supplementary bar scale for monitoring voltage trends. Plastic case, temperature sensor and probes included.

Velleman DCM270



Small, simple clamp meter limited to measuring DC and AC currents up to 80 A; no autoranging. Cannot measure voltage or resistance. Built-in pocket torch and contactless AC power voltage detector. Supplied with carrying case.

Voltcraft VC-521



Small, handy instrument for hobby use; rotary switch does not feel especially sturdy. The least expensive clamp meter in this survey, with a large number of measuring functions including frequency, duty cycle and capacitance. Built-in voltage detector for AC power voltage. Carrying case, probes and temperature sensor included.

Practical test and lab test

We tested all of the meters in a number of practical situations, such as measuring the current draw by an electric motor in a model aeroplane and the starter current of a car. These tests revealed that a peak function is especially handy (see tables). We also compared the clamp meters with each other in a test setup that generated reference currents of 10 A and 40 A. All clamp meters are suitable for use with these current levels.

The resolution of the meters at these current levels is 10 or 100 mA, whereby we must immediately mention that residual magnetism in the measuring circuit can easily cause errors of the same order of magnitude with DC currents. For this reason, it is important to zero the meter immediately before making each DC current measurement. Naturally, this problem does not arise with AC currents.

For both DC and AC, the accuracy of all of the clamp meters at the current levels used in the tests (or the maximum current if the measuring range was smaller) was within the tolerance specified by the manufacturer (1 to 3%). We expected nothing less from the more expensive meters, such as the Agilent U1213A, Fluke 355 and Metrix M675, and they were in fact well within their stated specs, but we were pleasantly surprised

Features	Agilent U1213A	Appa 30R	Benning CM2	ELV ST-9700T	Extech EX613	Fluke 355	HT 9021	Kyoritsu 2300R	Kyoritsu 2046R
Price (approx. converted)	$425	$275	$185	$125	$215	$835	$450	$185	$340
AC A	1000 A	300 A	300 A	600 A	400 A	2000 A	1000 A	100 A	600 A
Basic accuracy	±2%+5dgt	±1%+3dgt	±1%+3dgt	±3%+4dgt	±1.5%+5dgt	±1.5%+5dgt	±2.2%+8dgt	±2%+5dgt	±2%+5dgt
DC A	1000 A	300 A	300 A	600 A	400 A	2000 A	1000 A	100 A	600 A
Basic accuracy	±1.5%+3dgt	±1%+2dgt	±1%+2dgt	±3%+6dgt	±1.5%+5dgt	±1.5%+5dgt	±2%+8dgt	±2%+5dgt	±1.5%+5dgt
AC V	1000 V	600 V	600 V	600 V	600 V	1000 V	1000 V	–	600 V
Basic accuracy	±1%+5dgt	±1.5%+5dgt	±1.5%+5dgt	±1.5%+3dgt	±2%+5dgt	±1%+5dgt	±1%+4dgt	–	±1.5%+5dgt
DC V	1000 V	600 V	600 V	200 V	600 V	1000 V	1000 V	–	600 V
Basic accuracy	±1%+2dgt	±0.5%+2dgt	±0.5%+2dgt	±1%+2dgt	±0.1%+2dgt	±1%+5dgt	±1%+3dgt	–	±1%+5dgt
Resistance range	40 MΩ	40 MΩ	40 MΩ	2 kΩ	40 MΩ	400 kΩ	60 MΩ	–	60 MΩ
Continuity tester	< 10 Ω	< 50 Ω	< 50 Ω	< 25 Ω	< 50 Ω	< 30 Ω	< 50 Ω	–	< 100 Ω
Max. conductor dia.	48 mm	22 mm	22 mm	30 mm	33 mm	60 mm	42 mm	10 mm	33 mm
True RMS	X	–	–	X	X	X	X	X	X
Autoranging	X (selectable)	X	X	–	X (selectable)	X (selectable)	X (selectable)	–	X
Auto shut-off	15 min./X	30 min./–	30 min./–	30 min./–	30 min./X	20 min./X	15 min./X	10 min./–	15 min./–
Peak/Δ Zero	X/X	X/X	X/X	–/X	X/X	X/X	X/X	–/X	X/X
Min/Max/Hold	X/X/X	–/–/X	–/–/X	–/–/X	X/X/X	X/X/X	X/X/X	–/–/X	X/X/X
Display/backlight	3-3/4 digits/X	3-3/4 digits/–	3-3/4 digits/–	3-1/2 digits/–	4-3/4 digits/X	3-3/4 digits/X	3-3/4 digits/X	3-1/2 digits/–	3-5/6 digits/–
Freq. measurement	X (1 MHz)	–	–	–	X (100 MHz)	X (1 kHz)	X (60 kHz)	–	X
Temp. measurement	X	–	–	X	X (dual)	–	X	–	X
Extras	Dual display Bar scale Duty cycle Capacitance measurement				Dual display Duty cycle Capacitance measurement µA range	Dual display Internal low-pass filter	Bar scale Duty cycle Capacitance measurement	Open jaws	Bar scale Duty cycle Capacitance measurement

Features	Mastech MS2102	Megger DCM340	Metrix MX675	Multimetrix CM605	PeakTech 1615	PeakTech 1645	Velleman DCM268N	Velleman DCM270	Voltcraft VC-521
Price (approx. converted)	$75	$240	$390	$200	$110	$115	$160	$100	$72
AC A	400 A	600 A	1000 A	100 A	1000 A	200 A	1000 A	80 A	400 A
Basic accuracy	±2%+5dgt	±1.5%+5dgt	±1.5%+5dgt	±2%+10dgt	±3%+5dgt	±2.5%+8dgt	±2.8%+8dgt	±2.8%+8dgt	±2.5%+10dgt
DC A	400 A	600 A	1400 A	100 A	1000 A	200 A	1000 A	800 A	400 A
Basic accuracy	±2.5%+5dgt	±1.2%+5dgt	±1.2%+5dgt	±2.5%+10dgt	±2.8%+5dgt	±2%+5dgt	±2.8%+8dgt	±2.8%+8dgt	±2.5%+10dgt
AC V	600 V	600 V	1000 V	600 V	600 V	600 V	600 V	–	600 V
Basic accuracy	±1.5%+5dgt	±1%+5dgt	±1%+5dgt	±1.5%+5dgt	±1.8%+5dgt	±1.5%+8dgt	±1.5%+8dgt	–	±2%+8dgt
DC V	600 V	600 V	1400 V	600 V	600 V	600 V	600 V	–	600 V
Basic accuracy	±1%+5dgt	±0.7%+2dgt	±1%+2dgt	±1%+5dgt	±1.5%+3dgt	±1%+2dgt	±0.8%+2dgt	–	±1.5%+5dgt
Resistance range	400 Ω	400 Ω	10 kΩ	10 kΩ	40 MΩ	1 kΩ	40 MΩ	–	40 MΩ
Continuity tester	< 40 Ω	< 30 Ω	< 35 Ω	< 100 Ω	< 100 Ω	< 30 Ω	< 35 Ω	–	< 100 Ω
Max. conductor dia.	28 mm	36 mm	40 mm	12 mm	30 mm	16 mm	30 mm	16 mm	30 mm
True RMS	–	–	X	–	–	X	X	–	–
Autoranging	X (selectable)	X	X	X	X (selectable)	X	X	–	X
Auto shut-off	30 min./X	30 min./X	10 min./X	30 min./X	35 min./–	10 min./–	20 min./–	7 min./–	30 min./–
Peak/Δ Zero	–/X	X/X	X/X	X/X	–/X	X/X	X/X	–/X	–/X
Min/Max/Hold	–/–/X	X/X/X	X/X/X	–/–/X	–/–/X	X/X/X	X/X/X	–/–/X	–/–/X
Display/backlight	3-3/4 digits/X	3-3/4 digits/X	4 digits/X	4 digits/–	3-3/4 digits/X–	3-5/6 digits/X	3-3/4 digits/X	3-2/3 digits/–	3-3/4 digits/–
Freq. measurement	–	X (400 Hz)	X (10 kHz)	–	X (100 kHz)	–	X (4 kHz)	–	X (10 kHz)
Temp. measurement	–	–	X (in °C and °F)	–	X	–	X	–	X
Extras	Bar scale	Bar scale	Dual display	Analogue output for AC/DC A	Capacitance measurement Duty cycle	Bar scale	Bar scale Capacitance measurement		Capacitance measurement Duty cycle

by the accuracy of the inexpensive models, such as Mastech and Voltcraft.

All clamp meters are suitable for AC measurements at 50 or 60 Hz (AC power). Most clamp meters can also measure currents at somewhat higher frequencies, extending as far as a few hundred hertz. Accuracy degrades quickly at even higher frequencies. Only a few expensive clamp meters can do better. For example, the Fluke i30 is specified for AC current measurement up to more than 20 kHz.

If you need to measure AC currents with highly non-sinusoidal waveforms, such as currents in phase-control devices, it's a good ideal to select a clamp meter with true RMS capability, since it will deliver more accurate readings.

The choice is yours

A large variety of products are available; the prices of the clamp meters described here range from around 40 dollars to 850 dollars. Which one should you choose? Just as with multimeters, the prices of clamp meters are not determined by the manufacturing cost alone, but also depend on the guaranteed accuracy, whether they have been formally calibrated, and the level of technical support. These are all matters that are primarily significant for professional use, and for hobby use you should primarily look for an affordable instrument with many features. Absolute accuracy and formal cali-

bration are of secondary importance for hobby use.

Among the selected meters, we noticed striking similarities between clamp meters of different makes, which were most likely purchased from the same manufacturer in Asia. This similarity is especially clear with the Appa 30R and the Benning CM2, which are simply the same clamp meter with different colours. The specifications are also identical.

With the clamp meters priced under 150 dollars, we noticed that the mechanical finishing sometimes leaves something to be desired, and in some cases we wondered how long the rotary or slide switches would last. If we assume that hobbyists won't make especially intensive use of a clamp meter, the Voltcraft VC-521 and the Mastech MS2102 provide all the basic features at a low price, and the latter in particular has fairly good construction. Unfortunately, they both lack a peak function, which is a very handy feature with a clamp meter.

If you want a somewhat sturdier and more reliable clamp meter, you need to spend a bit more. The Extech EX613 is the most versatile instrument in the moderate price range, and it can do practically anything a normal multimeter can do. The HT 9021, Kyoritsu 2046R and Megger DCM340 are accurate, good and sound instruments, but somewhat less versatile. If you really want to have a properly calibrated instrument you can rely on, your only real choice is the Metrix MX675 or the Agilent U1213A, with the latter offering a lot of features for its price. We intentionally left the Fluke 355 out of the picture, since it is in a class by itself and serves here as a benchmark for all the other meters we examined.

(100429-I)

Clamp-on current probes





If you only occasionally need to make current measurements or observe current waveforms, a good alternative is a clamp-on current probe, which can be connected to a multimeter or an oscilloscope. The CA60 from ELV Germany is an affordable model, priced at about 60 pounds. It has two measuring ranges, so sufficient output voltage is available even with relatively low currents. The Fluke i30 is clearly intended for professional users. This device is also well suited to measuring relatively low currents, with a measuring range extending to 20 A. The i30 is supplied with a calibration report.

	ELV CA60	Fluke i30
Price	$90	$435
AC/DC A	60 A	20 A
Basic accuracy	±1.5%±5mA (DC) ±2%±5mA (AC)	±1%±2mA
Load resistance	> 10 kΩ	> 10 kΩ
Max. conductor dia.	9 mm	19 mm
Output sensitivity	100 mV/A 10 mV/A	100 mV/A
Special features	2 measuring ranges	Available with banana plugs or BNC connector (S version)

The following suppliers and/or manufacturers kindly made products available for this article:

Agilent (www.agilent.com): www.bfioptilas.com

Appa (www.appatech.com), Velleman: www.velleman.be

Benning (www.benning.de), Peaktech (www.peaktech.de): www.reichelt.de

ELV: www.elv.de

Extech (www.extech.com), Voltcraft: www.conrad.nl

Fluke: www.fluke.com

HT (www.htitalia.it), Megger (www.megger.com): www.euro-index.nl

Kyoritsu (Kewtech): www.kew-ltd.co.jp/en/

Mastech: www.p-mastech.com

Metrix, Multimetrix: www.chauvin-arnoux.com

FPGA Design Simulation

With Quartus Web Edition and ModelSim Altera Edition

By Paul Goossens (The Netherlands)



Simulations are an important part of circuit design. Circuits built with 'ordinary' components can be simulated quite well with conventional simulation packages, but as soon as you add complex digital logic to give your circuit a bit of intelligence, most conventional simulators are no longer up to the task. In such cases, it's necessary to use an emulator to mimic the behavior of the logic system.

Whenever you use an FPGA in a design, you're dealing with more than just hardware. An FPGA needs an internal design in order to do something useful. In a manner of speaking, you personally assemble the hardware inside the FPGA. You need special software to generate the FPGA design; this software is usually provided by the FPGA manufacturer. Special software is also available for simulating the internal design.

Many FPGA manufacturers offer a free version of their professional simulation program, which has certain minor limitations compared to the full version. For instance, there may be a limit on the maximum number of lines of code you can use, and in many cases the simulation is slower than usual. The simulation software discussed in this article has a built-in limit of 10,000 lines of code. However, a design with more than 10,000 lines of code is a rather large design. Even with this restriction, you can still use the software if you split your design into several smaller parts. You can then test these parts one at a time.

Software

For the examples described in this article, we used software that is available free of charge on the Altera website: Quartus Web Edition and ModelSim Altera Edition. First we'll look at what you can do with Quartus. In addition to generating designs, this package allows you to simulate designs on a small scale.
Incidentally, there are also other FPGA manufacturers that offer free simulation packages for their devices. For the truly demanding user, there is a broad selection of VHDL, Verilog and mixed HDL simulators available.



Basic aspects

A basic consideration with FPGA design simulation is that you are limited to digital simulation. With digital simulation, you have to connect your design to test code that provides the test signals for the design. You can view the output signals from the design under test in a window that strongly resembles a software logic analyzer, but first you need to generate suitable input signals. With the simulator included in the Quartus package, you can use a graphic interface to draw the waveforms of these signals. After all the signals have been defined, you can start the simulation, which causes the signals you just defined to be applied to the inputs of the design.

You can choose from two options for running a simulation. The first option is a functional simulation, which ignores the propagation delays inside the FPGA. This yields clearly defined results with ideal signal behavior. The major advantage of this type of simulation is that it only requires compilation of the design, so you can ignore the place and route, optimization and timing closure functions. This saves a lot of time with relatively large designs. Figure 1 shows the results of a functional simulation, based on a design for a simple shift register with only one output. You can see that the signal level on the output and the state of the internal register both change on the rising edge of the clock signal. This contrasts with Figure 2, which shows the results of simulating the same circuit with the second option: timing simulation. This type of simulation additionally takes the internal propagation delays of the FPGA into account. You have to zoom in to a high magnification factor in order to see the difference. Then you can see that the delay between the rising edge of the clock signal and the time when the output signal changes state is 6.006 nanoseconds. Is this fast or slow? The answer depends on how fast your design needs to be.

Optimization

One of the first pitfalls you encounter with a timing simulation is that sometimes one or more signals are not visible in the simulation, even though they are visible in the functional simulation. Why do these signals disappear? This usually results from design optimization by the software. Remember that the design only needs to be compiled for a functional simulation, but several additional steps are performed with a timing simulation, with a large number of design optimizations being made in the process. One of the consequences may be that a particular signal is no longer present in the FPGA.

If you need this signal for your analysis, you can connect it to an additional output of your design. When you do this, the software will think that this signal must be physically present at an output pin, so the optimization process will not eliminate the signal. However, this may significantly alter the timing of the end result.

It's nice to know that the optimizations never change the functionality of the design, so the design will not suddenly exhibit errors due to optimization. However, it will take up less space in the FPGA, and it will most likely run a good deal faster.

More oomph

As already mentioned, the built-in simulator of Quartus is very easy to use. The downside of this is that it has only limited capabilities. If you need something more powerful, you can use ModelSim. The

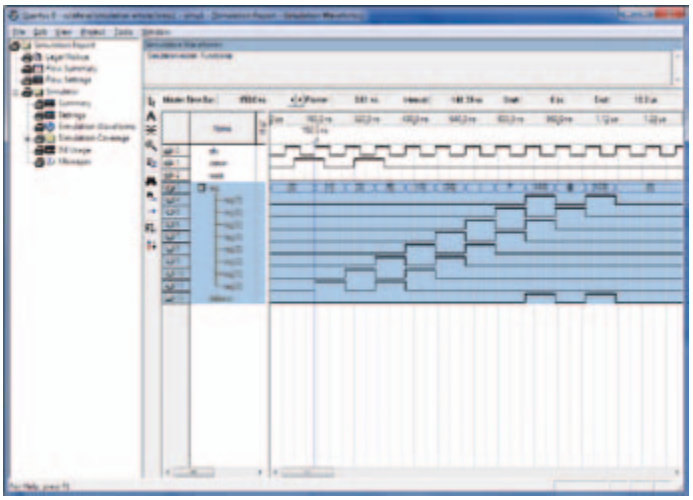


Figure 1. Results of a functional simulation of a simple shift register design with one output.

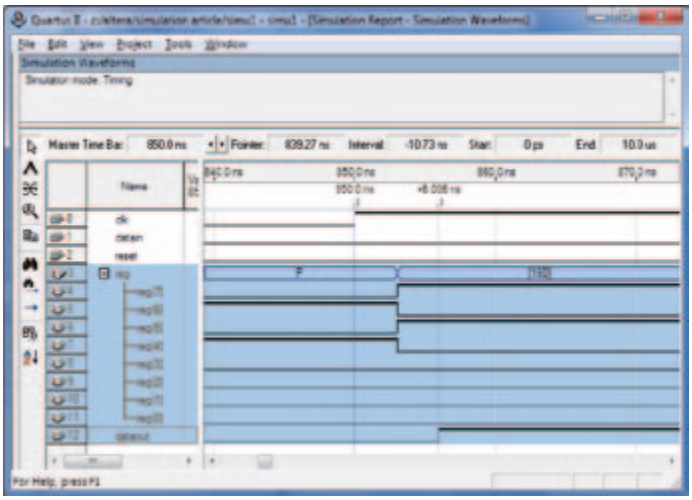


Figure 2. Results of a functional simulation of the same design as Figure 1.

Listing 1

```
Library IEEE;
Use     IEEE.std_logic_1164.all;
Use     IEEE.std_logic_textio.all;
Use     STD.textio.all;

entity test_simu2_file is
end test_simu2_file;

architecture stimulus of test_simu2_file is

  file RESULTS: TEXT open WRITE_MODE is "results.txt";
   procedure WRITE_RESULTS(
        clk: std_logic;
        reset : std_logic;
        datain : std_logic;
        dataout : std_logic
    ) is
        variable l_out : line;
    begin
        write(l_out, now, right, 15);
        write(l_out, clk, right, 2);
        write(l_out, reset, right, 2);
        write(l_out, datain , right, 2);
        write(l_out, dataout, right, 2);
        writeline(RESULTS, l_out);
    end procedure;


  component simu2
    port (
      clk    : in STD_LOGIC;
      reset : in STD_LOGIC;
      datain: in STD_LOGIC;
      dataout : out STD_LOGIC
     );
 end component;

 signal clk : std_logic;
 signal reset : std_logic;
 signal datain : std_logic;
 signal dataout : std_logic;

 begin

   DUT:simu2 port map (
        clk => clk,
        reset => reset,
        datain => datain,
        dataout => dataout
    );


   CLOCK_PROC : process
   begin
     clk <= '1';
     wait for 10nS;
     clk <='0';
     wait for 10nS;
   end process;

   STIM : process
   begin
     wait until (clk'event and clk='0');
                        -- wait for falling edge of clk
     reset<= '0';
     datain <='0';
     wait until (dataout='0');
                        -- wait for falling edge of clk
     wait until (clk'event and clk='0');
                        -- wait for falling edge of clk
     datain <='1';
     wait;
   end process;

     WRITE_RESULTS(
        clk,
        reset,
        datain,
        dataout
     );

end architecture;
```

free version of ModelSim can run simulations based on VHDL testbench files, which offer you the full range of VHDL functions.
Here we can use the shift register design mentioned above as an example. The most important part of the testbench file is printed out in Listing 1. For the time being, we'll ignore the lines shown in boldface.
Two processes are described here. The first process implements a clock signal generator. A major difference between a VHDL file intended to be used for synthesis and a testbench file is the option of using 'wait' statements. The line 'wait for 10nS' causes process execution to pause for 10 nanoseconds. This sort of statement in a design ultimately intended to be executed in an FPGA will cause an error during synthesis. FPGAs do not have any components that can be used to implement this statement directly, but it does not cause any problems in a simulation. This process is repeated indefinitely because there is no sensitivity list at the start of the process code. As soon as the process has finished executing, it starts again from the beginning.

Interactive

The biggest advantage of a testbench file is that it allows one or more of the outputs of the design under test to influence the input signals. In the STIM process, which is responsible for generating the 'reset' and 'datain' signals, we use an internal signal together with an output signal from the design under test to modify the input signals.
The line 'wait until (clk'event and clk='0');' causes process execution

to pause until the 'clk' signal changes state and the new state is ''0'. In other words, it waits until the next falling edge of the clock signal. The 'reset' and 'datain' signals are set to '0' only after this falling edge occurs. The initial state of all internal signals is 'U', which stands for 'unknown'.

In the next line, the process waits until the 'dataout' output of the design under test goes to '0'. The 'datain' signal is set to '1' after the next falling edge.

The final statement of this process is 'wait' without any time specified. What is the purpose of this line? Without it, the process would normally repeat itself immediately after completing execution, since it does not have a sensitivity list. The 'wait' statement without any time specified causes an infinite delay and thus prevents the process from repeating.

Figure 3 shows the results of this simulation. All testbench signals and all internal signals of the design under test (DUT) are visible here. All of these signals start with the state 'U', since the simulator cannot determine what the actual state should be. In reality, all of these signals must assume either the '1' state or the '0' state. From the simulation, you can see whether the design ensures that this happens, or whether the state of a signal is arbitrary. The initial state of a signal may change as a consequence of a different optimization, so you should check that all signals have defined states after a certain point in time, such as after a reset.

Testbench format

A testbench file differs from a normal VHDL file in several respects. Taking Listing 1 as an example, you can see that entities are declared in the usual manner. However, a remarkable feature of these declarations is that these entities do not have any input or output signals. A design usually has at least one input and one output, so that it can do something useful. After all, your design must be able to respond interactively to its surroundings. From this, we can conclude that a VHDL testbench file is not a design that can be programmed in an FPGA.

Advertisement



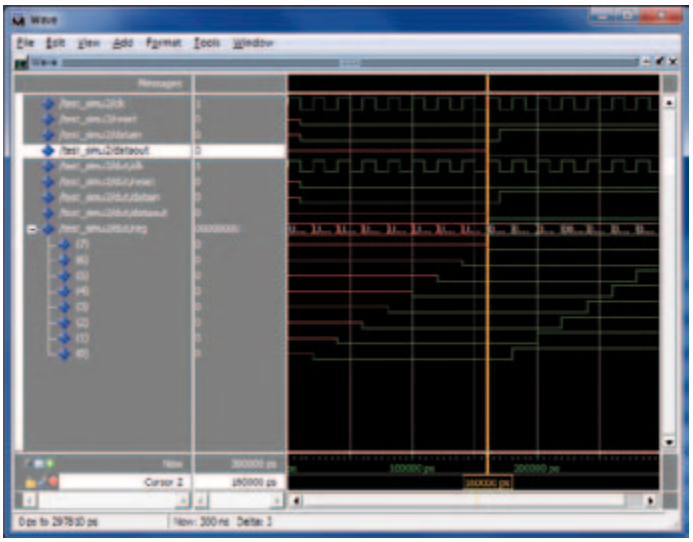


Figure 3. Simulation results from ModelSim. All testbench signals and all internal signals of the design are visible here.

The design under test is declared as a component; in this example it is declared as 'simu2'. All necessary signals are also declared. The architecture section includes a component of type 'simu2' with the name 'DUT' (short for 'device under test'), although you're free to choose any name you wish. The input signals for the design are described in the two processes following the architecture section.

Additional features

You can also use files in a VHDL testbench. For example, you can automatically create a file during a simulation and use it to save all changes to signal states in plain text format. You can also read the contents of a file.

The final example shows how to save all the signal changes in a text file. The lines added to the file contents in Listing 1 are shown here in boldface. Listing 2 shows the contents of the resulting text file.
The functions you need for using files are located in the 'std_logic_textio' library, and you declare them in the usual manner. You also declare the file in the architecture section.
The WRITE_RESULTS procedure is responsible for writing the data to the file. This procedure is self-explanatory except for one detail. We use a variable with the name 'now' in this procedure. This variable has a special function in VHDL: it holds the current time (in the context of the simulation). The procedure is called at the end of the listing. It is called whenever a 'wait' statement is executed in one of the processes or whenever a process completes execution.

Conclusion

FPGA simulations are especially important with relatively complex designs. VHDL testbenches have many more features than we can possibly describe here, but the features we have described are sufficient for quickly running large simulations.
For students and novices, these simulation tools provide a good opportunity to experiment with digital electronics to your heart's content at minimum cost, with no need to touch even a single piece of hardware (other than your computer).

(100370-I)

The files for Quartus Web Edition and ModelSim Altera Edition used for the simulations described in this article are available on the Elektor website for downloading (item no. 100370-11).

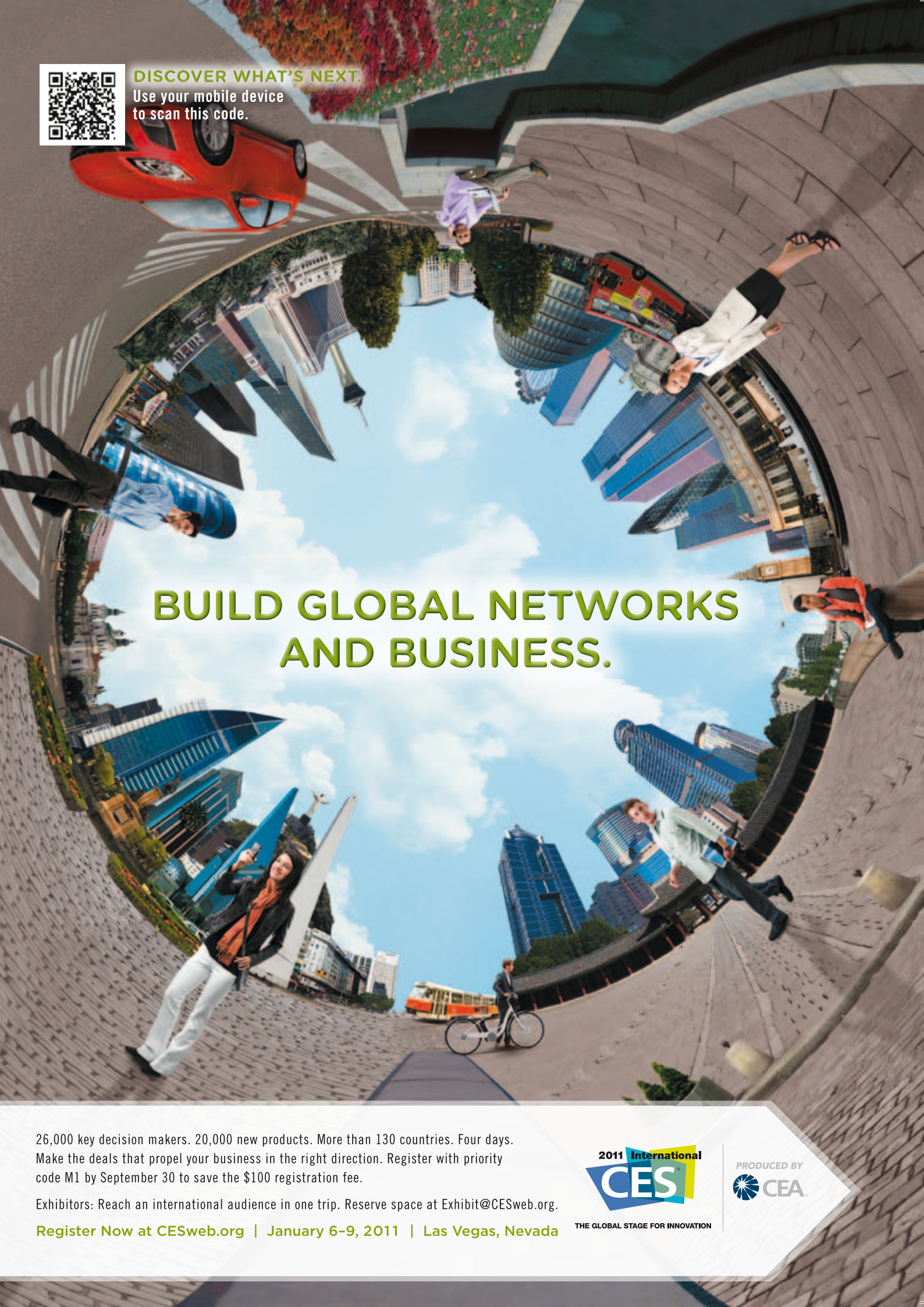
Internet Links

www.altera.com/products/software/quartus-ii/web-edition/qts-we-index.html

www.altera.com/products/software/quartus-ii/modelsim/qts-modelsim-index.html

Listing 2

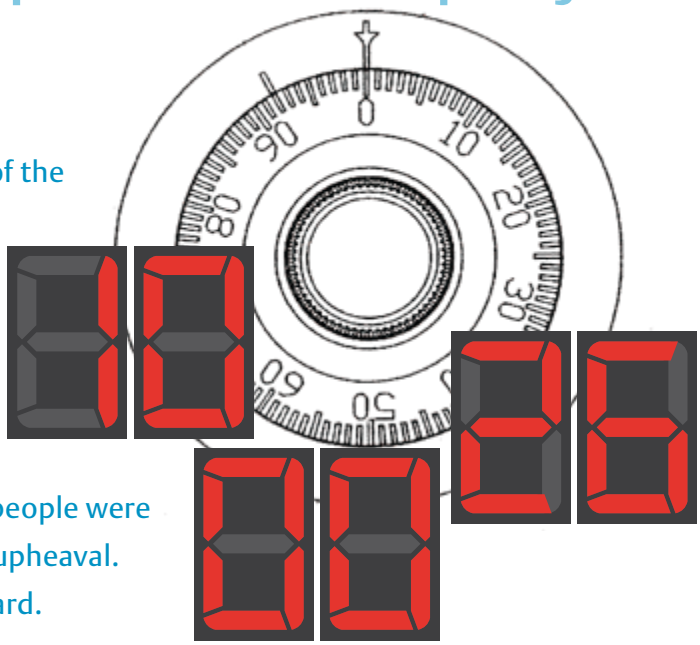
```
  0 ns U U U U
  0 ns 1 U U U
 10 ns 0 U U U
 10 ns 0 0 0 U
 20 ns 1 0 0 U
 30 ns 0 0 0 U
 40 ns 1 0 0 U
 50 ns 0 0 0 U
 60 ns 1 0 0 U
 70 ns 0 0 0 U
 80 ns 1 0 0 U
 90 ns 0 0 0 U
100 ns 1 0 0 U
110 ns 0 0 0 U
120 ns 1 0 0 U
130 ns 0 0 0 U
140 ns 1 0 0 U
150 ns 0 0 0 U
160 ns 1 0 0 U
160 ns 1 0 0 0
170 ns 0 0 0 0
170 ns 0 0 1 0
180 ns 1 0 1 0
190 ns 0 0 1 0
200 ns 1 0 1 0
210 ns 0 0 1 0
220 ns 1 0 1 0
230 ns 0 0 1 0
240 ns 1 0 1 0
250 ns 0 0 1 0
260 ns 1 0 1 0
270 ns 0 0 1 0
280 ns 1 0 1 0
290 ns 0 0 1 0
300 ns 1 0 1 0
```


DISCOVER WHAT'S NEXT.
Use your mobile device
to scan this code.
BUILD GLOBAL NETWORKS
AND BUSINESS.
26,000 key decision makers. 20,000 new products. More than 130 countries. Four days.
Make the deals that propel your business in the right direction. Register with priority
code M1 by September 30 to save the $100 registration fee.
Exhibitors: Reach an international audience in one trip. Reserve space at Exhibit@CESweb.org.
Register Now at CESweb.org | January 6–9, 2011 | Las Vegas, Nevada
2011 International CES
THE GLOBAL STAGE FOR INNOVATION
PRODUCED BY
CEA

CL-3 Digital Rotary Combination Lock

From black box to open-source project

By Dale Wheat (USA)



The CL-3 got designed and built way back at the end of the 20th century. It used an Atmel AVR AT90S1200 flash microcontroller with a rotary encoder to emulate a mechanical combination lock, triggering a relay when the correct combination was dialed. Back in those days, it was considered prudent to keep project development and design documents a closely guarded secret. Tin-lead solder was king and people were stockpiling food and weapons for the upcoming Y2K upheaval. Today we know better — open source is the way forward.

The CL-3 was a delight to design and build but very disappointing in the marketplace. I attribute this to my complete lack of marketing skills and not on the merits of the project itself. Phillip Torrone of Adafruit Industries encouraged me to have another go at it, this time as an open source project. So here we go, but not before mentioning that a story on the design history of CL-3 is available as a free download from the Elektor website at [1].

From the concept...

As shown in **Figure 1 t**he minimal CL-3 implementation uses a rotary encoder as input, emulating a mechanical combination lock dial as used on vaults. The user gets feedback via a dual seven-segment LED display, indicating the current dial position. The final output is a logic level pin that represents the 'locked' or 'unlocked' state. This level controls a relay that governs the opening of the 'vault' door.

There is also another pushbutton input that is used in conjunction with the dial to program the combination in the field. This pushbutton needs to be located in the secure region of the circuit, where the general public does not have access.

In the normal mode of operation, the rotary encoder is the primary input. A quadrature output indicates movement as well as direction. You could also determine the speed at which the dial is being turned, if you wanted to get fancy, by measuring the period between changes in the input.

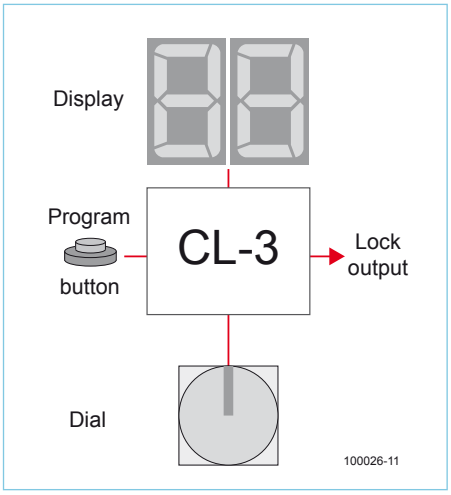


Figure 1. Functional diagram of the CL-3 electronic code lock.

A state machine is used to keep track of the current quadrature input. Note that this is not the same as the virtual dial position. Once movement is detected, i.e., the input has changed, two of the possible remaining three states are checked to determine if the motion is clockwise or anticlockwise. The information is used to update the virtual dial position in the range of 00 to 99. Just like a mechanical dial, the value should roll over from 99 back to zero as well as go from 00 to 99 in the opposite direction.

To the schematic

In terms of user interface, the CL-3 circuit has two outputs, which are also apparent from the circuit diagram in **Figure 2**. The first is the LED display LD1–LD2 and the second is the lock relay RE1. Everything runs under the tight control of microcontroller IC1. The current dial position is displayed on the multiplexed LED display, which is a separate unit connected to the microcontroller via connector pair K2–K6. A lookup

Features

- 6 digit operation (three 2-digit numbers in CW-CCW-CW sequence)
- ATtiny2313 microcontroller
- Optical or mechanical rotary encoder
- Hidden/secure programming button
- Free C code

table in the controller's memory is copied to the lower registers and used to translate the decimal value to the appropriate segment values. Those segment values are written to the ATtiny's output port, which is in turn connected to the LED segment leads via current limiting resistors R1-R9. Once a short period of time has elapsed, the tens digit is blanked and the same process is repeated for the units digit. Rapidly alternating between the two digits gives the visual impression that both digits are illuminated at the same time, due to the persistence of vision effect in the human brain. Your eye isn't fooled but your brain is.

The Atmel-recommended ATtiny2313 is a good choice for this type of project and is even pin-compatible with the AT90S1200 in the original version of the CL-3. More on-board peripherals, memory, clocks and power-saving features are just begging to be used!

The original AT90S1200 had only one external interrupt and it was used for the programming pushbutton input. I moved one of the encoder inputs to INT0 (PD2, pin 6). In the interrupt routine, the other encoder input is examined to determine the direction of dial motion.

The original CL-3 kit used a Panasonic mechanical rotary encoder that has also been discontinued. There is no direct replacement available from Panasonic, but any quadrature encoder should work. Mechanical encoders are much less expensive than optical devices, and for these in particular two small capacitors C1–C2 are provided on each of the outputs to prevent contact noise.

The relay driver is just one pnp transistor with a current limiter resistor in its base line. The power supply is dead conventional based around the 7805 voltage regulator with its usual flock of decoupling capacitors, solid (C5 and C7) and electrolytic (C4 and C6). Diode D2 affords protection against power supply reversal.

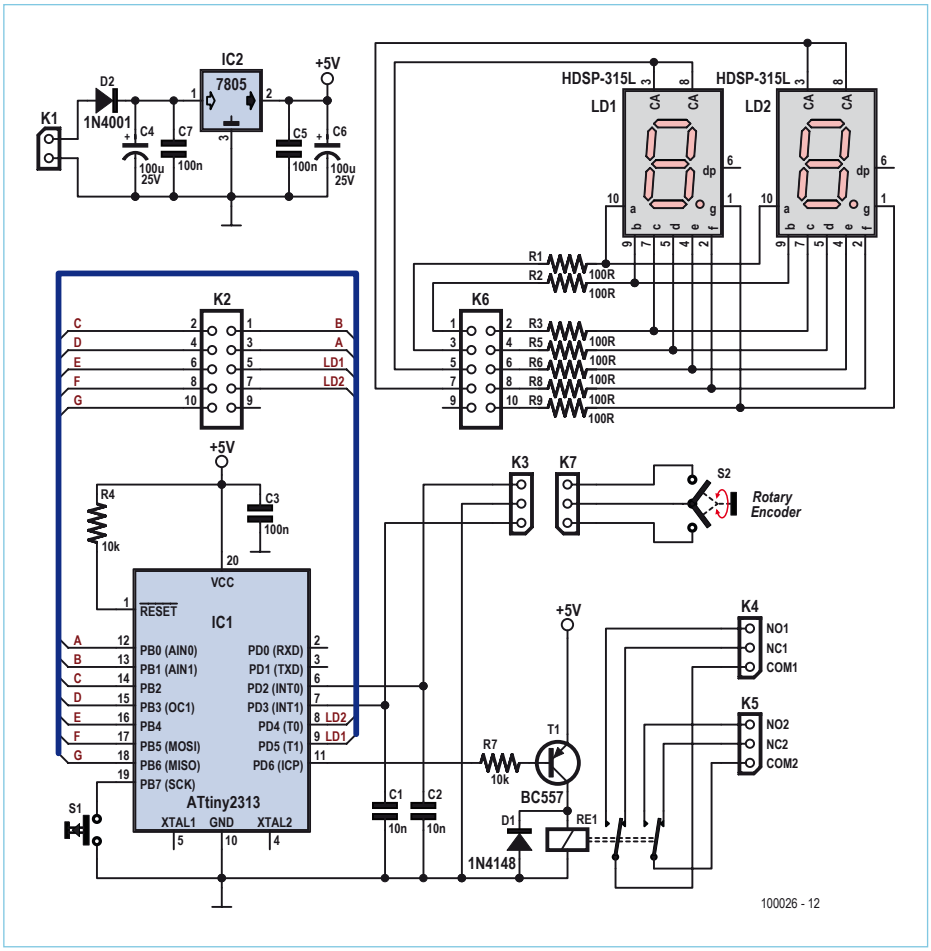


Figure 2. Schematic of the new CL-3. The project consist of a controller section and a display/encoder section.

firmware. On power up, if the unit was unlocked, the display revealed the last number of the combination for a few seconds. The new firmware corrects this, only a decade later. That's some kind of response time, eh?

The source code file written for the new CL-3 is called 'CL-3.c' and contains the C language version of the firmware. It can be downloaded free from [1]. For your amusement the same archive file also contains the AT90S1200 assembly code for the old CL-3.

The CL-3 software

I have corrected what could possibly have been a security issue in the original CL-3

Building it (them)

The circuit board designs for the new CL-3 are shown in **Figure 3**. The artwork for

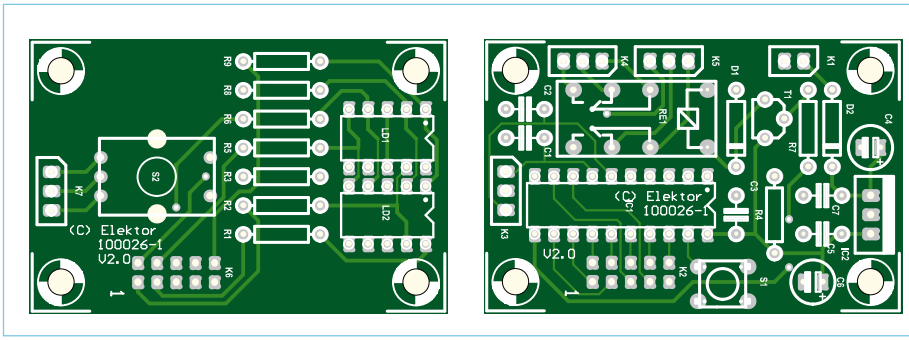


Figure 3. Component mounting plans of controller board and display/encoder board. Either connect them via cables/wires or stack the display/encoder board on top of the controller board. Copper track layout files available free from our website.

Quadrature decoding

A *quadrature* output consists of two alternating signals that are 90° out of phase. These two signals are traditionally referred to as *A* and *B*. The two signals don't have to be exactly 90° out of phase with each other, but it is important that they do not change state at the same time.

Imagine a compass that only has a 'north or south' output and an 'east or west' output. It will only tell you the approximate orientation of the compass. At any given moment, it can only report the ordinal (or intercardinal) direction (i.e., NE, NW, SE or SW). By periodically noting the reported direction, an external device can tell when the orientation changes by comparing the present reading with the previous reading. By analyzing these changes over time, the absolute position, direction of motion and angular velocity can be determined.

An *incremental shaft encoder* uses the same technique to report changes in the position of a rotating shaft or instrumentation dial. An *absolute* position is derived from the succession of changes reported by the sensor. The direction and velocity of the shaft (or dial) can also be derived.

Expanding on the compass example, the two outputs A and B correspond to the "North/South" and "East/West" outputs, respectively. Arbitrarily assigning the North and East conditions as "high", we get the following table:

Ordinal direction	North/South	East/West	Phase A	Phase B	Binary value
Southwest	Low	Low	0	0	0
Southeast	Low	High	0	1	1
Northwest	High	Low	1	0	2
Northeast	High	High	1	1	3

There are four possible combinations for any given reading. It follows that there are four possible transitions between one reading and the next for each of the possible original combinations. For example, the four transitions from the 'Southwest' state are:

New reading	Transition	Value
Southwest	None	0
Southeast	Anti-clockwise	–1
Northwest	Clockwise	+1
Northeast	Error	Unknown

Note that the unexpected transition from "Southwest" to "Northeast" implies either a faulty reading or a missing transition through one of the other, expected readings. Your response to this condition depends entirely on your application. For trivial or noncritical applications (e.g., a combination lock), these events can safely be ignored.

The 'Value' column, except for errors, can then be added to a running accumulation of similar values to provide a virtual absolute position.

these small boards is available free at [1] in the form of pdf files.
The project should be simple to build as no SMD parts or special assembly techniques are required. Two boards are installed at a distance from each other, to ensure the 'vulnerable' section is not easily accessible. The same goes for the relay contacts (which are subject to tampering). If you can afford to keep the circuitry in one piece, the display/encoder board can be stacked on top of the controller board by means of pin-header/socket pairs K6/K2 and K3/K7. Still, for security reasons, pushbutton S1 should be mounted at the copper side of the controller board.
Figure 4 provides a close look at the prototype boards built by Elektor labs.

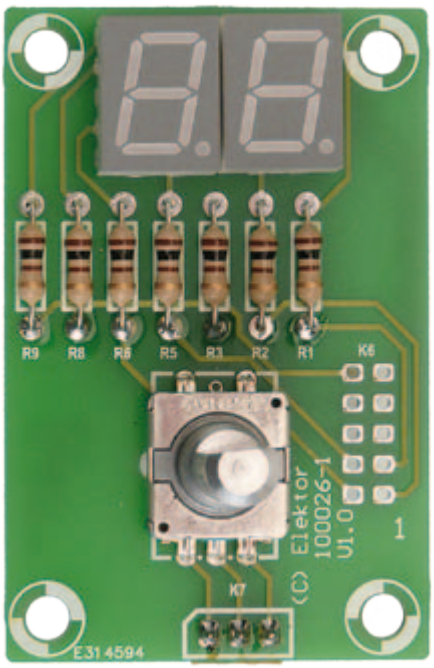


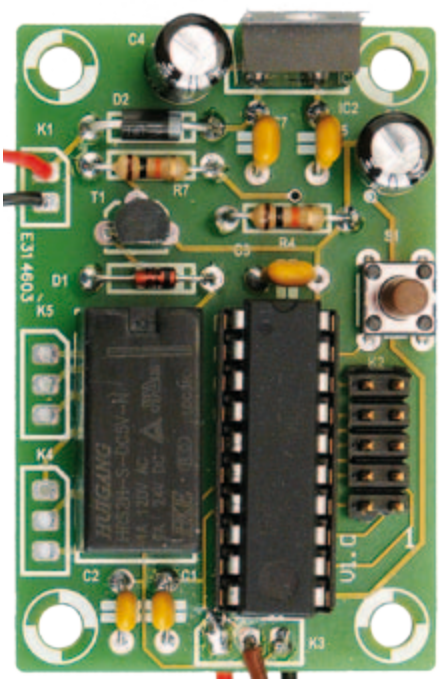
Figure 4. Prototype boards

Setting the combination

The 3-number (6-digit) code that opens the lock is field-programmed using the physically-secured programming pushbutton, S1. All opening and programming commences when the encoder is turned clockwise (CW). To program a new combination, dial in the first number and then press the programming button. The display blanks once to confirm the new number is stored in EEPROM. Dial the second number in counter-clockwise (CCW) direction and press the button again. The display blinks twice. Repeat CW for the third number, with the predictable result. Only once all three numbers have been entered does the firmware write the new combination to the non-volatile EEPROM memory. I encourage users to write down the combination first, then enter it into the device, then confirm the combination works.
If you disallow subsequent identical numbers (e.g., 1-1-1 is not allowed), there are 100 × 99 × 99 = 980,100 possible combinations.

Opening the lock

This is done just like programming the lock, i.e. CW-CCW-CW but obviously without



built for the project.

actuating S1 and with no blinking of the display. The lock opens when the 5th and 6th digit also match the programmed code. The relay remains actuated until the encoder is turned again either CW or CCW. The state of the lock is also stored in EEPROM, meaning that the relay is immediately actuated when the lock was open and the supply voltage gets switched off and on again.

Using an Arduino

Attaching the user interface panel to an Arduino is very simple. The firmware is contained in CL_3.pde, which is also found in the software archive for this project [1]. I used a polling technique instead of interrupts to make it simpler to understand. The same basic functionality is there. The logic lights up the built-in LED on the Arduino when the lock is unlocked. You could easily change the code to send a message via the serial port or take other appropriate action.

Unlock the potential

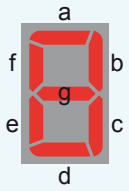
I really enjoyed working on this project, which allowed me to see ten years of progress in microcontroller technology and programming. If you can, take a moment and let me know what you think about it. I'd really like to know.

Now it's time to turn it loose on the world. While the copyrights of this article remain the property of the Publishers (because writers gotta eat!), the CL-3 software and PCB design are hereby placed in the public domain with no restrictions other than "commercial use prohibited". Go nuts!

(100026)

Multiplexed 7-segment display logic

A single numeric digit, based loosely on the Arabic numerals popular in Western languages, can be represented with as few as seven independent 'segments', traditionally labeled 'a' through 'g'. See below. LEDs prearranged in this pattern have been available for decades in various colors and sizes. To save pins, either the anodes or the cathodes are connected together and the other terminals brought out separately, thus the characterization 'common cathode' or 'common anode'.



100026-13

To directly drive the LED segments from a microcontroller, connect seven output lines (via current limiting resistors) to the LED display module. Connect the LED common pin to either V+ for common anode displays or ground for common cathode displays.

If you have lots and lots of extra output pins available, you can connect a single output line to each LED segment for as many digits as your application requires. If not, you can *multiplex* the outputs. This reduces the number of dedicated output lines. Generally speaking, you then give up the ability to illuminate all of the LED segments simultaneously.

One way to multiplex the LED display is to arrange them in a row and column array, where the rows correspond to segments and the columns to digits. All of the 'a' segments would be connected together, as would the 'b' segments, etc. Instead of connecting the common line from each display to either V+ or ground, the common lines are individually selected (or *strobed*) by more dedicated output lines. These 'digit select lines' are almost always buffered using some sort of current-amplifying circuit, such as a common-emitter amplifier, consisting of a transistor and a resistor.

Each digit is displayed for a very brief period of time, then the next one, etc. If this happens fast enough, the display appears to be uniformly illuminating all the digits at once.

COMPONENT LIST

Resistors
R1,R2,R3,R5,R6,R8,R9 = 100Ω
R4,R7 = 10kΩ

Capacitors
C1,C2 = 10nF
C3,C5,C7 = 100nF
C4,C6 = 100µF 25V radial

Semiconductors
D1 = 1N4148
D2 = 1N4001
LD1,LD2 = 7-segment LED display, common anode (CA), h=10mm, Avago type HDSP-315L
T1 = BC557
IC1 = Atmel ATTINY2313-20PU, programmed, Elektor # 100026-41
IC2 = 7805

Miscellaneous
S1 = Tactile switch, 6mm, Multicomp type MC32830
S2 = rotary encoder, Alps type EC11E15204aE
K1 = 2-pin pinheader, 0.1 inch lead pitch.
K2,K6 = 10-pin (2x5) pinheader 0.1 inch lead pitch
K3,K4,K5,K7 = 3-pin pinheader, 0.1 inch lead pitch
RE1 = PCB mount relay, DPCO, 5VDC, Multicomp type HRS2H-SDC5V
PCB, see www.elektor.com/100026

[1] www.elektor.com/100026

One-Button Data Entry

Drop-in BascomAVR routines

By Vladimir Mitrovic (Croatia)



In microcontroller based projects you often need to set a bunch of parameters or initial values. If the project already has an alphanumeric or some other kind of display, even complex multiple-digit values can be effectively set with just one pushbutton that can serve for other purposes as well.

Based on an ATtiny2313, the test circuit in **Figure 1** is 'general purpose' and could be part of just about any project requiring a user interface. Pushbutton S1, together with an LC alphanumeric display, enables a form of interactive data entry.
The trick is, of course, in the program, which is written in BascomAVR. The program will run on all similar circuits based on AVR microcontrollers as well as on 8051 micros if you do the necessary family-related adaptations.

The idea is to monitor not only if, but also how long, S1 is pressed. Two different cases can be distinguished:

- the button is pressed briefly (shorter than 1 s);
- the button is pressed for a long time (longer than 1 s).

When the button is pressed for longer than one second for the first time, the program will enter data-entry mode. In this mode, the initial parameter value is displayed and the cursor is placed under the first digit (see **Figure 2**). Every short press on the S1 will toggle the sign and/or increment the selected digit by 1. Pressing the button longer than one second again will move the cursor under the following digit, which can now be edited by short presses on the button. Pressing the button longer than one second while the cursor is under the last digit will terminate data-entry mode and the program will continue to execute code in the main loop.

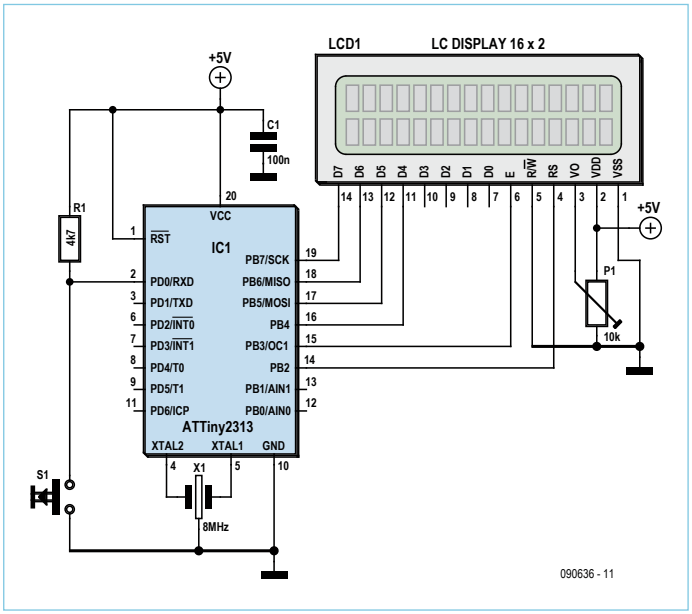


Figure. 1. One button is all you need for an elegant and effective data/parameter entry (test circuit shown).

Examples

In order to explain how data-entry routines can be implemented in the real program, two example programs were written: EE_1_button_HEX.bas and EE_1_button_DEC.bas. Both programs can be downloaded free of charge from the Elektor website [1]. They perform a simple main task: increment a counter ('Cntr' variable) approximately ten times per second and display every new value.

The programs differ visibly in the way the counter is displayed: the first program shows the counter value as a hexadecimal number, whereas the other one shows it as a signed decimal number. The real difference between the programs is in the way hexadecimal or decimal values are edited when the programs enter data-entry mode. After the counter value has been changed and the program control is returned to the main loop, both programs will continue to count from the value that has just been set.

If you extract the counting/displaying part of example programs, the remaining code contains the structure and the routines that enable 1-button data entry, which should be easy to 'port' or 'migrate' to other similar projects.

Program concept

The heart of any program that alters its behavior depending on duration of some event is the time-measuring routine. In our programs, in the 'Check_t1' subroutine we check if, and how long, the

button is pressed. Note that although the switch is labeled S1 in the diagram, it's invariably 'T1' in the software.

```
T1 Alias Pind.0       'T1 input pin

Check_t1:
   T1_time = 0
   Debounce T1 , 0 , T1_on
Return

T1_on:
   T1_time = 1
   While T1 = 0
      Waitms 10
      Incr T1_time
      If T1_time > 100 Then
         Exit While
      End If
   Wend
Return
```

The 'Debounce' statement checks if the pushbutton is pressed at all. If the check fails, program control returns to the main loop with 'T1_time' variable set to 0. If the 'Debounce' statement establishes that the button is pressed (T1=0), the program branches to the 'T1_on' routine and waits in While-Wend loop until the button is released or 1 second passes (whichever comes first) and then returns to the main program. If the button is released before 1 s passes, the 'T1_time' variable will have any value from 1 to 100 (for time periods from approx. 10 ms to 1 s). If the 1-second period lapses, the program will stop monitoring the button and will return to the main loop with T1_time = 101.

To enter the data-entry mode, you should periodically check in the main loop if the switch is pressed for longer than 1 s and if it is, call the data-entry subroutine:

```
Do
   Gosub Check_t1    'check if T1 is pressed >1s
   If T1_time > 100 Then
      Gosub Edit_cntr 'if yes,
                      'enter editing mode
   End If
   ...                'else, do whatever
Loop
```

The data-entry subroutine consists of three parts:
1. initialization, in which the initial value is converted to the appropriate format for display;
2. loop, in which S1 (T1) is periodically checked and the displayed value is edited as explained before and
3. finishing, in which the edited value is saved to become the new initial value.

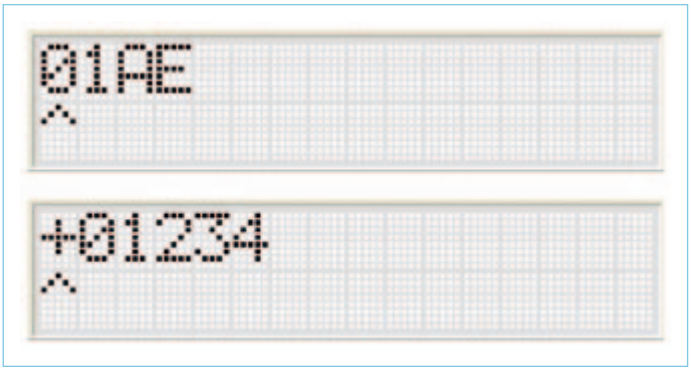


Figure 2. Display in data-entry mode: hexadecimal and signed decimal input is possible.

It is obvious that the program will not be able to execute the commands from the main loop while the data-entry subroutine is executed. Interrupt routines, if there are any, will be executed normally. It is the programmer's responsibility to ensure that such a condition does not affect the hardware controlled by the microcontroller in a destructive manner.

We will not explain the data-entry subroutine in detail. However, several notes might be helpful in order to enable you to adjust it to your own needs.

EE_1_button_HEX description

The initial value is stored in the 'Cntr' variable (the name comes from its use in example programs and you may edit it as you please). The variable type can be Byte, Word, Integer or Long. To enable manipulation of individual digits, the variable is converted to the string 'Edit_string' which should be properly dimensioned to accept the 'Cntr' variable (2B for Byte, 4B for Word/Integer and 8B for Long).

```
Edit_cntr:
   Edit_string = Hex(cntr)
   Cls
   Lcd Edit_string
```

The editing loop that extracts hexadecimal digits from the string is limited by the string length:

```
   For I = 1 To Len(edit_string)
      Edit_x = Mid(edit_string , I , 1)
      ...
```

Since BascomAVR has no function to increment the hexadecimal digit in the 'Edit_x' variable, a simple assembler routine 'Incr_hex' is written and called when a short press on the button is detected. Every edited digit is merged into the initial string and displayed before the next digit is selected:

```
      If T1_time > 0 Then
         Gosub Incr_hex
         Mid(edit_string , I , 1) = Edit_x
         Lcd Edit_string
      End If
   Next
```

Near the end, after the last digit has been edited, the new value is converted back from the string into the numeric value and saved in the 'Cntr' variable:

```
   Cntr = Hexval(edit_string)
Return
```

EE_1_button_DEC description

The initial value is stored in the 'Cntr' variable (again, rename it as you please). The variable type can be Byte, Word, Integer (signed) or Long (signed). To enable manipulation of individual digits, the variable is converted to the string 'Edit_string' which should be properly dimensioned to accept the largest possible value in the 'Cntr' variable. Allow for an extra byte for signed variables.

```
Edit_cntr:
   Edit_string = Str(cntr)
   Edit_string = Format(edit_string , "+00000")
   Cls
   Lcd Edit_string
```

Note that 'Edit_string' is formatted with the Format() function. This is necessary if you want to display the + sign and leading zeroes; only displayed digits can be edited! The + character at the beginning of the mask is necessary only for signed variables and should be omitted otherwise. The editing loop that extracts digits from the string is limited by the string length:

```
   For I = 1 To Len(edit_string)
      Edit_x = Mid(edit_string , I , 1)
      Edit_9 = Val(edit_x)
      ...
```

Every digit is extracted as a hexadecimal character ('Edit_x') and a decimal number ('Edit_9'). This is necessary as you have to manipulate string (sign) and numeric (digits) values.
What will happen if the short press on the button is detected depends on the character that is extracted. If it is a sign, it will toggle:

```
      If T1_time > 0 Then
         If Edit_x = "+" Then
            Edit_x = "-"
         Elseif Edit_x = "-" Then
            Edit_x = "+"
```

This part of the program may be deleted if the initial value is unsigned (i.e. if it is stored in the Byte or Word variable). If the extracted character is a number, it will be increased:

```
         Else
            Incr Edit_9
            If Edit_9 > 9 Then Edit_9 = 0
            Edit_x = Str(edit_9)
         End If
```

Every edited digit is merged into the initial string and displayed before the next digit is selected:

```
         Mid(edit_string , I , 1) = Edit_x
         Lcd Edit_string
      End If
   Next
```

Finally, after the last digit has been edited, the new value is converted back from the string into to the numeric value and saved in the 'Cntr' variable:

```
   Cntr = Val(edit_string)
Return
```

The data-entry routines are explained in a somewhat simplified manner; check the example programs in the free download [1] for the complete routines!

(090636)

Internet Link

1. www.elektor.com/090636

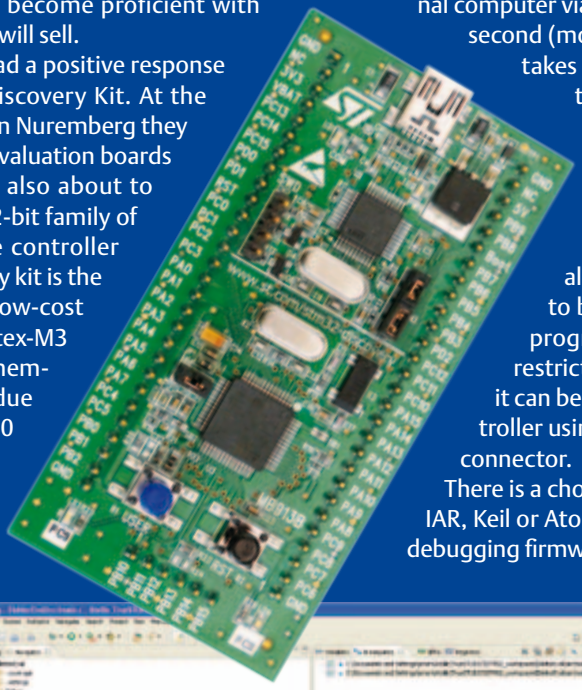
Advertisement

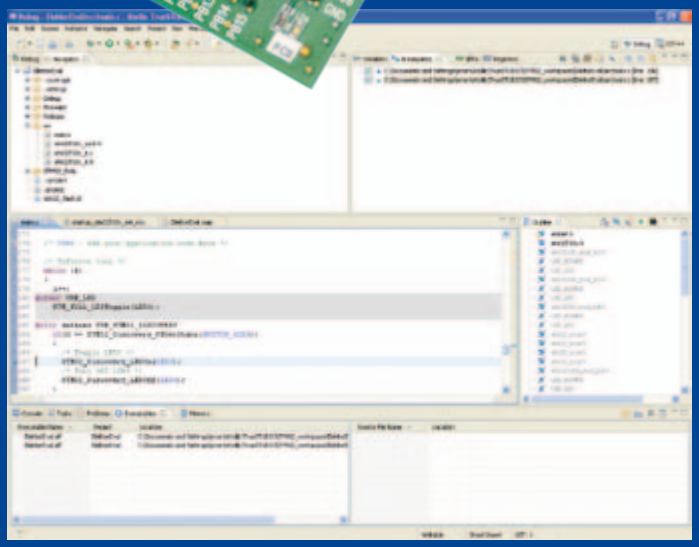


Discover the STM32!

By Jens Nickel (Elektor Germany Editorial)

Microcontroller evaluation kits are a wonderful resource. Those supplied by chip manufacturers are usually reasonably priced as development costs can be recouped in chip sales. For the engineer/student it's a good opportunity to work hands-on with the devices and the software tools. From the manufacturers viewpoint the more people who become proficient with their devices the more chips they will sell.
STMicroelectronics has already had a positive response to their low-cost 8-bit STM8S Discovery Kit. At the last Embedded World exhibition in Nuremberg they handed out 5,000 of these 8-bit evaluation boards free to visitors. The company is also about to introduce a similar kit for their 32-bit family of microcontrollers (STM32F). The controller chosen for the STM32VL-Discovery kit is the STM32F100RBT6B, one of their low-cost 'Value line', based on an ARM Cortex-M3 architecture with 128 KB Flash memory and 8 KB RAM [1]. The kit is due to be shipped mid September 2010 and will be stocked by a number of suppliers. Farnell already have plenty on back-order, not surprising considering the retail price of the kit is just £6.80 or $9.90 in the US.





STMicroelectronics also supply a range of STM32xxx-EVAL evaluation platforms but the STM32-Discovery is a much more economical introduction to the Value Line family. All software is available for download from the Internet and a USB cable will be needed to connect the kit to a computer. Unlike many other manufacturers whose evaluation boards are designed in the form of a large USB stick and are quite densely populated the STM32 Value Line Discovery has more board space and uses a rectangular board. Single rows of pin headers are fitted along the long side and at the lower end through which the processor pins have direct access to the outside world. Many other evaluation boards provide just a few solder pads for connecting external circuitry but the Discovery board is more versatile and can be used as a processor board with peripherals wired in the prototyping area or linked to an additional circuit board.

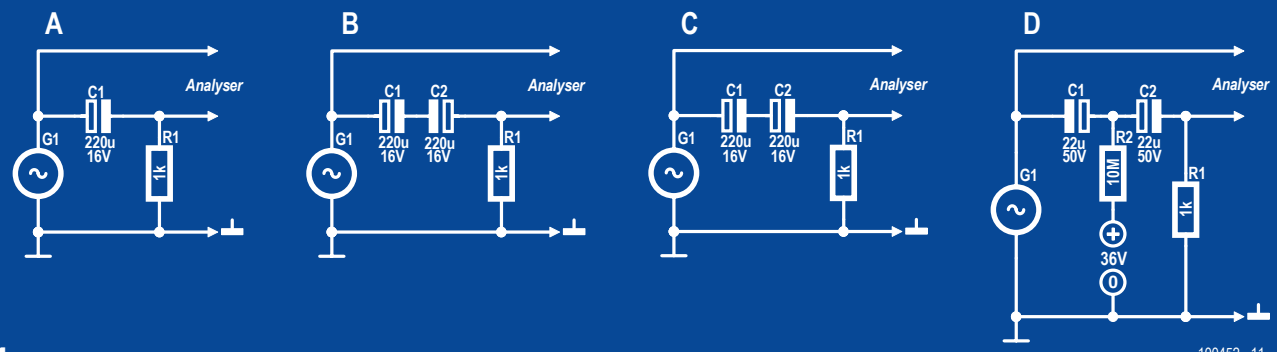
The hardware is divided into two areas; the main part contains the target controller together with a reset button, a 'user' button and two LEDs. These allow you to run and interact with simple demo programs without the need for any additional hardware.
The somewhat smaller upper area of the PCB is fitted with a USB socket. Power for the board is derived from the external computer via the USB cable. Underneath there is a second (more powerful) STM32 controller which takes care of programming and debugging the target processor. The functions of this debugger are compatible with the ST-LINK programmer/debugger tool. This means that free ST-LINK software such as the 'ST-LINK utility' [2] also runs on the board to allow the STM32F100 memory contents to be read. A nice feature also is that the programmer/debugger functions are not restricted to the on-board target controller; it can be hooked up to an external STM32 controller using the 4-pin SWD (Serial Wire Debug) connector.
There is a choice of three tool chains available from IAR, Keil or Atollic to deal with the job of writing and debugging firmware for the STM32. We chose the 'TrueSTUDIO for STM32' from Atollic AB as the development environment. The Lite version can be downloaded for free [3] and is neither time nor code size limited but has fewer functions than the professional version. This powerful IDE based on ECLIPSE is simple to install and includes a good selection of project templates for different hardware platforms so for example it is not necessary to concern yourself with generating your own make-files (the first steps of creating a new project are described in the 'quick start guide' of the development environment). Selecting 'STM32_Discovery' as the evaluation board will load a small demo project to control the two LEDs in response to user button presses. Although the newcomer may find the development environment a little daunting at first, they will soon get to know how the individual project files hang together, what information is shown in the windows and where the most important debugger control panel is. To run your own programs in the 'lite' version it is necessary to activate the debug process, the run procedure and

generation of binaries is only possible in the professional version. In the 'Build Configurations' menu (accessible from the main menu under 'Project') make sure that 'Set Active' has been selected in 'Debug'. Otherwise new or modified programs will not be transferred to the controller for debugging.
Now there's no reason why you can't start thinking up your own applications for this powerful system. A good starting point for those new to the environment is the examples posted on the STM32-Discovery website [4]. Running through these will quickly boost your confidence with the system. The downloadable data describes the board in detail (circuit diagram, pinouts and jumpers). STMicroelectronics have indicated that the website will be active by the 15th September at the latest.

(100454)

[1] www.st.com/mcu/inchtml-pages-stm32.html
[2] www.st.com/mcu/familiesdocs-110.html (the last one in the list)
[3] www.atollic.com/index.php/download/downloadstm32
[4] www.st.com/stm32-discovery

Electrolytic capacitors in audio circuits



1

By Ton Giesberts (Elektor Labs)

Here at Elektor, for more than 20 years we've held the opinion that electrolytic capacitors have the worst properties for audio signal paths, possibly with the exception of ceramic capacitors. Our dielectric of preference is plastic film, with polyester/terephtalate as a minimum. Even better are polypropylene and polystyrene versions. Of course, there are 'ultimate' capacitors like Teflon or silver-mica devices, but we're talking about electrolytic caps here.

Electrolytic capacitors are commonly used as coupling devices in valve amplifiers, but we also frequently find them in solid-state amplifiers. The advantage of electrolytic capacitors is their large capacitance to volume ratio. In the original design of the '5532 Power Amplifier' (first part of this edition), two electrolytic capacitors were used, which we eliminated in the final design; a DC control is added instead to compensate for any offset. In this way any discussion as to whether electrolytic capacitors have an audible effect on the sound, in whatever way, can be avoided. Nevertheless we were curious what the effect of the electrolytic capacitors would have been if we had left them in the signal path. We will show the results of the THD measurements, tests with MLS and standard IMD signals did not result in any clear differences between input and output of the test configuration. The various test configurations are shown in **Figure 1**.
We started with the simplest measurement of a high-pass filter (**Figure 1a**). **Figure 2** shows the FFT analysis of the generator and the output of the network. The generator generates a sine-wave at 20 Hz with an amplitude of 5 V_{rms}. The graph shows the signal from the generator (cyan) and the voltage across R1 (green). There is therefore an increase in distortion, but the harmonics are below –120 dB! In reality they are even lower, because they are only a little stronger than the harmonics from the generator, which are at –130 dB (2nd and 3rd harmonics). Expressed as a percentage the distortion increased from about 0.00017 % to 0.00023 %. The measurement was repeated for other types of 220-µF electrolytic capacitors. Next was a non-polarised electrolytic. It came as a surprise that the comparison with the generator signal shows practically no difference. This was followed by the two different types of electrolytic cap from the first measurement, this time connected in series in a bipolar manner (**Figure 1b**). There still was practically no difference to be seen between input and output. To find out whether the polarity made a difference, we turned the second electrolytic around (**Figure 1c**); the measurement across R1 now showed two harmonics which were a few dB larger than the measure-

ment with one electrolytic. We can therefore conclude that a bipolar configuration, with respect to distortion, is preferable over a single electrolytic. We assume that the non-linearities are cancelling each other. We followed this with measurements using other electrolytics (different manufacturers and rated voltages). The results gave different pictures, but always an increase in distortion. In all these situations a bipolar connection had a positive effect.
After this we did tests with electrolytic capacitors that were 10 times smaller. The corner frequency is now at 7 Hz instead of 0.7 Hz with the 220 µF device. There is now a greater voltage drop across the capacitor. The result of a measurement using the configuration of **Figure 1a** at 20 Hz (5 V_{rms}) can be seen in **Figure 3**. There is now considerably more distortion (about 0.005 %), and that is only due to the electrolytic! We also tried a bipolar connection, which gave a chart with a second harmonic that was about 17 dB lower, but the third was a little bigger. The rounded distortion figure remains the same.

We had one remaining question. Does the DC voltage across an electrolytic capacitor have an effect on the distortion? That is why we carried out a measurement according to **Figure 1d**. We don't have to show the result, because the two curves (with and without DC voltage) are practically on top of each other.

To get a feel for the quality of standard plastic film capacitors (Siemens/Philips 'MKT') we did two more tests with two versions of the high-pass filter with a corner frequency of 20 Hz. The first version was a large 4.7 µF/250 V capacitor and a 1.69-kΩ resistor. The second version was a cheap 2.2 µF/100 V capacitor (type without plastic case) and a 3.65-kΩ resistor. The results of the measurements are shown in **Figure 4**. Both versions gave pretty much the same result. Only the 2nd harmonic increased by 12 dB and the third remained practically identical.

From these tests we can conclude that when using electrolytic capacitors in the audio signal path it is desirable to locate the corner frequency well below the desired audio range. In cases where the impedances are low (kilo-ohms) there is no real alternative to electrolytics for blocking potential DC voltages. The disadvantage of the large capacitance is that a change in DC voltage will still be partially allowed to pass, because of the long time constants involved. Switch-on phenomena also last longer. A consideration can be to increase the impedance (results in more noise), so that it is still possible to use a polyester (MKT) device. The advantage is then that the polyester cap can be dimensioned for the desired corner frequency.

From this we can conclude that when using electrolytic capacitors as coupling capacitors there is practically no measurable effect on the audio signal provided that the capacitor is considerably over-dimensioned. With these 'too large' electrolytics it is also beneficial to use them in a bipolar connection.
We have looked here at only one aspect (harmonic distortion). There are obviously many more characteristics of electrolytic capacitors that could have an 'audible' influence on the sound quality.
Here is an overview of interesting publications if you would like more information about capacitors.

(100452-I)

Literature and Internet links

Capacitors in A.F. Circuits, Elektor February 1992

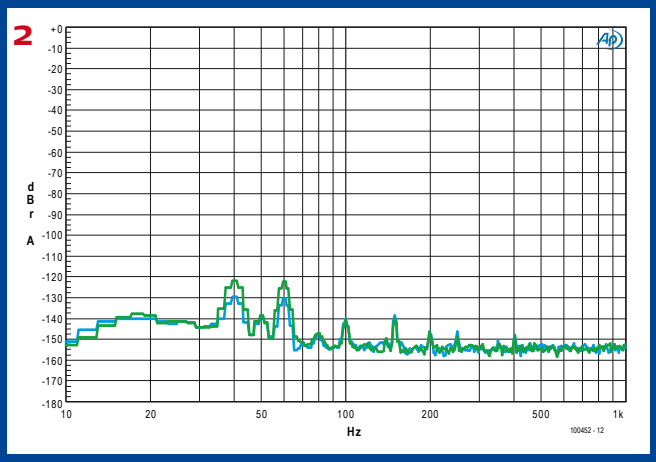
A real-time signal test for capacitor quality,
The Audio Amateur, April 1985

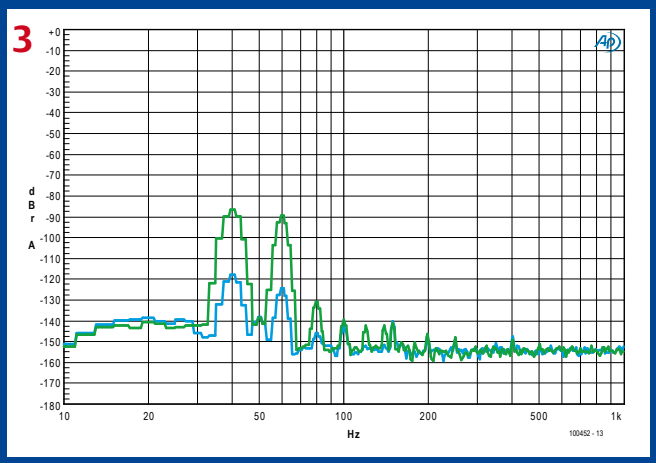
Capacitor Sounds, Electronics World, July 2002 – January 2003

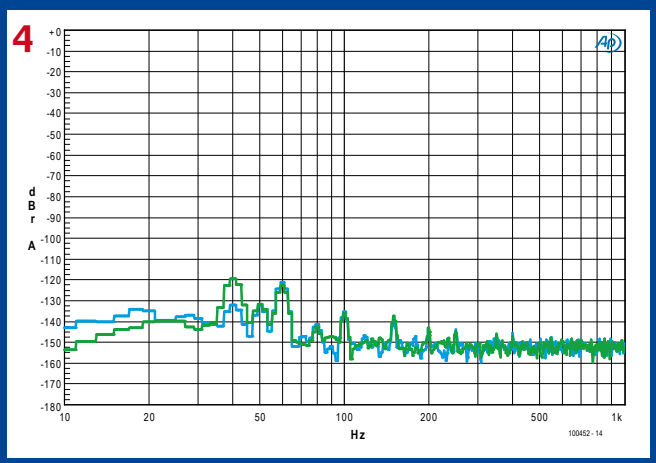
Picking Capacitors, Audio Magazine, February 1980

http://sound.westhost.com/articles/capacitors.htm

http://www.national.com/rap/Application/0,1570,28,00.html







A Pocket Projector

By Jens Nickel (Elektor Germany Editorial)



Advances in high power LED technology has made it possible to shrink the size and price of LCD projectors. Makers of so-called pico-projectors boast that their devices will fit into your pocket and are ideal for projecting stills and videos from flash memory video players, camcorders and portable DVD players onto a wall for everyone to see. Serious bit of kit or just a toy? With Conrad Electronic [1] offering the 'Aiptek Pocket Cinema T15' for 99 euros (some 80 pounds) we thought it was time for us to find out.

Our first impression was that the term 'pocket projector' is in no way an exaggeration. The device sits in the hand and looks well built. Included in the kit are a rechargeable battery, an AC power charger, a small tripod and an AV cable (3 x RCA sockets). The only video input on this unit is the AV connector for stereo sound and video signal. An S-Video signal provided by some laptops (or mobile phones) will also be suitable but you will need to buy an adapter cable. For our test we took the signal from an old DVD player.
In the first test we projected an A4-sized image (35 cm diagonal). Our initial subjective impression of the image was surprisingly favourable with colour saturation better than expected. The 640 x 360 resolution is less than a PAL signal, so the image is understandably a little soft and the picture shows some evidence of video processing. The biggest limitation however is poor image brightness (8 Lumen compared with 2000 to 15000 Lumen for a standard metal halide LCD projector). Attempts at viewing a bigger image (it can focus images with a diagonal of up to 127 cm) required an absolutely dark room.

At this point curiosity got the better of us; brandishing a set of screwdrivers we went in search of screws to undo. With the bottom half of the case removed we could see the main PCB and at the front, the projector lens extending from a black box which presumably contained the complete optical arrangement and the light source. To go any further we needed to lift the lid but it looked like it was glued to the middle section. Luckily lab assistant Jan Visser had come over to see what we were doing and he volunteered to lend a hand. He seems to have a sixth sense, able to identify the position of concealed screw heads, plastic clips and double-sided tape.
A couple of minutes later the unit was dismantled. Inside we found the power LED fitted to a PCB with an aluminium plate to aid heat dissipation. A finned heat sink is also fixed to the plate. At the opposite side of this optical box we can see a thumbnail sized display screen. The operating principle is now fairly clear; light for the white LED (from Cree) passes through a series of lenses to produce a parallel beam of light. The beam passes through a half-silvered mirror set at 45° in the optical path and strikes the reflective display. The image on the display is reflected back and then out through the lens via the half-silvered mirror.
Identification marks on the LED PCB shows that the unit originated from the Hong Kong based company iView. Their website indicates it is possible to order the optical module type IPL-512DG which was specially developed for the Pico projector [2]. The site News pages report that this module has also been integrated into a mobile phone to become the first phone with this feature.

We also discovered that the mini display unit in the projector is a LCoS (Liquid Crystal on Silicon) unit. This type of display similar to an LCD is based on liquid crystal technology but works in a reflective rather than transmissive mode. The liquid crystals are applied to a mirrored substrate, as a liquid crystal pixel flips between on and off, light is either reflected from the mirror or blocked. This technology can produce high resolution images and is compact. We couldn't find an English website with information on the HX7009 chip which is supplied by Himax in Taiwan [3]. The same company are also responsible for the HX8852 display driver chip which accepts digital video conforming to the ITU656 protocol [4]. Next to it is the TVP5150AM1 chip from TI [5], this converts PAL input signals into ITU656 digital signals. The largest chip on the board is an 8-bit microcontroller type HT46R23 from Holtek [6].

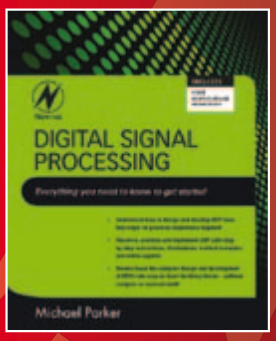
(100450)

[1] www.conrad.de (Part No 346313)
[2] http://iview.apaci.com.hk/en/products/products_details.php?pageNo=1&pid=11
[3] www.himaxdisplay.com
[4] www.himaxdisplay.com/en/product/HX8852.asp
[5] http://focus.ti.com/docs/prod/folders/print/tvp5150am1.html
[6] www.holtek.com/english/news/products/022701.htm



Newnes Press

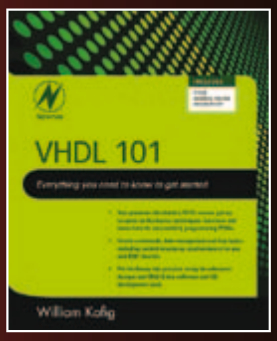
Education Never Ends. Everything you need to know to get started.



By: Michael Parker
ISBN: 9781856179218
$54.95



By: Gina Smith
ISBN: 9781856177061
$44.95



By: William Kafig
ISBN: 9781856177047
$44.95



By: Lou Frenzel
ISBN: 9781856177009
$44.95

Newnes

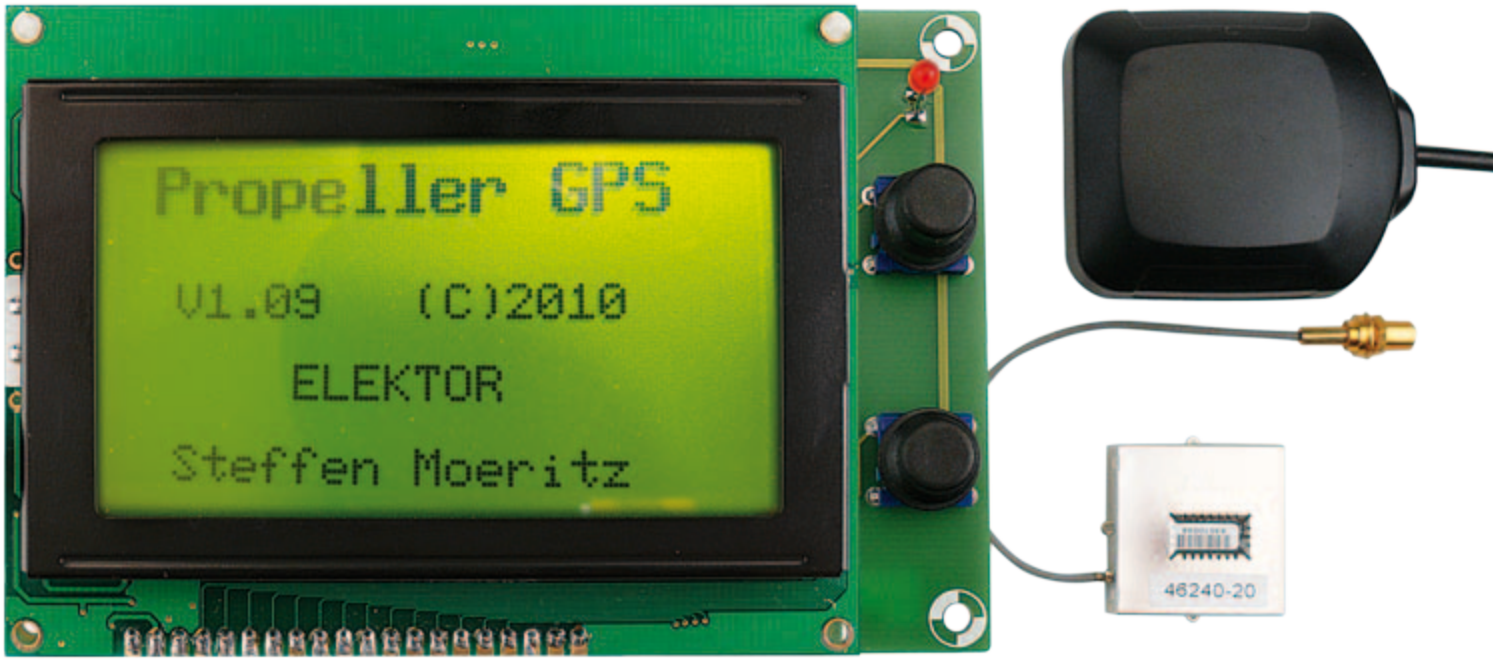
Visit newnespress.com today and sign up for our Newnes Online Membership.
Receive our best discounts · Hear about books before they publish
Access to free sample chapters, video tutorials and more!

www.newnespress.com

Find these books and more at newnespress.com or your favorite online retailer!
Order today!

GPS ft. Propeller

Parallax multiprocessor enhances satnav functionality



By Steffen Möritz (Germany)

A more versatile GPS receiver for in-car use and radio-control model applications was the spur to designing this project, with capturing motion speed and presenting this in both digital and analog form a primary requirement. With eight CPUs onboard working in parallel, the Propeller microcontroller from Parallax manages these demanding graphic applications with ease.

For quite some time now there have been a number of approaches to capturing the speed of moving objects extremely accurately by means of GPS. Despite this, off-the-shelf gadgets produced for in-car route navigation generally do not have a built-in speed capture function. Maybe the manufacturers do not want complaints from customers when their tacho reading (which intentionally shows higher than actual speed) doesn't correspond with the GPS display. An additional hand-held satnav device doesn't make much sense in this situation, particularly as the speed display is very small. Squinting at tiny figures is not necessary with the GPS receiver described here, which shows the GPS speed with clarity in both analog and digital form. Furthermore it can track your progress and speed changes during the last 90 minutes. The device can be used out on the road and equally well in model sports such as radio control (RC) cars.

Hardware

It was back in May 2006 when the Californians at Parallax launched their remarkable Propeller microcontroller. Truly exceptional was the provision of eight integrated CPUs that operated practically in parallel. Parallax calls these CPUs 'Cogs'. The system speed is 80 MHz, producing a maximum performance of 160 MIPS.
The architecture of the Propeller makes it hard to compare with traditional microcontrollers. Because the eight Cogs can share tasks among themselves, interrupts are no longer required and the programmer has full control over the use of the Cogs. Reading in serial data, processing this data and output to the graphical LCD (GLCD for short) all take place in parallel.

The system speed of the Propeller is shown in the schematic (Figure 1), using a 5 MHz crystal that is multiplied internally by a factor of 16.
The KS107/108-compatible GLCD equipped

Features

- Automatic baud rate recognition (4800 or 9600 baud) of the GPS mouse
- Designed for GPS mouse models with 3.3 V or 5 V supplies
- Graphical presentation of speed values for the last 90 minutes
- Speed and direction of movement analog and digital
- Position- and time display (UTC time)
- Switchable between metric (m) and imperial (miles/feet) units
- Two buttons for selecting image and function within an image

with 128 x 64 pixels is controlled by an 8-bit wide data bus.
A 24LC256-I/P EEPROM (IC2) is used for storing an application-specific program (the firmware).
The MAX3232CPE (IC3) serves to adapt the levels between the Propeller and the GPS mouse used as GPS sensor. The latter can use either a 3.3 V or 5 V supply and must provide an RS-232 interface (4800 or 9600 baud). Serial GPS mouse units of this kind generally have a sub-D connection and it's worth checking this and the supply voltage before purchase.

Propeller firmware

Software for the Parallax Propeller is programmed with SPIN. On the Parallax homepage the necessary objects are already waiting for you:

- "FullDuplexSerial"
- "Propeller Eeprom"
- "Ks0108V1.6" (revised by the author)

With these objects we can create an EEPROM, a RS-232 interface for hooking up to a GPS mouse and the controls for a KS107/108-compatible GLCD.

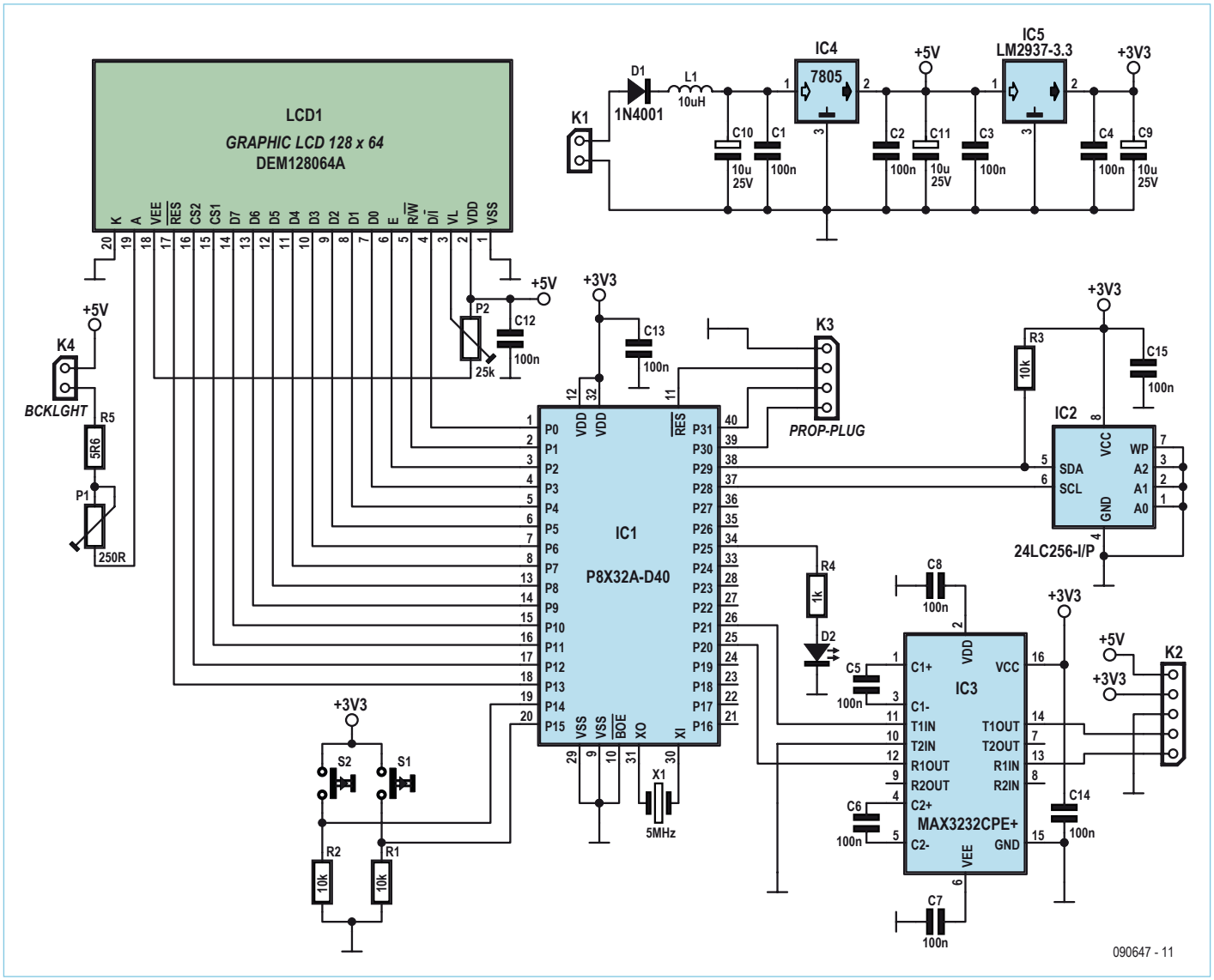


Figure 1. The circuit comprises basically just a single Propeller chip (IC1) and an LCD for the graphics. K2 is for connecting a serial GPS mouse.

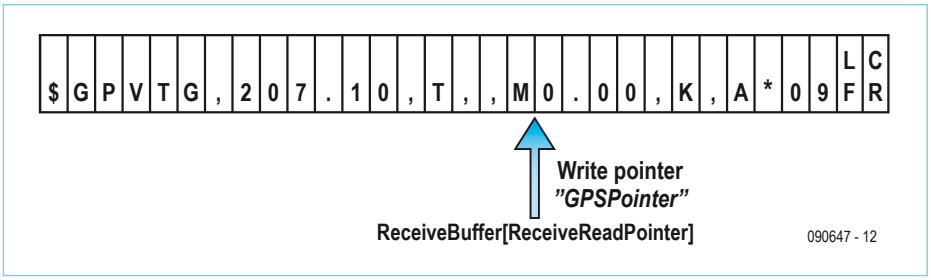
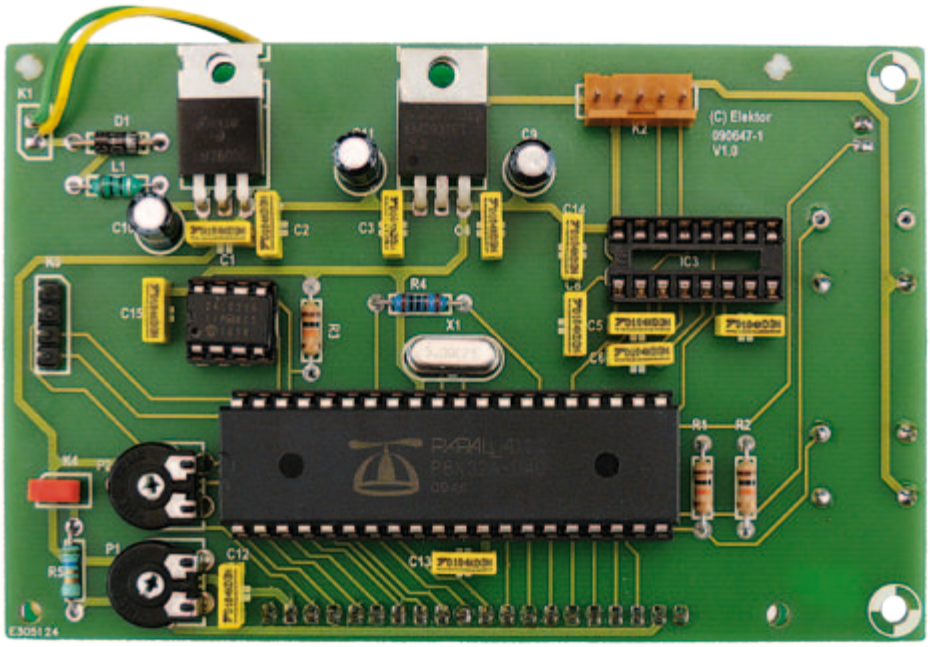


Figure 2. Format of a GPS data set.

The parallel processes of the Cogs make interrupts superfluous, which as already mentioned is a significant advantage of the Parallax Propeller.

In this GPS project you'll have the pleasure of programming five Cogs:

1. The main program GPS.Start requires one Cog. From this main program the Cogs described next are called using the command COGNEW(entry,..).
2. Cog for FullDuplexSerial.start. Reads in data from the GPS mouse over the serial interface.
3. Cog for KS0108V106.start. Drives GLCD with 128 x 64 pixels with KS107B/KS108B-Controller. Preparation for text and graphic functions.
4. Cog for ReceiveDatas. Writes data from the RS-232 interface into a ring buffer (circular buffer).
5. Cog for Picture_Page_4_Cog. Graphical functions are programmed on this screen. As they require a relatively long processing time a dedicated Cog is provided.



Let's now investigate the ReceiveDatas function of the fourth Cog in detail.
With the library function FullDuplexSerial. spin a character from the serial interface is read in. The program waits in this line of programming for the period that the character is read in. For this reason it is both logical and necessary to start a dedicated process (Cog) (cognew ReceiveDatas). Every new character received is written into the ring buffer ReceiveBuffer (array[0..50]) by means of the write pointer ReceiveWritePointer. The write pointer is incremented by 1 for each new character received. When the write pointer reaches a value of 51, it is reset to zero. To generate a GPS string, the function ReadBuffer is read out from the ring buffer in the main program. To this end the read pointer ReceiveReadPointer is compared with the write pointer ReceiveWritePointer. If the pointers are unequal, then the Variable ReceiveBuffer[ReceiveWritePointer] is read out and the read pointer is incremented by 1. This process is repeated until the write pointer is the same as the read pointer.
The GPS mouse delivers data using the NMEA-0183 protocol into ASCII format. Each set of data begins with the character '$', followed by a two-character long transmit indicator and a three-character data label. After this come the data sets, separated by commas. Finally the set is closed with an optional checksum and CR/LF. A set can contain up to 82 characters, in a format designated by the number of commas.
The character determined by the read pointer is written into the array GPSBuffer. The start of a GPS data set is recognized by the '$' character, after which the write pointer GPSPointer is set to zero. The character LineFeed (decimal 10) enables the end of a GPS string to be recognized. A GPS data set written to the GPSBuffer has the sample structure seen in Figure 2. In this example we are reading the GPS data sets $GPGGA, $GPVTG and $GPRMC containing the following GPS data:

- $GPGGA includes Latitude, Longitude, Quality of the signal received, number of satellites received and height above sea level.
- $GPVTG includes the speed.
- $GPRMC includes clock time, date and direction of movement (effectively compass direction).

Practical matters

To simplify construction a printed circuit board (Figure 3) has been designed, on which all components (apart from the GLCD) are mounted on the top side. The GLCD is attached to the other side.
The power supply voltage is connected to the multipin connector K1; a range between about 8 V and 18 V DC is permissible.
The GPS mouse is plugged in at multipin connector K2. Power for the mouse is applied either to pin 5 (5 V) or pin 4 (3.3 V) and Pin 3 (supply return). Pin 1 is commoned with the transmit line (TxD) of the GPS mouse and pin 2 with the receive line (RxD).

A jumper on K4 switches on the background lighting of the GLCD. Brightness is preset with P1 and contrast with P2.
LED D2 indicates the state of the data received as follows:

- Steady light = Checksum and quality of received data in order
- Rapid flashing = Checksum error
- Slow flashing = Quality error

The Parallax Propeller chip is programmed in-circuit using the SPIN programming language, which can be downloaded free at the Parallax homepage and the 'Prop Plug' programming adapter from Parallax. Connection to the PC is by USB cable. On the GPS board the 'Prog Plug' is plugged into the multipin connector K3 (Figure 4).

Before operation you need to check whether the GPS mouse still needs to be configured with software that either came with it or else can be downloaded from the manufacturer's website. The serial interface of the GPS Mouse should be configured as follows: 9600,N,8,1.
After powering up the GPS Propeller board the Receiver searches for the GPS mouse, first at 4800 baud. If a 9600 baud receiver is used, then the display will indicate only random characters initially. Afterwards the correct presentation of received data at 9600 baud will appear (Figure 5).
If after one second the data from a GPS mouse cannot be interpreted correctly the error message 'no GPS signal' is shown. A correct signal will produce an image with digital and analog speed display (Figure 6). At lower left the maximum speed achieved previously is shown.
Press button S2 can now switch between metric and imperial units (statute miles and feet). This setting is now valid for all subsequent displays and remains stored in the EEPROM even when power has been removed.

Operating S1 allows the following functional displays to be called up sequentially:

Direction of movement display (Figure 7) similar to a compass (digital and analog).
History display (Figure 8) with graphical progress readout through 90 minutes in 1

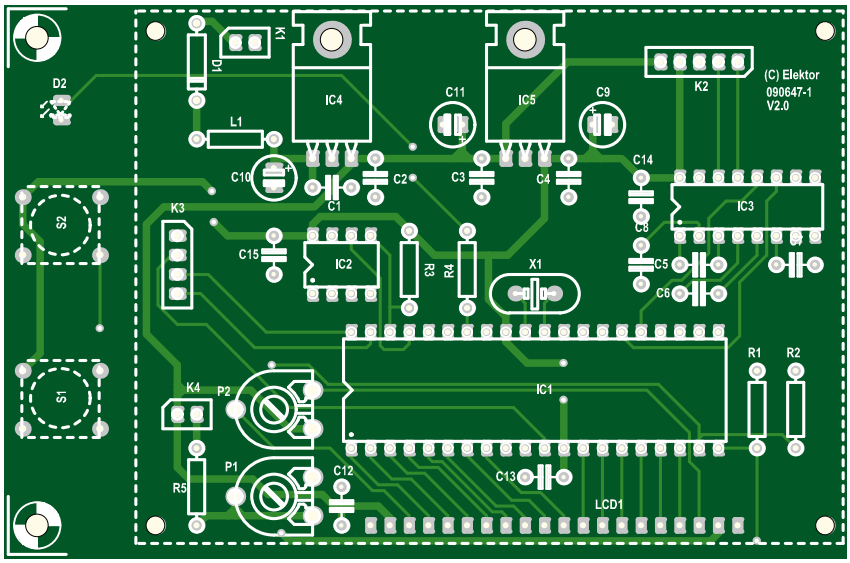


Figure 3. Inserting the components of the PCB developed for the GPS-Propeller.

COMPONENT LIST

Resistors
R1,R2,R3 = 10kΩ
R4 = 1kΩ
R5 = 5.6Ω
P1 = 250kΩ trimpot
P2 = 25kΩ trimpot

Capacitors
C1–C9,C12–C15 = 100nF
C9,C10,C11 = 10µF 16V

Inductor
L1 = 10µH

Semiconductors
D1 = 1N4007
D2 = LED (3mm)
IC1 = P8X32A-D40 (Propeller chip; Parallax)
IC2 = 24LC256-I/P
IC3 = MAX3232CPE+
IC4 = 7805
IC5 = LM2937ET-3.3

Miscellaneous
X1 = 5MHz quartz crystal
LCD1 = graphic LCD 128 x 64, DEM128064
K1,K4 = 2-pin pinheader
K2 = 5-pin pinheader
K3,K5 = 4-pin pinheader
PCB # 090647-1 (www.elektor.com/090647)

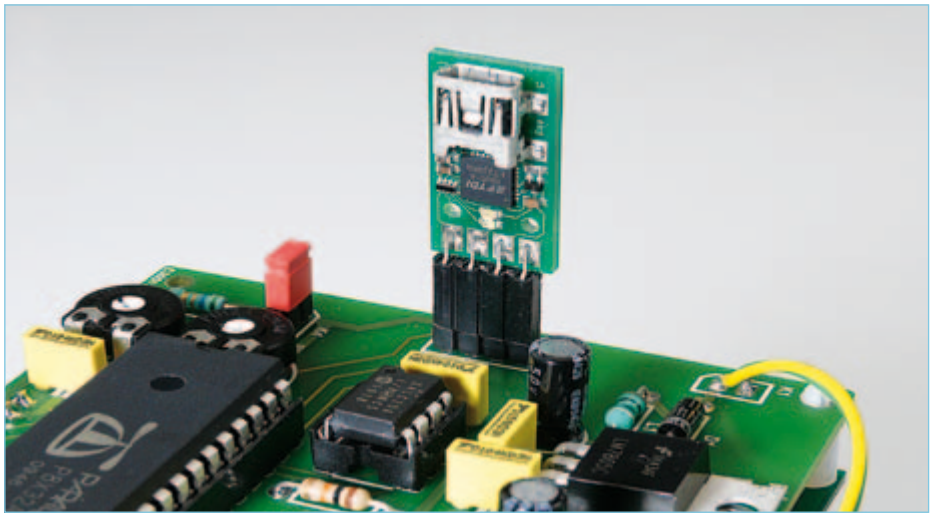


Figure 4. Programming uses the USB programming adapter 'Prog-Plug', which is plugged into the PCB.



Figure 5. Switching on the unit displays the GPS Search Image based on data received at 9600 baud.

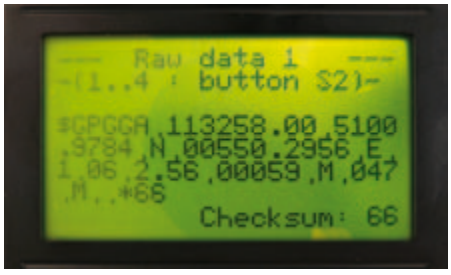


Figure 9. Display of raw GPS data. Data blocks can be called up individually.



Figure 10. The group display combines data from all three GPS data blocks.



Figure 6. If the data is correct a speed display appears in km/h. Pressing S2 will switch to miles per hour (mph) which is the norm around Rocklin, CA.



Figure 7. The compass-like display of motion direction.



Figure 8. History readout with graphical display of the speed progression.

minute steps and additional display of current speed. At power-up the History function is first disabled. The word 'OFF' is displayed (on the right, next to 'History') indicates there is no data recorded. Operating switch S2 initiates recording and 'ON' appears. If switch S2 is held down for longer than 5 seconds in 'OFF mode, the data is wiped. The legend 'Erase Data' alerts this. Another brief push of S2 from 'ON' to 'OFF' saves the current data into the EEPROM.
At lower left (at '#60' on the display) a countdown mechanism is included. This decrements from 60 to 0, one second at a time, then the last minute is shown. Next the countdown starts again from the beginning. This makes it easy to spot when the next display refresh is coming up. The countdown display is static when no GPS data is being received. Every minute a line is displayed showing the minimum and maximal speed limiting values.

Raw data display (Figure 9) with the data received from the GPS mouse.
Press button pages through the data blocks $GPGGA, $GPVTG and $GPRMC.

Group data display (Figure 10) with the display of all the data blocks: Speed in large characters, height above sea level, direction of movement, signal quality (0/1), total number of satellites, clock time and date (UTC time), position and maximum speed. The maximum speed achieved previously, which is also stored in the EEPROM, can be recalled by pressing S2. According to the module that was preselected for display on the analogue and digital speed display (Figure 6), the screen can show kilometres per hour (km/h) and metres (m) or miles per hour (mph) and feet (ft).

(090647)

Internet Links

[1] www.parallax.com
[2] www.spinvent.co.uk/
[3] http://en.wikipedia.org/wiki/NMEA_0183 (Wikipedia, NMEA data format)
[4] www.kowoma.de/gps/zusatzerklaerungen/NMEA.htm (detailed information on NMEA in German, use Google search engine or Google Chrome to translate)
[5] www.elektor.com/090647 (project page with software download and ordering details for PCB)

About the author

Following Communication Technology studies at University of Applied Sciences (UAS) in Bingen, Germany, Steffen Möritz has been employed for more than 20 years in the industrial automation field in the automotive industry. His spare time is occupied designing microcontroller circuits for automotive and model applications, primarily using Parallax Propeller and PIC microchips. Steffen can be reached at steffen@moeritz.com.

Saelig

UNIQUE PRODUCTS + FREE SUPPORT!

www.saelig.com 1-888-7-SAELIG info@saelig.com

We have the testgear you need!

Call us for technical advice!

60 - 300MHz DSOs

SALE!



60/100/200/300MHz 2 ch, 2GS/s DSO 2000 wfm/s refresh rate. High quality, ultra Compact Design with small footprint. Totally new price.

DS1052E $399

• • thru • •

FreeCase!

DS1302CA $1995

Thumb-sized USB Tools



Tiny sophisticated PC-based tools for any toolkit. 10MHz Scope, 50MHz Counter, 12MHz Waveform Generator, 100MHz Pulse Generator. USB isol.

Mixed -Signal PC Oscilloscopes



100 MHz Scope and Logic Analyzer lets you do complex triggering to find hard-to-get-at glitches, spikes, etc. Huge 4 or 8 MS buffer for deep data drilling and zooming. Optional built-in swept signal generator. 2 Analog channels x 10, 12, 14 bit with more than 60 dB dynamic range. 8 digital inputs for mixed signal display/trigger.

CS328A-4 (4MS Buffer) $1259

CS328A-8 (8MS Buffer) $1474

CS700A (signal generator) $299

LCD Scopes

BEST SELLER



Owon - 25 or 60MHz color LCD 2-ch bench scope **OR** 20MHz handheld scope/meter. USB interface for printouts. Includes scope probes! Battery versions available.

PDS5022S / 6062T $287 / $419

HDS1022MN / 2062MN $589 / $699

USB Bus Analyzers



Packet-Master™ - best value USB1.1/2.0 USB analyzers and generators. Identify USB problems fast, fine-tune performance, easily view Host commands, emulate host/device sequences, etc.

USB12 (USB1.1) $699

USB480+ (USB1.1/2.0) $1199

USB500AG (USB1.1/2.0/Gen) $1399

7 in 1 USB Scope

NEW!



2-ch 10-bit 2MHz scope/spectrum-analyzer, 3MHz 8-bit wfm gen; 16 x I/O; Network Analyzer; Noise Generator; PWM. Windows/Linux/Mac compatible! USB-powered, great for toolbox, education, etc. **CGR-101™** $199

EMC Spectrum Analyzers



EMC RF & EMF Spectrum - Analyzer 1Hz to 7GHz for measuring transmissions from radar, radio/tv towers, WLAN, WiFi, WiMAX, Bluetooth, microwave ovens, etc.

from $835 / $1395

microCAM



Compact compressed-serial output camera module for any host system. JPEG OmniVision™ CMOS VGA color camera for embedded imaging.

uCAM TTL or 232 $58

Sound Module



14-pin Tiny Audio-Sound Module plays back pre-stored audio files (voice and music) from micro-SD card - ideal for embedded audio output.

SOMO-14D $25

USB to I2C



Devasys - Provides a simple "drop-in" solution for connecting I2C/SMBUS to 1Mbps; 32 I/O. Free software. Use multiple boards for more I²C/IO.

USB I2C/IO $89

XP Emb Touchpanels



Touch-input 10.2/15" Atom/Geode processor backlit TFT color LCDs USB 2.0 + Ethernet 12V-powered complete Windows PC.

CUPC-P80/P100 from $849

Pen Scopes



High-perf USB 2.0 socpe-in-a-probe! Up to 100MS/s, 10/25MHz 24kS buffer. +/-100mV to +/-20V. 20ns/div - 50s/div C/VB/Delphi/LabView/VEE drivers.

PS2104 / PS2105 $193 / 280

RF Testing/EMI Tents



Economical, portable RF test enclosures, for initial compliance testing. **from $1295**

Shielding Tents with external frame, instant up/down for emissions-free room. **from $2000**

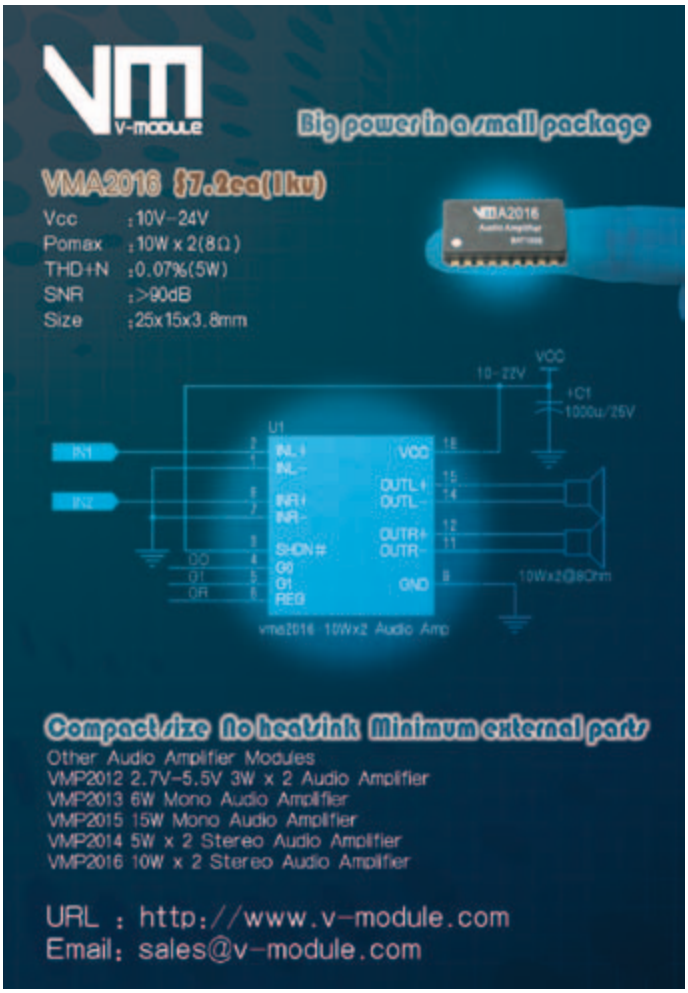
I started Saelig as an engineer - for engineers! **Saelig** is an olde English word means 'happy, prosperous, blessed'



Check our website for lots of neat stuff!

Alan Lowne • Saelig CEO

Saelig .com unique electronics



eweekly

elektor newsletter

Take out a free subscription to E-weekly now

Do you want to stay up to date with electronics and computer technology? Always looking for useful hints, tips and interesting offers? Subscribe now to E-weekly, the free Elektor Newsletter.

Your benefits:

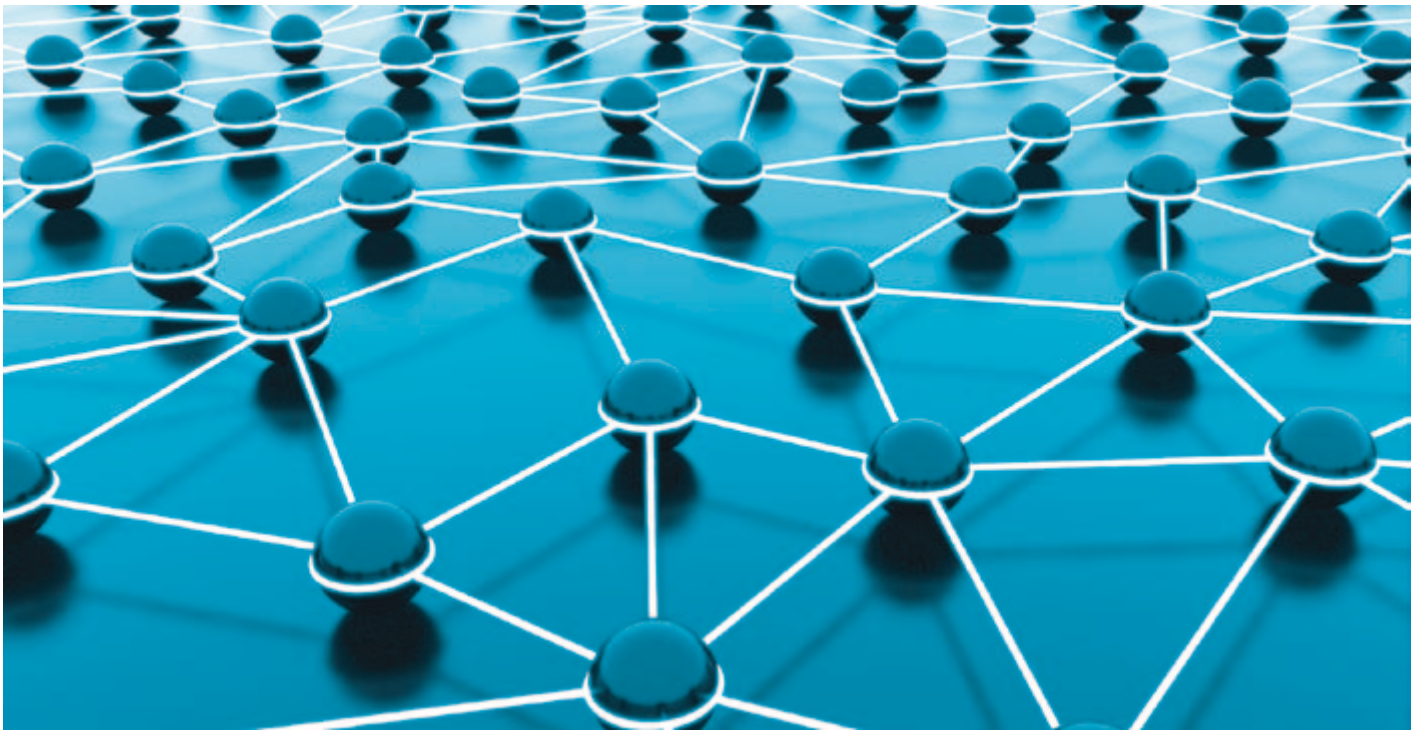
- The latest news on electronics in your own mailbox each Friday
- Free access to the News Archive on the Elektor website
- You're authorized to post replies and new topics in our forum



Register today on www.elektor.com/newsletter

ZigBee Today & Tomorrow

Technology and applications



By Joe Lomako (TRaC) (UK)

When it comes to applying ZigBee technology, the ideas people are coming up with are proving to be more and more elaborate and inventive. It is no surprise then that many (if not all) of the biggest names in wireless and microprocessor technology have shown considerable interest if not direct involvement. What's humming out there?

ZigBee is a specification which defines a high level communication protocol using low power digital radios using the IEEE 802.15.4 standard. The idea behind ZigBee is that it offers an infrastructure for a Wireless Personal Area Network (WPAN) which is highly adaptive, simpler, less expensive and consumes less power than other WPANs.

There are essentially three flavors of ZigBee: ZigBee, ZigBee PRO and ZigBee RF4CE which is a similar technology that is used for RF control of consumer electronics.
The differences between the various technologies can be defined using a combination of the Network topologies, the security employed and the method of Network addressing. This can be shown in contrast in **Table 1**.

Let's start networking...

Each ZigBee network is essentially made up of a 'coordinator', 'router' and an 'end device'. They can all be fully functioning devices with an intrinsic function but will also perform ZigBee functionality. The coordinator forms and manages the network; the router can route messages as well as allow other devices to join the PAN router and the end device is just that. It can join a network but has no routing capability. These devices are defined in **Figure 1**. In essence the ZigBee network can be made up of two topologies: Tree/Star (**Figure 2**) or Mesh (**Figure 3**).

Table 1.Zigbee basic versions and their capabilities

	ZigBee	ZigBee PRO	RF4CE
Topology	Star / Tree	Mesh	Tree
Security	Normal	High	Normal
Network Addressing	Distributed	Stochastic	Pairing

One of the strengths of ZigBee PRO is the meshing network topology which means that the networks can be extended over considerable geographical areas, such as in a large buildings or even an industrial pipeline. It has a 'self healing' mechanism which means that if one of the components of a multihop route from one device to another leaves the network for any reason an alterative route using alternative adjacent devices will be identified and implemented.

As for the end products, in simple terms, a ZigBee device is constructed of a ZigBee compliant platform (a radio part and a ZigBee part) with the appropriate application (profile) sitting on top. The radio is based around the 802.15.4 standard (and comprises of a PHY and MAC layer) and the ZigBee 'stack' sits on top. The abstract layer models in **Figures 4 and 5** illustrates this.

.. and then profiling

The ZigBee platform becomes a so called functioning 'ZigBee device' when it has a 'profile' placed on the top of it. A profile is a set of commands and attributes which are used to send specific messages over a ZigBee network.
There are two types of profile; a Public Profile, which has been developed by the ZigBee Alliance members and has specific command attributes. Anybody employing a Public Profile must adhere to the rules of that particular profile. Presently there are several Public Profiles, which we will touch on later. There is also another type of profile, the Manufacturer Specific Profile (MSP). These are proprietary profiles which a manufacturer may develop because he wishes to use the ZigBee technology but not the Public Profiles.

Public ZigBee profiles

There are several profiles at present. These include

- ZSE, also known as Smart Energy;
- ZHA, also known as Home Automation;
- ZTS, also known as Telecoms Applications;
- ZHC, also known as Personal Healthcare;
- ZBA, also known as Construction and Building;
- ZRC, also known as Consumer Electronics.

Each is discussed briefly below.

Smart Energy Profile (ZSE) has been designed to be used in smart home area networks (HANs), to manage and improve the efficiency of energy consumption. There are many devices presently on the market from utility meters (gas, water and electric) to in-home displays, which can provide historical and real-time data indicating energy usage. Smart energy devices (**Figure 6**) are being enabled across the entire world from small households to entire governments.

Home Automation (ZHA) — was one of the first profiles to reach maturity and has developed to become a very robust and ubiquitous tool in the ZigBee box. It enables the user to simplify the household tasks and create a unique experience within the household. There are many products on the market which are very diverse in their applications; these include simple lighting control such as on/off and dimmer switches and lights. When used in connection with other types of technology the whole home automation system can be enhanced. For example, the light mood settings on one's home can be set from a smartphone, or if arrival at home is going to be late the drapes could be closed remotely. The possibilities are end-

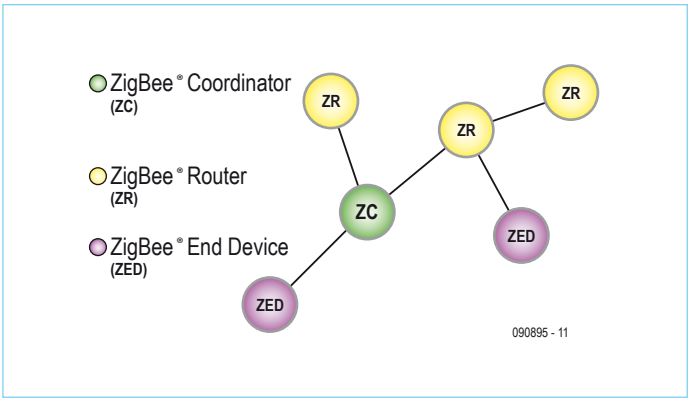


Figure 1. The message routing within a Zigbee network is largely governed by the Zigbee Coordinator (ZC).

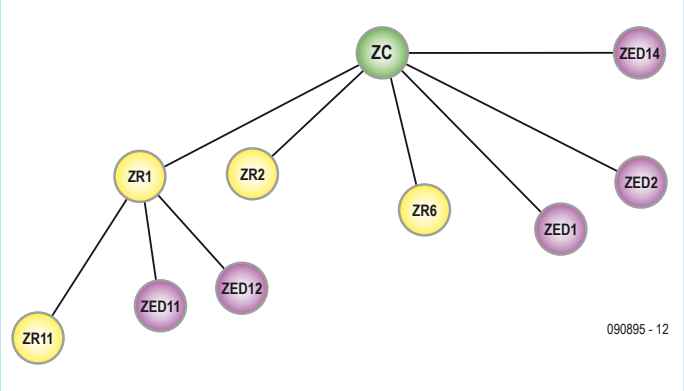


Figure 2. Zigbee network with tree structure.

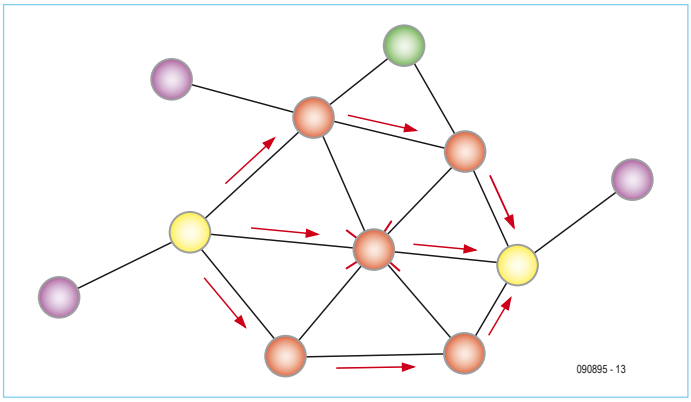


Figure 3. Zigbee network with mesh structure.

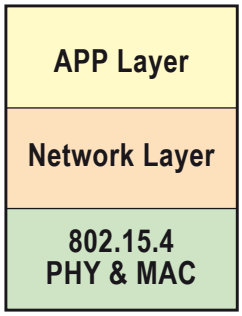


Figure 4. The compliant platform.

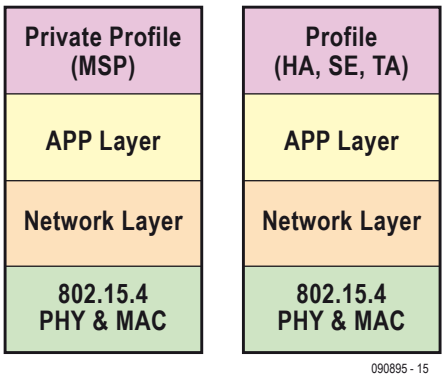


Figure 5. Examples of Public and Private Profiles.

less and applications are becoming more and more versatile.

Telecoms Profile (ZTS) – is designed to enable information delivery to mobile-enabled devices. Imagine a visitor walking round a museum viewing the exhibits and when a particular exhibit is reached further information is required on this. Quite often it would mean reading the programme or typing in a number on a cumbersome audio handset supplied by the museum to play the specific audio. With ZigBee telecoms applications, the ZigBee enabled mobile device will automatically detect the location and send the appropriate information for that exhibit creating a more enhanced user experience.



Figure 6. A ZigBee'd Smart Energy meter.

Healthcare (ZHC) – is one of the newest profiles to be developed and is probably one of the most important profiles available. The world's population is ageing, therefore greater demands are being placed on the healthcare infrastructure. ZigBee technology is being used to support the ageing population maintain their independence by providing assisted living support. There are devices which can be installed in an elderly user's home which can monitor if they have a fall or can go further and monitor if a bath is overflowing or a gas cooker has been left on. In the instance that an 'alert' is issued a central monitoring station can pick up the message and provide assistance if needed.

In addition to this there is an increase in chronic medical conditions such as obesity, diabetes, chronic pulmonary disorders and high blood pressure. A ZigBee'd blood pressure meter is shown in **Figure 7**. As a result of this there are many organisations which have been formed with the objective of developing solutions and infrastructure to support the medical professions in meeting the demands of their patients needs. ZigBee technology is playing a very important role in healthcare and is increasingly being employed in medical devices or aids. This type of remote monitoring has attracted considerable interest over the last few years and some studies have suggested it could provide considerable savings for the worlds health services or enable doctors and health professionals to increase the number of patients they can attend to, in some cases doubling them!

Take for instance a diabetic who has to monitor their blood sugar 2-3 times per day. In the traditional system, they would take their reading on their handheld system and then usually record the results in a journal. They would take this to the doctor at their next appointment, which could be days or weeks away. The doctor would analyse the data and act upon it by which time the information recorded may have no bearing on how the patient is today. However, by using a ZigBee-enabled blood sugar monitor which is connected to a remote monitoring system (which could be a specialist centre staffed by qualified nurses or health professionals). The patient would use a device which would be connected to the remote monitoring station via a cradle. The patient would make their measurement which would be displayed on the meter, when the meter was replaced on the cradle the recorded data would be automatically sent to the remote monitor. This takes a few seconds compared to several days on the traditional system. Now the remote centre would assess the data and determine if any immediate action need be taken. A real life case in a trial of a similar system showed that a diabetic patient was not adhering to a strict diet and via the remote monitoring system a doctor was able to intervene before any serious condition occurred. So clearly the healthcare industry is one which can really benefit from ZigBee technology.

Construction and Building Automation (ZBA) — is designed to provide an adaptable system of management of complex buildings. It provides a means of economically centralising lighting, HVAC and security. This also allows remote monitoring of the efficiency of many of the systems. In addition to this, in new constructs where lighting and/or security systems need to be adaptable; this ZigBee profile provides an excellent way of achieving this adaptability.

RF4CE (ZRC) — This profile is built on the ZigBee RF4CE platform and will allow an advanced functionality and user experience in the control of home entertainment equipment and domestic products. Although at the time of writing this profile is in its infancy, the market requirement is constantly changing and the applications in which we will see the RF4CE profile are potentially endless.

Conclusion

Clearly ZigBee is incredibly versatile and in some respects it is only limited by the imagination of the designer to come up with innovative and fantastic new ideas for applications in which to employ the technology.

Yes ZigBee does have its critics, and always will, which is embraced, as criticism is the fuel of innovation. So in the greater perspective ZigBee has a lot to offer and is clearly here to stay; as can be seen from the various examples above ZigBee can (and will) be used in many different product types and applications and who knows what's next?

(090895)



Figure 7. This blood pressure monitor can be read out remotely over a Zigbee link.

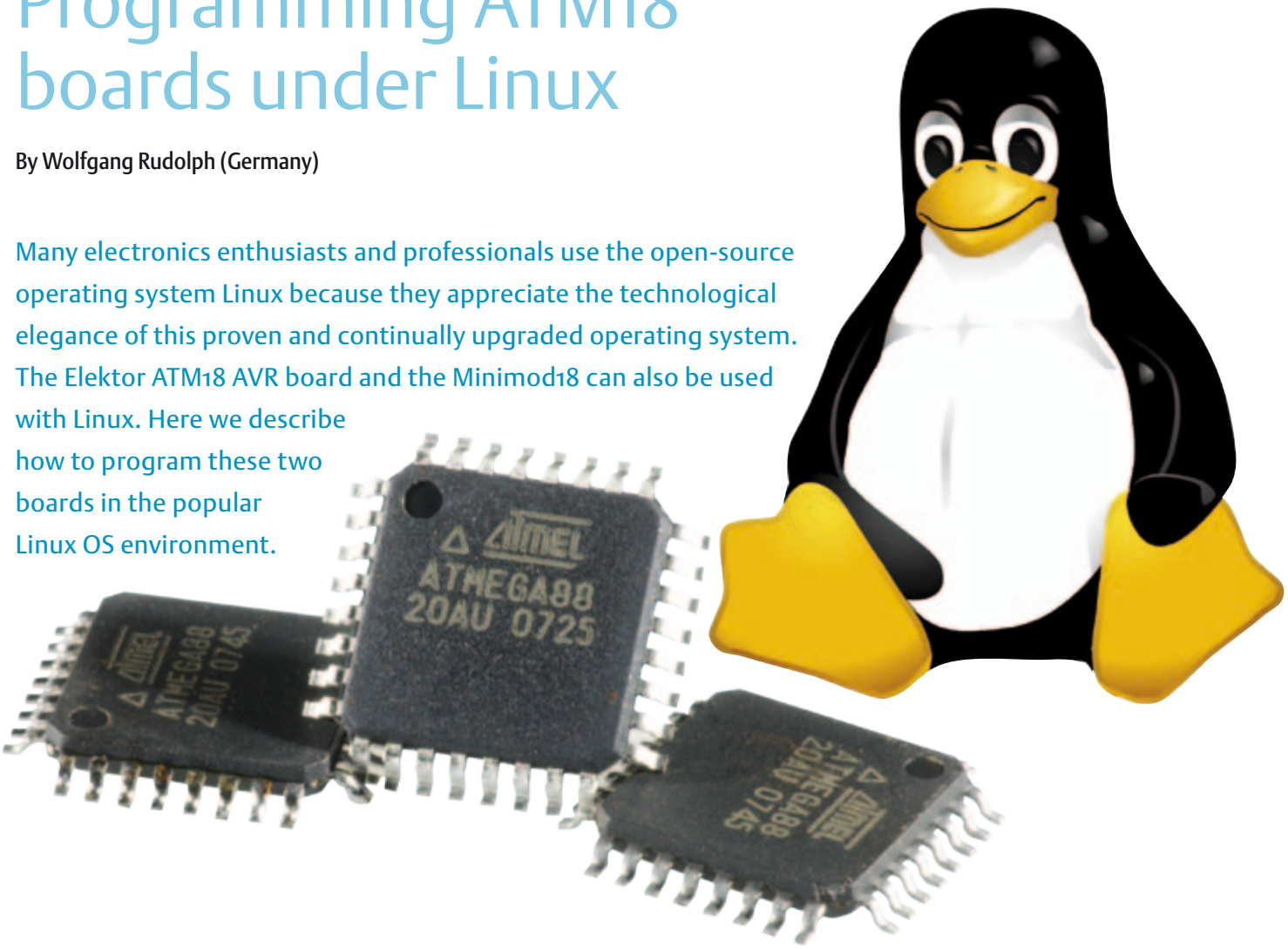
Advertisement



Tux and ATmega
Programming ATM18 boards under Linux

By Wolfgang Rudolph (Germany)

Many electronics enthusiasts and professionals use the open-source operating system Linux because they appreciate the technological elegance of this proven and continually upgraded operating system. The Elektor ATM18 AVR board and the Minimod18 can also be used with Linux. Here we describe how to program these two boards in the popular Linux OS environment.



Windows users have it easy. If you have a suitable USB programmer, you can program the microcontroller module of the ATmega board directly in the AVR Studio development environment [1]. Linux users, by contrast, are faced with an initial problem because AVR Studio is only available for Windows. Unfortunately, it does not run properly inside the Windows API wrapper Wine [2], which is able to simulate the Windows OS environment for many Windows programs.
But where there's a will, there's a way. With the command-line program AVRdude, you can use the ATM18 AVR board under Linux. Of course, this also works with Minimod18, although 'direct' microcontroller programming is usually not necessary with this especially compact module because Minimod18 has a boot loader that can receive hex files via USB and store them in memory. If you 'overhaul' the Minimod18 with a programmer, the boot loader will be overwritten and one of the key features of the module will be lost. In this case, the boot loader must be downloaded into flash memory again to restore normal operation.
The following instructions apply to a programmer compatible with AVRISP Mk II, such as the Elektor AVRprog USB programmer designed by Benedikt Sauter [3]. If you use a different type of programmer, see the inset for more information. The instructions are based on a Debian distribution of Linux.

Installation

Here we assume that you have a good basic understanding of how to install and use programs on a Linux system. In order to program the microcontroller of the Elektor ATM18 AVR board, you first need some software. As usual, you can use apt-get to meet this requirement fairly simply (assuming the computer has a connection to the Internet). However, you must first log in as the root user by typing su or sudo (depending on the distribution) and your password immediately ahead of the apt-get command.

Next, enter the following command after the prompt:

```
apt-get install avrdude avrp gcc-avr avr-libc
  gdb-avr avra make udev
```

Answer the question 'Do you want to continue?' with 'Yes'.

The necessary packages will now be loaded and preconfigured. A few older packages may be de-installed and replaced by other packages or newer versions. If you see a message reporting that the kernel does not support udev, you must update the kernel before udev (or a new version of udev) can be loaded. Although it is possible to continue with the installation in this situation, you should not do so, since there is a risk of a system crash. A reliable kernel update is always the preferred solution. However, you can rest assured that Linux does not make it easy for foolhardy users to make mistakes of this sort. A particular file must be altered before Linux actually comes into danger.
Before you update the kernel, it's a good idea to quickly check whether the installation can actually run with the udev version already present. As the saying goes: nothing ventured, nothing gained!

After the installation process has completed, you can connect the USB programmer to the USB port and use the lsusb command to determine the device ID:

```
pole1:/home/wolf# lsusb
Bus 005 Device 003: ID 090c:6300 Feiya
   Technology Corp.
Bus 005 Device 001: ID 1d6b:0002 Linux
   Foundation 2.0 root hub
Bus 004 Device 002: ID 046d:c517 Logitech, Inc.
   LX710 Cordless Desktop Laser
Bus 004 Device 001: ID 1d6b:0001 Linux
   Foundation 1.1 root hub
Bus 003 Device 001: ID 1d6b:0001 Linux
   Foundation 1.1 root hub
Bus 002 Device 001: ID 1d6b:0001 Linux
   Foundation 1.1 root hub
Bus 001 Device 004: ID 0a12:0001 Cambridge
   Silicon Radio, Ltd Bluetooth Dongle (HCI
   mode)
Bus 001 Device 001: ID 1d6b:0001 Linux
   Foundation 1.1 root hub
Bus 001 Device 005: ID 03eb:2104 Elektor
wolf@pole1:~$
```

The ID of our programmer is 03eb:2104. If you can't read the ID with lusb (sometimes new devices are not shown), you can use dmesg instead:

```
[ 5145.834284] usb 5-7.4.4: new full speed USB
   device using ehci_hcd and address 10
[ 5146.150088] usb 5-7.4.4: config 1 descriptor
   has 1 excess byte, ignoring
[ 5146.150088] usb 5-7.4.4: configuration #1
   chosen from 1 choice
[ 5146.154083] usb 5-7.4.4: New USB device
   found, idVendor=03eb, idProduct=2104
```

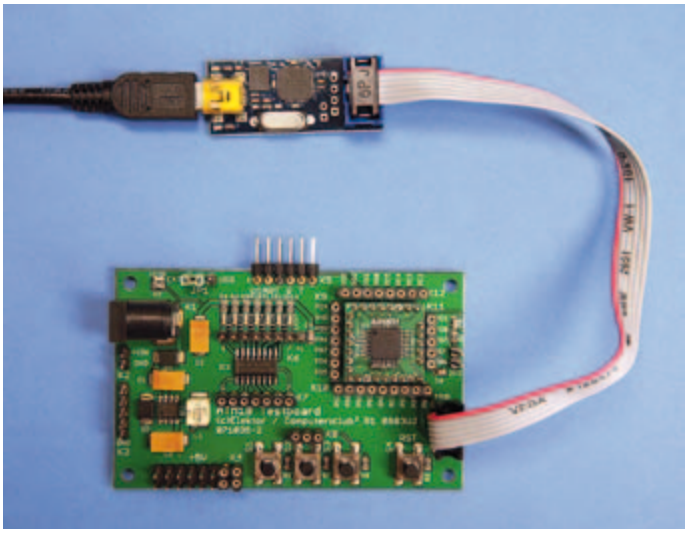


Figure 1. Hey, it works under Linux too: microcontroller programming with the Elektor AVRprog USB programmer [3].

```
[ 5146.154083] usb 5-7.4.4: New USB device
   strings: Mfr=1, Product=2, SerialNumber=3
[ 5146.154083] usb 5-7.4.4: Product: AVRISP mk2
   (CC2)
[ 5146.154083] usb 5-7.4.4: Manufacturer:
   Elektor
[ 5146.154083] usb 5-7.4.4: SerialNumber:
   0000A00128255
wolf@pole1:~$
```

The most recently recognised device appears at the end of the (long) output list. With the Elektor programmer, you will see idVendor=03eb, idProduct=2104. This gives you the assurance that the programmer has been recognized properly. If you don't like wading through the full dmesg output list, you can type dmesg | tail to display only the tail of the list. Incidentally, the number in square brackets at the start of each line in the list is not significant; it is simply the elapsed operating time of the computer, and it is not displayed by all versions of Linux.

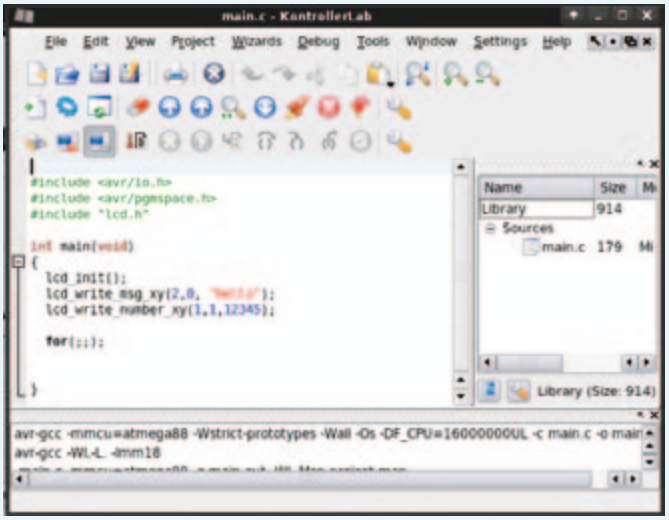
If you use a different programmer, it will of course be reported with a different ID. If you can't find it in the device list, disconnect the programmer from the USB hub and enter the lsusb or dmesg command again. Now you should be able to see what has changed in the command output (which device is missing or has been added).

To avoid having to log in as the root user every time you use the programmer, you can edit the permissions.rules file, which is accessed via path /etc/udev/rules.d/020. Near the end of this file, just before LABEL="permissions_end", there is an entry containing the device ID you found above. You can use the vi editor (or any other suitable editor) to make the desired changes:

```
vi /etc/udev/rules.d/020_permissions.rules

# AVR ISP mkII Atmega Programmer
SUBSYSTEM=="usb_device",
   SYSFS{idVendor}=="03eb",
   SYSFS{idProduct}=="2104", GROUP="plugdev",
```

A matter of taste: command lines



Graphic front ends for AVRdude (which has a command line user interface) are available on the Web, although we haven't tested any of them. The fact that we restrict ourselves to the command line interface here should not be regarded as a value judgement; it simply reflects the notorious difference between Linux users and Windows users.

If your distaste for command line interfaces is sufficiently large, you can try alternatives such as a Java GUI [6] or a KDE program called Kontrollerlab [7], although it appears that the later program is no longer being maintained. With the exception of the simulator, Kontrollerlab is certainly usable as a substitute for AVR Studio under Linux. Unlike AVR Studio, it supports AVRdude without plugins, so you can download program code to the ATmega directly from the IDE.

Other programmers

The AVRdude program has a large number of options. For example, you can use the -c option to select a different programmer. If you only have a programmer with a parallel (printer) port interface available, you can use it this way. You can also ask AVRdude whether it recognizes the connected programmer:

```
avrdude -vvv -c help
```

If it doesn't recognize the connected programmer, it responds:

```
avrdude: Can‘t find programmer id „help“

Valid programmers are:
  dasa3     = serial port banging, reset=!dtr
   sck=rts mosi=txd miso=cts [/etc/avrdude.
   conf:693]
  dasa      = serial port banging, reset=rts
   sck=dtr mosi=txd miso=cts [/etc/avrdude.
   conf:680]
  siprog    = Lancos SI-Prog <http://www.
   lancos.com/siprogsch.html> [/etc/avrdude.
   conf:667]
```

If you have a programmer of a completely unknown type or use a homemade programmer, you can view the AVRdude main page to see how to configure the pin assignments for the parallel port:

```
    Default Parallel port pin connections
      (these can be changed, see the -c option)
      Pin number    Function
      2-5           Vcc (optional power supply
   to MCU)
      7             /RESET (to MCU)
      8             SCK (to MCU)
      9             MOSI (to MCU)
      10            MISO (from MCU)
      18-25         GND
```

```
   MODE="0660", SYMLINK+="foo"

LABEL="permissions_end"
```

If you enter "plugdev" for GROUP=, users without root privileges will also be able to use the programmer.
If vi (the grandfather of all editors) isn't your cup of tea, you can make the changes with any other editor that has root privileges. A good choice here is Midnight Commander, which is something of a Swiss army knife for Linux.
The changes take effect only after the udev configuration has been reloaded as follows:

```
udevcontrol reload_rules
```

Now you can query the programmer with the following command:

```
avrdude -c avrispv2 -P usb -p m88
```

It replies:

```
avrdude: AVR device initialized and ready to
   accept instructions

Reading | ##################################
   ############# | 100% 0.01s

avrdude: Device signature = 0x1e930a

avrdude: safemode: Fuses OK

avrdude done. Thank you.
```

All of the above applies equally well to the Minimod18. Its boot loader simulates a programmer (more specifically, a USBasp programmer) and can also communicate with AVRdude. In this case, you must enter the parameter -c USBAsp instead of –c avrispv2 -P usb.
You also have to enter -p m328p for the microcontroller, as other-

wise AVRdude will complain that the signature is wrong.

A hot topic: fuses

This is not the place for playing around, since you can easily mess things up with the wrong fuse settings, or even make the microcontroller unusable. Whenever you need to change fuse settings, always engage your brain first and think things through twice before you do anything.

Enter the following command to read the fuse settings:

```
avrdude -p m88 -c avrispv2 -P usb -F -v -B 10
   -U hfuse:r:high.txt:i -U lfuse:r:low.txt:i
```

AVRdude responds with:

```
avrdude: Version 5.10, compiled on Jan 19 2010
   at 18:01:15
         Copyright (c) 2000-2005 Brian Dean,
   http://www.bdmicro.com/
         Copyright (c) 2007-2009 Joerg Wunsch

...

avrdude: AVR device initialized and ready to
   accept instructions

Reading | ##################################
   ############## | 100% 0.02s

avrdude: Device signature = 0xff00ff
avrdude: Expected signature for ATMEGA88 is 1E
   93 0A
avrdude: safemode: lfuse reads as 62
avrdude: safemode: hfuse reads as DF
avrdude: safemode: efuse reads as 7
avrdude: reading hfuse memory:

Reading | ##################################
   ############## | 100% 0.00s

avrdude: writing output file "high.txt"
avrdude: reading lfuse memory:

Reading | ##################################
   ############## | 100% 0.00s

avrdude: writing output file "low.txt"

avrdude done. Thank you.

pole1:/home/wolf#
```

There's not enough space here to print the full response (AVRdude is a real blabbermouth). The two lines you're interested in at this point are:

```
avrdude: safemode: lfuse reads as 62
avrdude: safemode: hfuse reads as DF
```

This gives you the fuse settings you need to know. At the same time, they are written to the files low.txt and high.txt as specified in the command. You can view the file contents with:

```
cat low.txt.orig
:01000000629D
:00000001FF
```

and

```
cat high.txt.orig
:01000000DF20
:00000001FF
```

If it's necessary to change the fuse settings, there is a handy tool available for calculating the hex values: Fusecalc [4]. Of course, you can also calculate them by hand with the aid of the data sheet. However, remember what we said: a single mistake could be fatal for the microcontroller.

You can use AVRdude to write the fuse settings to the microcontroller in the same way as you read them:

```
avrdude -c avrispv2 -P usb -p m88 -U
   lfuse:w:0x62:m -U hfuse:w:0xDF:m
```

Here we omit the response from AVRdude, which gets a bit boring after a while. The main thing to check is that there aren't any error messages. If there are, first check the connecting cables and the supply voltage. If errors are indicated but you cannot find the cause, you can use the -f option to force AVRdude to try to write the settings to the microcontroller despite the error message(s).

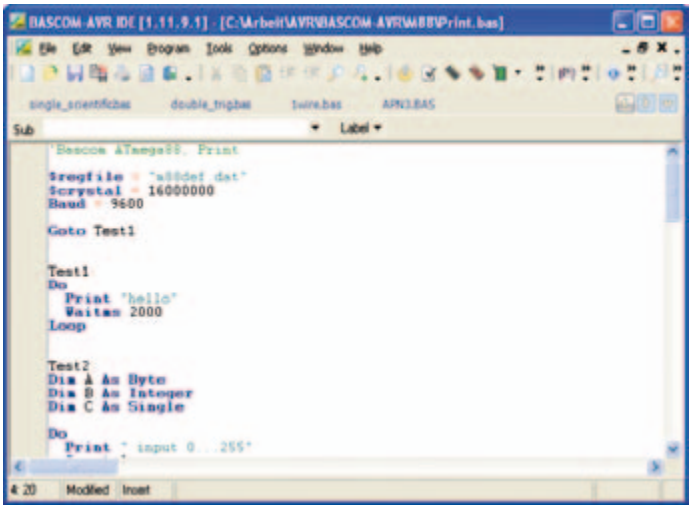


Figure 2. Whipping up a test program: BASCOM feels perfectly at home under Linux with the Windows API wrapper Wine.

Knuckle down, ATmega!

The next thing you need is a program for the ATmega. You can write your own with gcc or BASCOM (which runs nicely under Wine), or you can use any desired program you already have available, such as the LED running-light display program from the first article in the ATM18 AVR board series (which can be downloaded free of charge from the Elektor website [5]). In any case, you only need the hex file, which is designated main.hex here. Use the following command to download the hex file to the flash memory of the microcontroller:

```
avrdude -p m88 -c avrispv2 -P usb -F -v -B 10
   -F -U flash:w:main.hex
```

The response from AVRdude (only the final part is printed here) is:

```
...

avrdude: AVR device initialized and ready to
   accept instructions

Reading | ##################################
   ############## | 100% 0.01s

avrdude: Device signature = 0x1e930a
avrdude: safemode: lfuse reads as FF
avrdude: safemode: hfuse reads as DF
avrdude: safemode: efuse reads as 1
avrdude: NOTE: FLASH memory has been specified,
   an erase cycle will be performed
          To disable this feature, specify the
   -D option.
avrdude: erasing chip
avrdude: reading input file "main.hex"
avrdude: input file main.hex auto detected as
   Intel Hex
avrdude: writing flash (146 bytes):

Writing | ##################################
   ############## | 100% 0.14s

avrdude: 146 bytes of flash written
avrdude: verifying flash memory against main.
   hex:
avrdude: load data flash data from input file
   main.hex:
avrdude: input file main.hex auto detected as
   Intel Hex
avrdude: input file main.hex contains 146 bytes
avrdude: reading on-chip flash data:

Reading | ##################################
   ############## | 100% 0.07s

avrdude: verifying ...
avrdude: 146 bytes of flash verified

avrdude: safemode: lfuse reads as 62
avrdude: safemode: hfuse reads as DF
avrdude: safemode: efuse reads as 1
avrdude: safemode: Fuses OK

avrdude done. Thank you.
```

Now the microcontroller has the new program code in its flash memory, and you can use the program.
Don't forget to connect the appropriate I/O pins of the microcontroller to the inputs of the ULN2003 on the ATM18 AVR board [5], so you can see the running-light pattern on the LEDs.

You need a different program for the Minimod18, since it doesn't have any LEDs on board (but it does have a display module). A program that outputs a simple message is adequate for testing.

As you can see, it's not that difficult to use the ATM18 AVR board or Minimod18 module with a Debian Linux distribution. If you use a different distribution, you will need to modify these instructions appropriately because program installation is slightly different and there are a few other differences in how things are done.

We conclude our instructions in the friendly spirit of AVRdude:

```
Elektor/cc2 done. Thank you!
```

Now you can start having fun with the ATM18 AVR board or Minimod18 in your Linux environment!

(100177-I)

Internet links

[1] www.atmel.com/dyn/products/tools_card_mcu.asp?tool_id=2725
[2] www.winehq.org
[3] www.elektor.com/080083
[4] http://frank.circleofcurrent.com/fusecalc/fusecalc.php
[5] www.elektor.com/071035
[6] http://avr8-burn-o-mat.aaabbb.de/
[7] http://sourceforge.net/projects/kontrollerlab/

DISTANCE LEARNING COURSE

Programming Embedded PIC Microcontrollers

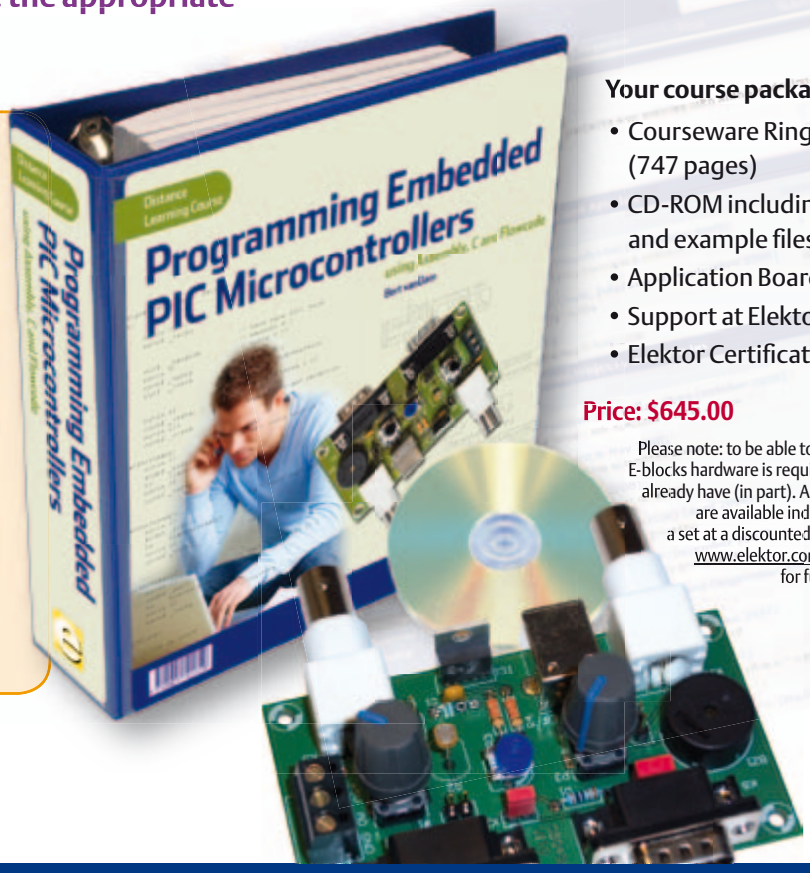
using Assembly, C and Flowcode

Including Elektor electronics worldwide Certificate

In this course you will learn how to program an embedded microcontroller. We will start with the absolute basics and we will go into a lot of detail. You cannot learn about software without understanding the hardware so we will also take a close look at the components and schematics. At the end of the course you will be able to design your own embedded applications and write the appropriate software for it.

Contents:

- Background
- Digital Ports
- Serial Communication (RS232)
- Analog Signals
- Pulse Width Modulation
- Timers/Counters/Interrupts
- Memory
- LCD Display
- I²C Communication
- SPI Communication
- USB Communication
- Configuration (Fuses)
- Answers to the assignments
- Appendix



Your course package:

- Courseware Ring Binder (747 pages)
- CD-ROM including software and example files
- Application Board
- Support at Elektor Forum
- Elektor Certificate

Price: $645.00

Please note: to be able to follow this course, E-blocks hardware is required which you may already have (in part). All relevant products are available individually but also as a set at a discounted price. Please check www.elektor.com/distancelearning for further information.

elektor ACADEMY
the school of electronics

Further information and ordering at

www.elektor.com/distancelearning



Power Line Communication & the Chip Issue

Will S-FSK win the 'format war'?

By Giacomo Cesari (Future Electronics, Italy)

If spread-spectrum frequency shift keying (S-FSK) becomes the dominant standard for smart meters, components implementing it will become commercially attractive to OEMs for any kind of PLC with a low data-rate requirement, for applications such as building automation and street lighting control. Here's a guide to implementing S-FSK technology in new modem designs, describing how System-on-Chip (SoC) devices address the challenges of the application. Chip hunters — enjoy!

While technology for implementing Power Line Communication (PLC) has been in existence for decades, it has not yet succeeded in becoming a mainstream application. This is not least because of the technical difficulty of transmitting data reliably over a medium that also carries high alternating currents.

Governments are responding to the threat of climate change by investing billions in the installation of smart energy meters, which promise to reduce power consumption and to improve the regulation of demand. The vision for smart meters, however, requires a means of communicating to and from a control centre, and the power line would appear to be a convenient medium for this. And so meter manufacturers and their utility company customers are now witnessing something like the 1980s' Betamax vs. VHS 'format war', as competing semiconductor suppliers push rival technologies for implementing meter networks, not only via PLC but also short-range radio, cellular radio and so on.

What makes S-FSK so popular?

Frequency band allocations across power lines differ from region to region of the world. In Europe, EN 50065-1 (published by CENELEC) specifies the frequency allocations from 3 kHz to 148.5 kHz, see **Table 1**.

In North America, FCC Part 15 defines a wider and less rigid spectrum allocation, across a range greater than 500 kHz.

In FSK modulation schemes, information is transferred to the Power Line in the form of two frequencies: f_s and f_m (where the index 's' (space) means 0, and 'm' (mark) means 1). FSK modulation has been used for many years, and in the past, when it was implemented in the analogue domain, it was neither cost-effective nor easy to set these two frequencies more than around 2 kHz apart. Consequently these systems were very vulnerable to noise: any other device connected to the power line that generated noise at the frequency of the signal — this could be as simple as a vacuum cleaner — could cause the communication channel between nodes to be dropped.

S-FSK is much less vulnerable to noise: this is because, in S-FSK, f_s and f_m are set typically 10 kHz apart. This development was possible because, in the digital domain, it is easy to generate these frequencies inside an IC. Because f_s and f_m are far apart, it is extremely unlikely that noise will swamp both frequencies simultaneously.

The latest S-FSK ICs from ON Semiconductor and STMicroelectronics are also able to switch back to amplitude modulation to keep the channel open in case extremely high noise levels make frequency modulation impossible.

So noise at one of the frequencies might reduce the effective data rate, but the communication channel stays alive. This means that the S-FSK modulation scheme offers very high reliability — a vital characteristic for smart meter applications, which transmit mission-critical usage data.

The S-FSK technique is supported by industry collectively: IEC 61334 is a set of standards, aimed primarily at Smart Meter applications, which implements S-FSK. Large-scale deployments are now start-

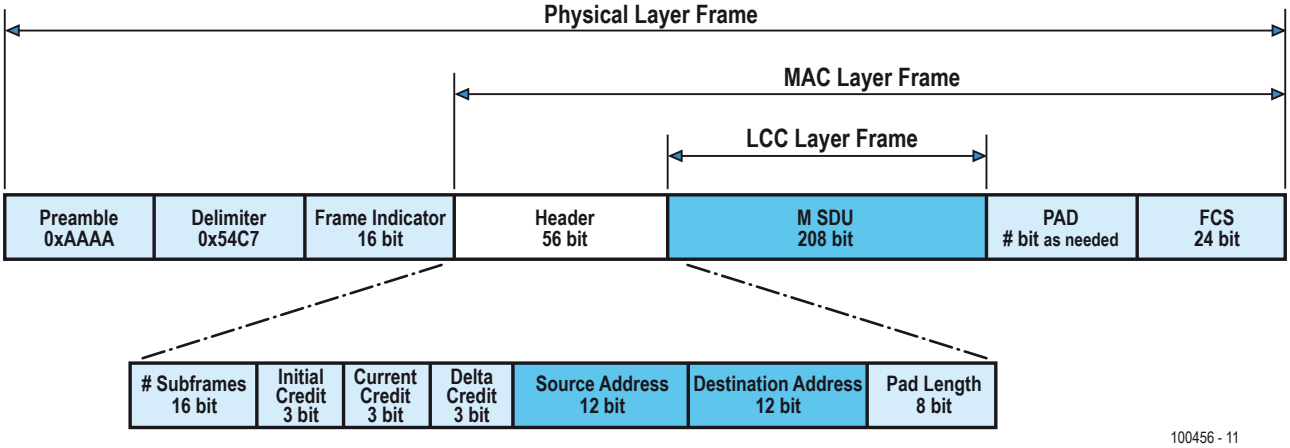


Figure. 1. Standard power line data frame structure (IEC61334-5-1).

ing to happen: France, for instance, has begun a very large smart meter deployment that uses S-FSK. But other countries are waiting for regulatory bodies to define other standards before they make a decision on which technology to implement.
Indeed, while S-FSK provides a low data rate (up to 2400 bits/s), other modulation schemes promise higher rates. Some of these (for instance OFDM and DSSS), are being tested or even, in the case of the Differential Code Shift Keying (DCSK) technique developed by IC manufacturer Yitran, being deployed (in Spain).
But for smart meters, S-FSK is definitely the front runner because of its proven reliability in the field. This means that integrated devices supporting the technique are becoming available in volume and at competitive prices. This in turn could spur a wider range of applications to adopt S-FSK.
What, then, are the main challenges facing the designer of a PLC modem that implements S-FSK? And to what extent do today's SoCs deliver a complete solution? Let's begin by understanding the principal functions of a power line modem.

Basic architecture of a power line modem

A PLC modem's architecture typically consists of three blocks:

- Analogue Front End (AFE), comprising a coupling device, filters and a power stage
- Physical layer (PHY)
- Protocol

The physical layer incorporates a system for FSK modulation, filters and an amplifier.
The protocol layer is the means by which communication between multiple nodes is managed. The protocol is responsible for safely transferring information between two or more nodes, managing the payload by encrypting it (if needed — this is not required in all cases), and generating the correct formatting for the frame to transmit properly. **Figure 1** shows a standard PLC frame format, as defined by IEC 61334-5-1.
Whatever the frame format used, the protocol layer provides the following functions:

- Acknowledgement-based signalling, with the capability to retransmit lost packets
- CRC error detection to test the integrity of received data
- Carrier Sense Multiple Access (CSMA) capability using the BIU (Band In Use) detector to check if the line is in use — a means of collision-avoidance.
- Addressing
- Encrypting of data for transmission
- Full control over the following transmission parameters:
  - Acknowledged
  - Unacknowledged
  - Repeated transmit
  - Sequence numbering

Extent of integration in today's modem ICs

Early moves by semiconductor manufacturers to satisfy demand for S-FSK devices failed to provide completely integrated solutions, or left a significant amount of software implementation to the OEM designer. A popular reference design for S-FSK modems, DRM035, was released by the then Motorola Semiconductor in 2003, based on the 56F801 digital signal controller. Still marketed by Freescale Semiconductor today, the reference design can be used as a blueprint for the design engineer to develop their own solution.
But this approach of implementing modulation and protocol layer functions in software left the design engineer to implement the AFE discretely — a tricky task. PLC systems connected to the AC grid must, at least in Europe, comply with the following standards:

- Powerline signalling (EN50065-1:2001, FCC Part 15)
- Powerline immunity (EN50065-2-1:2003, EN61000-3-2/3)
- Safety (EN60950)

How to couple a PLC system to the grid

Generally speaking, a coupling network (capacitor and transformer) is the means by which signals are injected (or received) onto (or from) the AC power line ('mains'). One side of the transformer is driven by the output stage of the PLC modem's amplifier.
The role of the capacitor is to reject the grid's 50 Hz (60 Hz) voltage; it also provides impedance to make the connection of the two voltage sources (AC grid and power line signalling) in parallel.
The power amplifier driving the transformer can be implemented in two ways: with discrete transistors integrated inside an S-FSK IC (as in the ST7570); or in the form of a dedicated IC (such as the

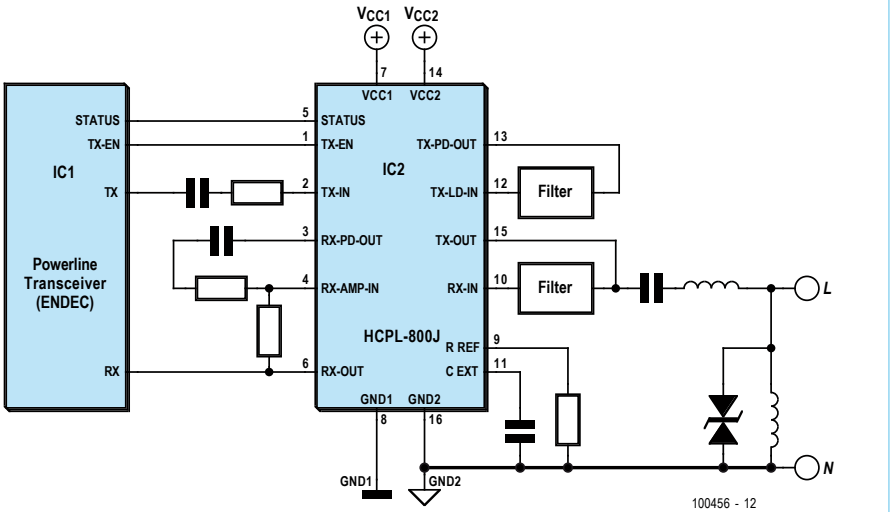


Figure 2. Block diagram of PLC modem AFE using the Avago HCPL-800J.

AMIS-49587). An integrated power amplifier offers a very compact design, but it might in some instances restrict range, and be limited in its temperature tolerance. This could occur, for example, if the impedance at the power amplifier is very low.
For applications that require galvanic isolation, Avago Technologies has introduced the HCPL-800J coupling IC. As shown in **Figure 2**, the isolated output stage can directly drive a coupling network made of a capacitor and inductor.
Coupling to the power line is not the only problematic area of the AFE — the band pass filter is also important. Before designing a suitable filter, it is necessary to consider in which region of the world the modem is to be operated. In Europe, the EN50065 spurious emission limit curve governs the maximum level of all harmonics for all frequencies in the range from 10 kHz to 148 kHz. For example, if a modem transmits on a carrier frequency of 120 kHz, it is necessary to ensure that the second and third harmonics are at a level below 62 dBµV and 58 dBµV respectively.
The situation in the US is different: here, regulations do not specifically limit all harmonics, but rather limit only the harmonic levels at frequencies greater than 500 kHz. This means that if the same 120 kHz modem is to be used in the US, only out-of-band harmonics greater than the fourth order are of concern. Also there is a limit in the amplitude of the output signal of 122 dBµV.

Today's integrated solutions

The latest semiconductor product introductions for S-FSK modems are far more integrated than the Freescale reference design mentioned above — in fact, they are best described as S-FSK modem systems-on-chip. The AMIS-49587 from ON Semiconductor, released in its latest version in December 2009, implements the physical interface (PHY) in mixed-signal hardware blocks and the Media Access Control (MAC) and protocol layer on an embedded firmware ROM. The firmware runs on an embedded ARM7 core. The device can communicate with an applications processor via Serial Communications Interface (SCI).

By eliminating the need for the system designer to develop the protocol layer, ON Semiconductor greatly accelerates the end product development process — at an applications level, the system just needs to feed raw data to the AMIS-49587 over the SCI, and the SoC handles all the processing and transmission of the data.
The intention of STMicroelectronics' S-FSK SoC, the ST7570, is similar. It is a complete implementation of an S-FSK modem, including the whole AFE. Its architecture is slightly different from the AMIS-49587: the ST7570 performs modulation through turnkey firmware running on a DSP core; it uses an embedded 8051 controller core to implement the protocol layer's PHY and MAC.

These new devices – the ST7570 is about to come out of the 'sampling' phase — illustrate the level of integration that has just become available to designers of S-FSK modems. The main challenge in designing PLC networking gear has therefore now shifted from implementing the communications — this job is now done by SoCs — to value-added functions, such as the user interface, and appliance monitoring and control capabilities.

Perhaps this availability of turnkey IC designs, from multiple IC manufacturers that are big enough to support high-volume production, will do more than anything to drive the market towards the S-FSK as the modulation technique of choice for power line communications. The decisive blow in the PLC modulation 'format wars' might already have been landed.

(100456)

Table 1. Frequency band allocations under EN 50065-1.

Band name	Frequency range	Usage
Band A	3 kHz – 95 kHz	For utility companies only
Band B	95 kHz – 125 kHz	Applications without an access protocol
Band C	125 kHz – 140 kHz	Applications with an access protocol
Band D	140 kHz – 148 kHz	Alarm and security applications with no access protocol

8th International System-on-Chip (SoC) Conference, Exhibit & Workshops

November 3 & 4, 2010 – Hilton Irvine/Orange County Airport

www.SoCconference.com

The Most Educational, Targeted, and Affordably Priced Chip Design Conference of the Year!

Gold Sponsors

- Keynote Speeches
- Technology Presentations
- Informative Panels
- Technical Workshops
- Many Door Prizes

- Table-Top Exhibit (Free Passes)
- IEEE-OC Job Fair
- Networking Opportunities
- IEEE-OC Student Design Contest
- And Much More. . .

Keynote Speakers



Mindspeed Technologies, Inc.
Raouf Y. Halim
Chief Executive Officer (CEO)



Xilinx Inc.
Dr. Ivo Bolsens
Senior Vice President and
Chief Technology Officer (CTO)



IBM
Dr. J. Antonio Carballo
WW Manager, IBM Microelectronics
IBM VC Group

Selected Participating Companies, Universities & Organizations

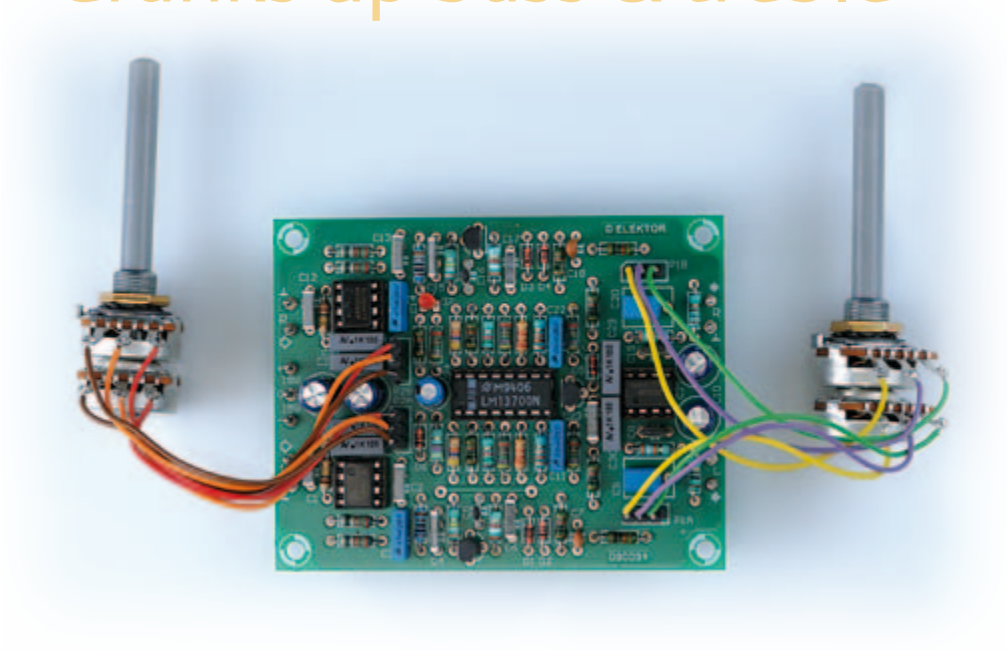
Technology & Media Sponsors

For More Information or Questions, Please Contact: SoC@SoCconference.com or (949) 851–1714

www.SavantCompany.com & www.SoCconference.com

Booster for Audio Signals

Cranks up bass & treble



By Markus Aebi (Switzerland)

Dull and washed-out sound? With modern recording technologies this is unlikely to happen.
There are nevertheless situations where a fuller sound would do no harm (live bands, for example, but cheap headphones could also benefit). A small amount of 'effect' could make the sound experience just 'perfect'.

Weak bass and dull treble frequencies are things of the past with this circuit. The ingenious principle of the project described here makes the reproduction more delicate, fuller and subjectively louder. The circuit was originally intended to be built into a mixing desk (immediately before the Master Fader), but works just as well as a stand-alone device when the input and output voltages are adjusted appropriately (about 1.5 V_p/0 dB at the first op amp).

The principle

The high and low frequencies are processed independently of each other. The left and right channels are identical, with the exception of the part of the circuit controlling the amplification of the low frequencies, which is used for both channels and therefore does not need to be implemented twice (see **Figure 1**).
After the high-pass filter with C4 (C15 for the right channel) the high frequencies are amplified 'quick and dirty' with the circuitry around T1 (T2). The diode pair D1, D2 (D3, D4) generates higher harmonics which are added to the original signal with potentiometer P1A (P1B). This makes it sound 'fresher'.
The low frequencies are separated from the original signal with the network around IC1B (IC2B) and subsequently passed on to the current-controlled operational transconductance amplifier (OTA), which is configured as a VCA here (Voltage Controlled Amplifier, IC4A and IC4B respectively). The 'Dynabass' potentiometer P2A (P2B) determines how much of the original signal is processed. RC network R16/C11 acts as a variable low-pass filter (and also has a variable phase shift with respect to the original signal, which results in a subjective amplification of the low frequencies). The values of the RC pair affect the tuning of the filter. The selected resistor of 33 kΩ in combination with a capacitor of 22 nF gives optimum tuning.
The control current of the VCA, which determines the gain of this IC, is generated with the circuit around T3. This circuit works as a kind of limiter circuit (quasi limiter function) and shows via LED D7 how much 'control' is applied. The processed signal is added to the signal immediately after the 'Harmonics'-potentiometer (P1A and P1B respectively).
When both potentiometers are set to their minimum positions the signal passes through unchanged.
An external symmetrical power supply of ±15 V completes the story. The current consumption at this voltage is about 40 mA for the positive supply rail and 35 mA for the negative supply rail. Each IC is provided with decoupling capacitors and the PCB is fitted with additional 100 µF buffer electrolytics.

Construction

When assembling the PCB you follow the traditional procedure: first the 'small' parts such as resistors and diodes, then the 'bigger' parts such as capacitors and transistors. We used sockets for the ICs so that swapping the op amps for a different sound is very easy. The construction is not all that difficult because no SMD components are used.
In our prototype we chose to use headers and sockets for the connections to the two double potentiometers. These are mentioned in the parts list. It is, of course, also possible to omit those headers and connect the potentiometers directly to the board using short wires.
The double-sided PCB has been made as compact as possible (88 × 69 mm) and has not been designed with a specific enclosure in mind (see **Figure 2**). The PCB layout can be downloaded from the project page [1].

Measurements

The two graphs summarize how the circuit influences the signal. The graph in **Figure 3** shows the amplitude characteristic of the low-pass filter. This shows that the

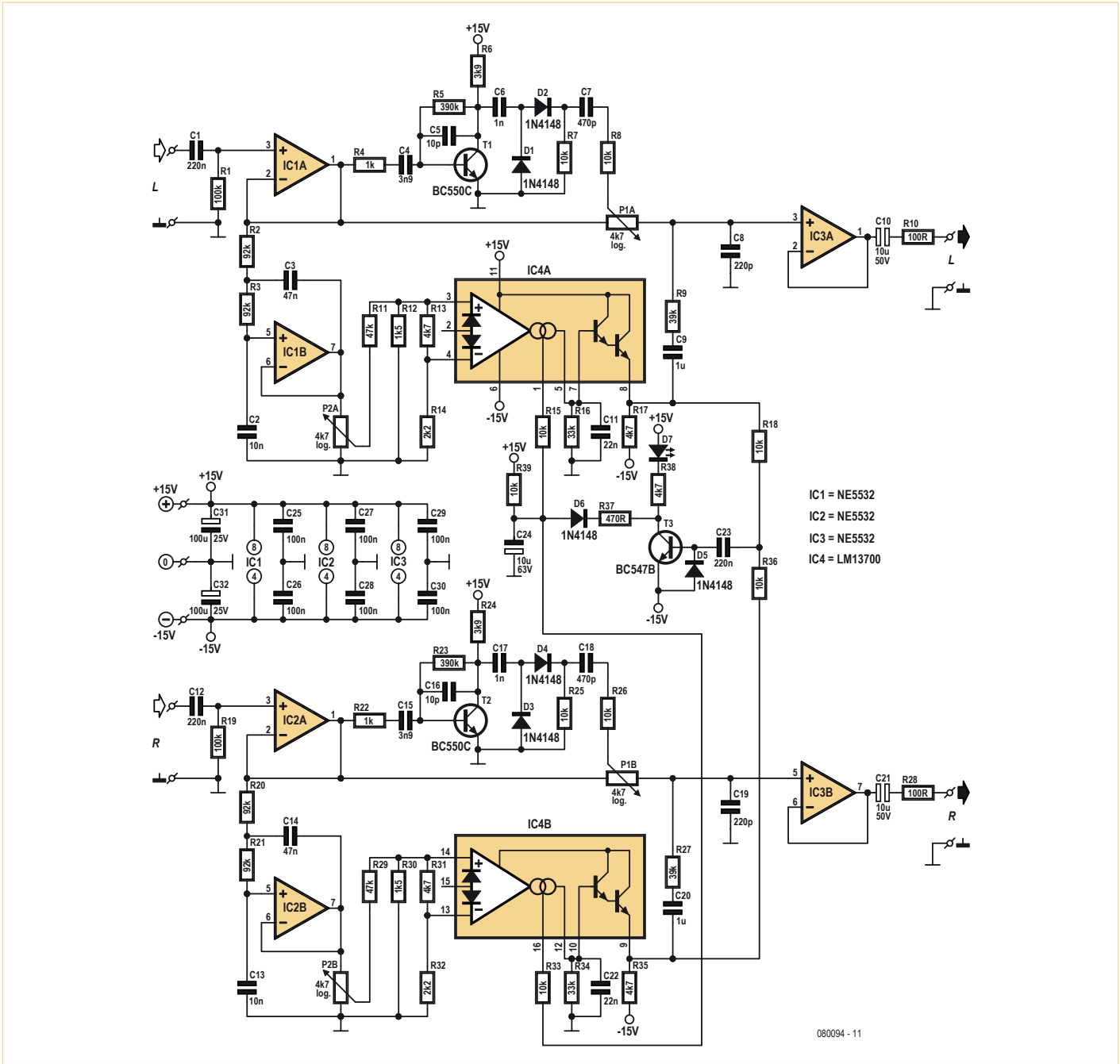


Figure 1. The schematic may strike as quite sizeable, but the dimensions of the PCB are very reasonable.

low-frequency part of the circuit operates below about 100 Hz. At the high-frequency end the circuit operates from around 5 kHz, based on the clipping of T1 (T2).

The second curve (**Figure 4**) shows the ratio between the amplitudes of the input and output signals of the VCA (green curve), measured at pin 9 of IC4. It shows that the curve is linear up to about –10 dB, after which compression occurs. The effect of this is that the low frequencies are accentuated a bit more and the entire sound sounds fuller.

The same graph also shows the distortion of the output signal at 60 Hz and 1 V input

COMPONENT LIST

Resistors

R1,R19 = 100kΩ
R2,R3,R20,R21 = 92kΩ
R4,R22 = 1kΩ
R5,R23 = 390kΩ
R6,R24 = 3.9kΩ
R7,R8,R15,R18,R25,R26,R33,R36,R39 = 10kΩ
R9,R27 = 39kΩ
R10,R28 = 100Ω
R11,R29 = 47kΩ
R12,R30 = 1.5kΩ
R13,R17,R31,R35,R38 = 4.7kΩ
R14,R32 = 2.2kΩ
R16,R34 = 33kΩ
R37 = 470Ω
P1,P2 = 4.7kΩ logarithmic, stereo

Capacitors

C1,C12,C23 = 220nF, lead pitch 5 or 7.5mm
C2,C13 = 10nF, lead pitch 5 or 7.5mm
C3,C14 = 47nF, lead pitch 5 or 7.5mm
C4,C15 = 3.9nF, lead pitch 5 or 7.5mm
C5,C16 = 10pF, ceramic, lead pitch 5mm
C6,C17 = 1nF, lead pitch 5 or 7.5 mm
C7,C18 = 470pF, ceramic, lead pitch 5mm
C8,C19 = 220pF ceramic, lead pitch 5mm
C9,C20 = 1µF, lead pitch 5 or 7.5mm
C10,C21 = 10µF 50V, radial, bipolar, lead pitch 2.5mm, diam. 8.5mm max.
C11,C22 = 22nF, lead pitch 5 or 7.5mm
C24 = 10µF 63V, radial, lead pitch 2.5mm, diam. 6.3mm max.
C25–C30 = 100nF, lead pitch 5 or 7.5mm
C31,C32 = 100µF 25V, radial, lead pitch 2.5mm, diam. 8.5 mm max.

Semiconductors

D1–D6 = 1N4148
D7 = low current LED, red, 3mm
T1,T2 = BC550C
T3 = BC547B
IC1,IC2,IC3 = NE5532, 8-DIP case
IC4 = LM13700 16-dip (e.g. Farnell # 1651866)

Miscellaneous

11 pcs PCB solder pin
4 pcs 3-way pinheader (P1,P2)
4 pcs 3-pway socket
PCB, # 080094-1 see [1]

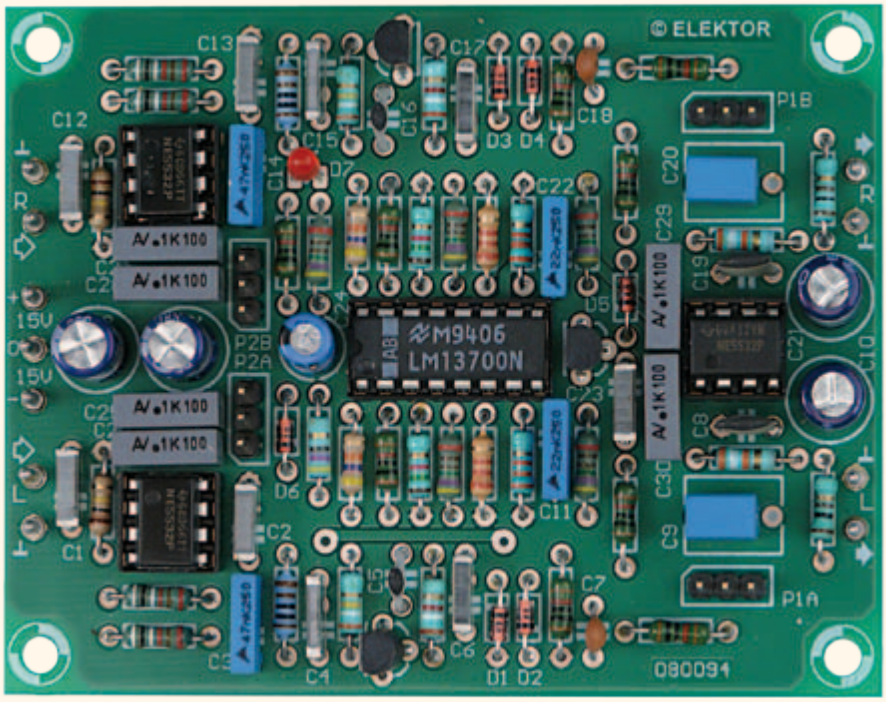


Figure 2. The components are quite close so the circuit will fit on a compact PCB.

voltage, measured at pin 9 of IC4 (blue). The –10 dB value is also represented in this curve, with the difference that the distortion increases exponentially from that point onwards (this makes sense because the signal is compressed above that value).

This is naturally not a circuit of particular interest for audiophiles. But they probably only use flawless signal sources. For everyone else who would like their sound to be fresher and livelier this booster circuit is a good alternative to an equalizer.

(080094-I)

Internet Link

[1] www.elektor-usa.com/080094

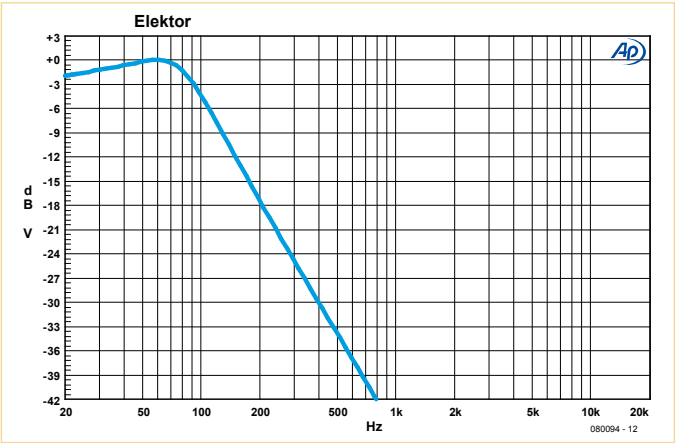


Figure 3. This clearly shows the frequency range of the low frequency part of the circuit.

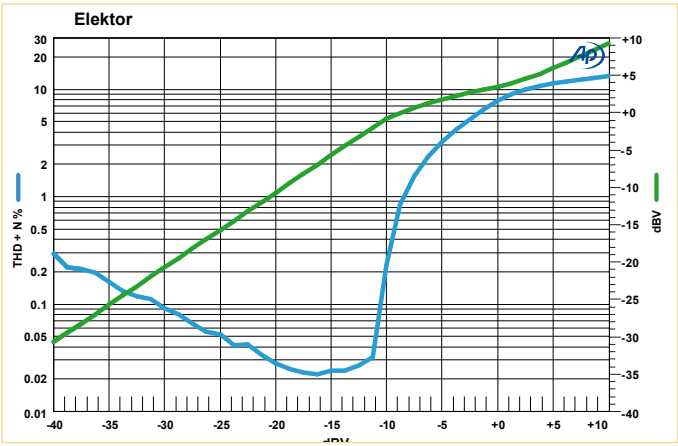


Figure 4. The gain and distortion of the low frequencies depends on the input voltage.

Subscribe to Circuit Cellar now!



This magazine has a topic that keeps me busy on making prototype projects, advances in electronic design ideas, & always wondering what would be the next. For me, being informed in my field of expertise, it really adds confidence in my career.

R. Arcilla,
Celestica Philippines, Inc.

Circuit Cellar Magazine

- Influencing the design and production of embedded hardware and software systems by providing in-depth articles & highly technical content since 1988.

- Enabling readers to make intelligent assessments and decisions in real-world project development scenarios when informed decisions are required.

- Delivering thousands of samples to engineers through global sampling and contest programs.





Sign up today and save up to 66% off the cover price!

Digital 2.0 for just $38

CC 2.0: Enhanced Subscription Services Give You More!

- Quickly link to code and project files
- Search the CC Library by author, title or topic
- Receive exclusive specials and "deals" from preferred vendors
- Access Circuit Cellar's contest archives for inspiration and abstracts from recent design contests

Visit www.CC-Access.com today to sign up for your preferred delivery method: Print, Digital or Combo 2.0! Every option provides exclusive entry to CC-Access and the incredible subscriber benefits listed above.

Take out your 2.0 subscription now: www.CC-Access.com

Phone 860.875.2199

CIRCUIT CELLAR
CC-ACCESS
SUBSCRIBERS RESERVED AREA

www.circuitcellar.com

CIRCUIT CELLAR®



Accidents Happen

By Gerard Fonte (USA)

About a year ago I had an accident and had to have six stitches (staples actually) to put my head back together (yes, they also took an X-ray and didn't find anything). If I hadn't lost my balance, I wouldn't have grabbed the ladder. If the ladder was still part of the scaffolding structure, it wouldn't have moved. If my house wasn't a geodesic dome, the ladder top wouldn't have moved past a bend. If the ladder top didn't move past a bend, it would have stayed in contact with the house. If the ladder top stayed in contact with the house, the 2 x 4 wooden spacer (to keep the side of the ladder from rubbing against the house), wouldn't have fallen. If I hadn't been exactly under that point, the wood would have missed me. If I hadn't been working in a tight space, I would have had my big straw hat on. If I had my big straw hat on, I probably wouldn't have been cut.

The point of all of this is to show two things. The first is that accidents will find a way. Nothing is perfectly safe. Don't believe anyone who says there is "no danger". Risk is everywhere. Simply being alive is hazardous. (Frankly, if you're dead, there's much less to worry about.) However, it's important to also realize most risks are very small. Being 'safe' means keeping the probably of an accident at a very low level.

The second point is related. 'Safe' situations usually require multiple things to happen to create a un-safe situation. This is seen regularly by accident investigators. They often describe a 'chain of events' that results in something bad. It's very rarely just one thing that goes wrong.

Accidents waiting to happen

Now compare that with inherently dangerous situations. This is when everything must work perfectly or else there's an 'accident'. Unfortunately, this is a fairly common situation, too. The big difference is that someone is not thinking. Or, doesn't think the accident will happen to them (which actually seems to be the same thing). The classic example is driving while impaired. Note that texting while driving actually impairs your driving ability worse than being drunk. Then there is the guy I saw while I was driving on a busy highway (with a speed limit of 55 mph) who was texting while on a bicycle! No hands, head down, oblivious to everything! I have no doubt that he thought he was safe.

And that's the problem that I'm trying to address here. Being safe and thinking you're safe are two entirely different things. Sometimes it's not evident which is which. Working with electricity, motorized tools, molten solder, sharp tools, and all the rest makes engineering inherently dangerous. And while it's not as life-threatening as being a lumberjack, there are still many ways for your hobby to bite you. But by adding some foresight, it's possible to pull it's teeth.

Running a ground

Probably the most dangerous part of electronics is working with 120 VAC. First note that this is 120 volts RMS. The peak voltage is 170 volts from ground which equates to 340 volts peak-to-peak. With a typical 15 amp circuit breaker, 1.8 continuous kilowatts are present. (Much more than that during instantaneous short-circuits.)

Always remember that uncontrolled AC and ground don't mix. Especially don't mix them through you.

An anti-static wrist-strap to ground is often recommended when working with static sensitive components. If you use one, be absolutely positive that it has a 1 megohm (or greater) series resistance. Otherwise it can be deadly. Without the resistor it connects you directly to ground. Also be sure the resistor is at the wrist-strap. Otherwise the wire could short out against a metal chassis and the resistor wouldn't protect you.

Always unplug the device you're working on (and discharge the capacitors) before replacing parts. This is supposed to be common sense. The danger comes from your soldering iron. Nowadays, the tips of the irons are often grounded. Would you normally think about poking around a live chassis with big ground probe?

Modern equipment often has 'off-line' power supplies. This means that there is no power transformer to isolate the AC (at least for the initial stage).It also means that the 'ground' of this power supply is probably not really 'ground'.I f you connect your oscilloscope ground to the chassis, you'll get strange measurements. If you connect your oscilloscope ground clip to the power supply 'ground', you may get 1.8 kilowatts where you least expect it. Be extremely careful with these power supplies. Always, that's ALWAYS, have the schematic and understand exactly what you are doing. If you aren't sure, don't try! An isolation transformer is a good investment.

Drill baby, drill

The next-most accident prone tool seems to be the electric drill. Most of these problems come from stupidity rather than ignorance. It's not a good idea to drill a board while it's in your lap.(Duh!) Nor should you drill something while holding it in your hand. Apart from drilling your finger, the bit can bind and the cause the work-piece to spin. Having a piece of sharp metal (or even a PC board) spinning in your hand can easily lead to many stitches at the emergency room.

Another common mistake is drilling blindly into a wall. There are many things in a wall you can't see: electrical wires, water pipes and sewer stacks. None of these appreciate being punctured and respond in unfortunate ways. Always know where you are sticking your bit.

A drill-press can be nasty, too. It's easy to get your face close while drilling; to make sure the hole is precise. While you're so close, it's also easy to catch a metal or plastic chip in your eye. Unless you're wearing safety glasses.

Never store the chuck-key in the chuck. Yes it's a convenient spot, but when someone turns it on without realizing it, the key flies away. If you're lucky, you only have to spend an hour searching for it. A simple solution is to put a magnet on top of the drill-press and stick the key to that.

Being safe means thinking about what you are doing and anticipating what can go wrong.You can never be perfectly safe but you can easily be accident prone.

(100650)

GIGANTIC!



The Elektor PLUS subscription

Keep $65.80 in your pocket!

+



Elektor PLUS advantages

- Cheaper than 11 issues from the newsstand: **Save 57%** off the cover price of $92.45
- $13.30 discount on the Annual DVD-ROM 2010
- With every issue subscribers get up to **40% discount** on selected Elektor products
- No lines, travelling, parking fees or "sold out"; Elektor is mailed to you every month
- Always up to date – read your copy before everyone else

* Offer available in US and Canada only. Canada add $11 per year.

You save:	Subscription PLUS
$79.50	10 Magazines
+ $12.95	1 Double Issue (July/August)
+ $28.30	Annual DVD-ROM 2010
= $120.75	**Total value of individual items**
– $54.95	**Elektor annual subscription PLUS***
= $65.80	**Your saving**

www.elektor.com/subs · Phone 860-875-2199

Or use the subscription order form near the end of the magazine.

elektor

80 Candles for the Pentode



Figure 1. Eighty years back in time. Left to right: tubes type RES164, 34, EF97 and 1j18b.

By Andre Adrian, DL1ADR (Germany)

The first transistor radio was called Regency TR-1 and appeared on the market in 1954, at a time when radios with vacuum tubes had been around for decades. One of the most successful tubes is the pentode, a vacuum electron tube with five (Greek: pente) electrodes. A famous early pentode was the 'RCA-34' (UX-234), it reached commercial use in the early 1930s and was announced as a 'Super-Control R-F Amplifier Pentode'.
To celebrate the Pentode's 80th birthday this article in the Retronics series describes the construction of a shortwave radio for the

build a shortwave radio based on the '34' pentode

49 m and 41 m broadcast bands, based on the '34' pentode or later types. With only one tube and a 5 foot wire antenna, reasonable reception at headphone volume levels is within reach. Depending on the tube used, the anode voltage is a safe 6 to 45 volts supplied by batteries. The radio can be built in 'classic' fashion using a flat coil and variable capacitor, or in modern guise using a ferrite core and a variable capacitance diode. The successor to the pentode, the field effect transistor (FET), can also be used, although its higher gain will make tuning the radio a real achievement.

In the beginning: tungsten

The hot tungsten filament of an incandescent lamp emits electrons. This was observed by Thomas Alva Edison in 1883 as he installed an electrode next to a filament in the bulb. In vacuum, a current flows between filament and anode. In the course of the years more electrodes were 'inserted' between filament and anode. Beside the cathode and anode, the pentode has a control grid, a screen grid and a suppressor grid. The control grid can be said to correspond to the gate of a FET. The screen grid is usually connected to the positive supply rail and the suppressor grid is tied to the negative terminal of the anode battery.
The '34' pentode has a barium oxide coated filament. The filament requires 2 V at about 60 mA. The resulting 120 milliwatts cause the filament to heat up to 800 °C and to glow nearly invisibly. The Russian subminiature pentode type 1Ж18Б (1j18b) requires even less heating power: 1.2 V at 24 mA.
In **Figure 1** you see pictured, left to right: type RES164 pentode (ca. 1928), type 34 pentode (ca. 1930), miniature pentode type EF97 (1957), and a subminiature pentode type 1Ж18Б. The (spectacularly) low-voltage type EF97 can work with just 6 volts on its 'plate'.

Basic operation of the Audion

An Audion consists of an LC resonant circuit for setting the reception frequency, and an amplifier. To enable very high gain to be achieved, part of the amplified RF signal is fed back to the input. Consequently the Audion operates as an amplifier on the verge of self-oscillation. The radio frequency is amplified and demodulated simultaneously. Amplitude demodulation is achieved by the different response of the control grid to negative and positive voltages. The rectifier in the tube between control grid and filament is conductive for positive voltages, but not for negative voltages. A 'grid leak' network of 1 MΩ in parallel with a capacitor of 68 pF at the control grid supports the grid rectifier.

A simplified Audion radio

Changes in the feedback cause changes in frequency. To keep this effect within limits, a radio ham called F.H. Schnell in the 1920s added an adjustable attenuator element in parallel with the feedback winding. In the simple circuit shown in **Figure 2**, all components determining the receiving frequency and feedback are connected to ground (earth) at a single point. The LC resonant circuit consists of variable capacitor C1 and a section of coil L1. The antenna and the control grid are connected to a tap on the resonant circuit.
Coils L1A and L1B work as an autotransformer and adapt the low AC resistance of the antenna and control grid to the high-impedance resonant circuit. The feedback is via C2 onto feedback winding L1C with its parallel connected attenuator in the form of potentiometer R1, which acts as the feedback control. L1C forms a second autotransformer with the rest of L1. With the center of L1 grounded, a phase shift of 180 degrees is established between the feedback winding and the resonant circuit. The desired positive feedback is obtained in conjunction with the phase shift of the amplifier.
High-frequency choke L2 separates the RF part of the Audion from the AF part. Every inductor has stray parallel capacitance — invisible but always present! For the RF choke we have about 10 pF. The stray capacitance of the primary winding of output transformer Tr1 is much higher. Without L2, it would effectively short-circuit the high frequency signal.

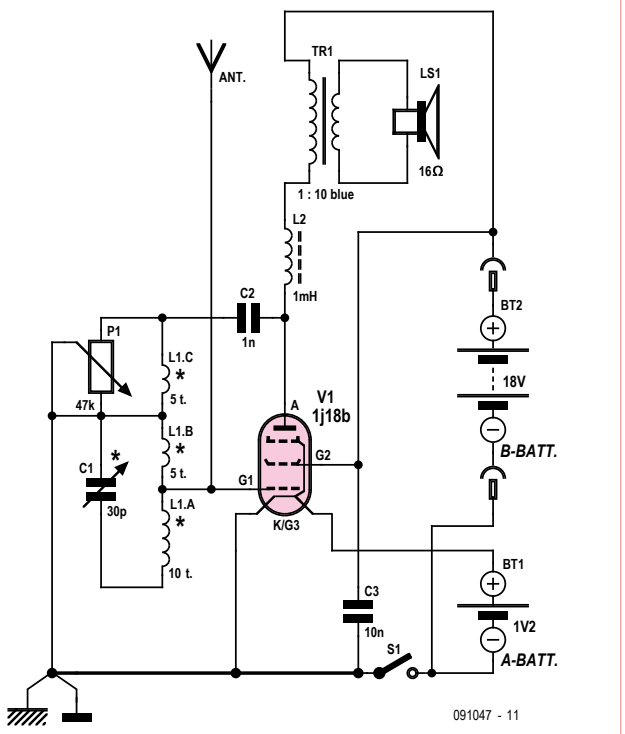


Figure 2. Schematic of the simplified Audion '2010 style'.

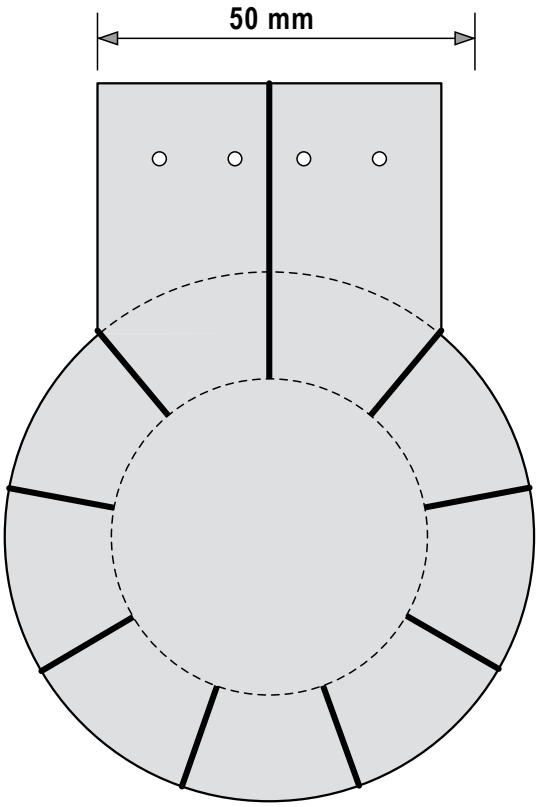


Figure 4. Template for the 41-mm holder for the spider web coil in the radio. US readers, please enlarge to obtain correct scale.

Output transformer Tr1 matches the high AC resistance of the tube to the low impedance of the Walkman-style headphones. The two 32 Ω earpieces are connected in parallel.
The 'A' battery supplies heater power to the tube, the 'B' battery, the anode (plate) voltage. An AA size NiMH battery is just fine as a correct filament power source. The anode battery consists of two series-connected 9 V batteries. Current consumption amounts to 24 mA from the A battery, and 2 mA from the B battery.
Capacitor C3 short circuits any RF signal at the screen grid. The secondary of Tr1 is intentionally not grounded. The front panel should consist of a grounded metal plate, or at least have some kind of metal foil (grounded, of course) on the inside. The antenna connector should be located at the rear of the enclosure. All these measures reduce the sensitivity of the circuit against the dreaded 'hand effect' — if the radio operator's hand is in the vicinity of the radio, the resonant circuit is detuned.
The length of the antenna should be limited to 1.5 m (5 ft.). A longer antenna is possible and allows you to pick up more stations but only if connected via a small capacitor of 4.7 pF to 33 pF. A proper antenna earth connection is essential to good reception. The GND connection of the circuit should be connected to conductive heating pipe.
Potentiometer R1 also adjusts the volume. If you turn it up too far you will hear a howling sound. Your Audion then works as a transmitter and may cause interference on other receivers. Remember, the Audion is a **regenerative** radio!

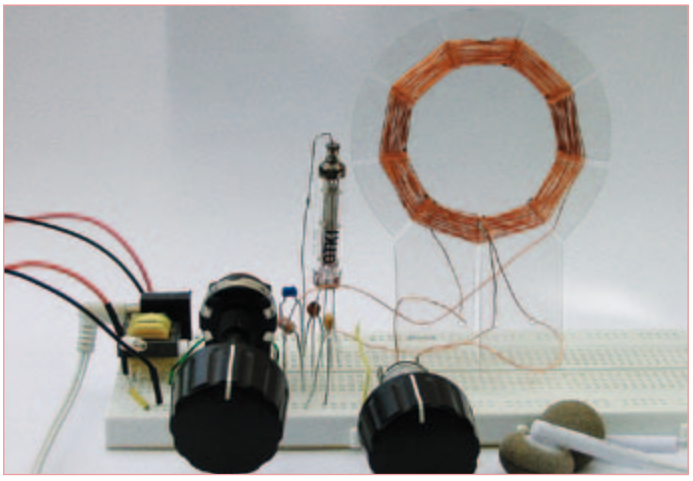


Figure 3. The author's simplified Audion constructed on breadboard.

Practicalities

The parts list of the proposed receiver is given in the **inset**.
The picture of the breadboarded prototype in **Figure 3** shows the

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

Audion Parts List

C1 = 35pF tuning capacitor with reduction gear (vernier), or Philips 'beehive' style

C2 = 1nF ceramic multilayer capacitor

C3 = 10nF ceramic multilayer capacitor

L1 = spider web coil 10+5+5 turns 0.3 mm (AWG #28) enameled copper wire.

L2 = 1mH choke (Fastron SMCC)

R1 = 47kΩ potentiometer, linear

S1 = SPST on/of switch

Tr1 = 1:10 miniature AF transformer, color code: blue

V1 = 1j18b tube (NOS on Ebay)

3.5mm stereo jack socket

Battery holder for one 1.5V AA cell

Clip-on leads for 9 V 6LR22 batteries

beehive trimmer, the tube, the potentiometer, the output transformer next to the jack socket and the earphones. The spider web coil is visible in the rear.

The spider web coil support consists of 0.4 mm thick transparent PE plastic which is sold as sheets in the stationery trade (anyone remember late afternoon Powerpoint presentations using overhead projectors?). The template shown in **Figure 4** is placed under the film and its outline is copied onto the sheet with a CD marker pen. The shape can be cut out using heavy duty paper scissors. To allow the slots to be cut easily 3 mm (1/8 inch) holes are drilled at the ends. For the complete winding you'll need approximately 11 feet of AWG #28 enamelled copper wire, plus two pieces of about 4 inches for the taps. The wire should be wound tightly onto the former. After 10 turns, a wire loop is bent. Before you continue winding, solder the wire loop to the connection wire. The second tap is after another five turns.

For more on tube radios, visit the author's website [1].

(091047)

Internet Link

www.andreadrian.de/sdr/ (in German)

Advertisement

50 PIC Microcontroller projects

A laser alarm, USB teasing mouse, soundswitch and much more

This book contains 50 fun and exciting projects for PIC microcontrollers such as a laser alarm, USB teasing mouse, eggtimer, youth repellent, soundswitch, capacitive liquid level gauge, "finger in the water" sensor, guarding a room using a camera, mains light dimmer (110-240 volts), talking microcontroller and much more. Several different techniques are discussed such as relay, alternating current control including mains, I2C, SPI, RS232, USB, pulse width modulation, rotary encoder, interrupts, infrared, analog-digital conversion (and the other way around), 7-segment display and even CAN bus. It is also discussed how you can migrate your project from one microcontroller to another - 15 types are supported - including two example projects. Three PIC microcontrollers are used in this book, the 16f877A, 18f4455 and 18f4685.



NEW

440 pages • ISBN 978-0-905705-88-0 • $58.10

Elektor US
PO Box 180
Vernon, CT 06066
USA
Phone: 860-875-2199
Fax: 860-871-0411
E-mail: sales@elektor.com

elektor

Further information and ordering at www.elektor.com/shop

Hexadoku

Puzzle with an electronics touch

In this the Northern hemisphere leaves are starting to fall and temperatures have gradually dropped to levels where you might want to stay indoors. Ideal conditions we say for a new release of Elektor's famed & famous Hexadoku puzzle. Enter the right numbers in the puzzle, send the ones in the gray boxes to us and you automatically enter the prize draw for four Elektor Shop vouchers. Have fun!

The instructions for this puzzle are straightforward. Fully geared to electronics fans and programmers, the Hexadoku puzzle employs the hexadecimal range 0 through F. In the diagram composed of 16 × 16 boxes, enter numbers such that **all** hexadecimal numbers 0 through F (that's 0-9 and A-F) occur once only in each row, once in each column and in each of the 4×4 boxes (marked by the thicker black lines). A number of clues are given in the puzzle and these determine the start situation. Correct entries received enter a draw for a main prize and three lesser prizes. All you need to do is send us the numbers in the gray boxes.

Solve Hexadoku and win!

Correct solutions received from the entire Elektor readership automatically enter a prize draw for one Elektor Shop voucher worth $140.00* and three Elektor Shop Vouchers worth $70.00 each, which should encourage all Elektor readers to participate.

* subject to exchange rate.

Participate!

Before November 1, 2010, send your solution (the numbers in the gray boxes) by email, fax or post to

Elektor Hexadoku – 4 Park Street – Vernon CT 06066

USA.

Fax (860) 8751-0411 Email: hexadoku@elektor.com

Prize winners

The solution of the July/August 2010 Hexadocube is: **2975EF**.

The Scepter/Interscepter kit worth $400 was won by: Simon Lehmayr (Germany).

The $70.00 vouchers have been awarded to: Andy Wood (Australia), Per Troelsen (Denmark) and Jean-Claude Carré (France).

Congratulations everyone!

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

(c) PZZL.com

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

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

ELEKTOR SHOWCASE

To book your showcase space contact Strategic Media Marketing Inc.

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

HAMEG® Instruments
A Rohde&Schwarz Company

- ☑ Oscilloscopes
- ☑ Power Supplies
- ☑ Spectrum Analyzers
- ☑ RF Instruments
- ☑ Programmable Measuring Instruments

HAPRO Electronics
Tel: +1-516-794-4080
sales@haproelectronics.com
www.haproelectronics.com

7 in 1 Scope !



CircuitGear CGR-101™ is a unique new, low-cost PC-based instrument which provides the features of seven devices in one USB-powered compact box: 2-ch 10-bit 20MS/sec 2MHz oscilloscope, 2-ch spectrum-analyzer, 3MHz 8-bit arbitrary-waveform/standard-function generator with 8 digital I/O lines. It also functions as a Network Analyzer, a Noise Generator and a PWM Output source. What's more – its open-source software runs with Windows, Linux and Mac OS's! **Only $199**

Saelig.com
1-888-7SAELIG
info@saelig.com
www.saelig.com

EasyDAQ
Neat products, low cost, no frills

- USB powered, 4 relays + 4 DIO channels
- Will switch 120/240VAC @ 10amps
- Screw terminal access
- LV,CVI,VB-C,C#,JV
- Free shipping
- From $57*



Design & supply of USB, Wireless, LAN, Serial & Internet DAQ, Relay/DIO card products & custom design work
www.easydaq.biz
info@easydaq.biz

Build Your Own:
THEREMIN



Theremax
The Ultimate Theremin
paia.com
Makers since 1959
Music/Tutorials/Kits
Analog Synthesizers
Guitar Effects
Tube Electronics
Studio Gear

SCIENCE, ROBOTICS & ELECTRONICS
IMAGES Scientific Instruments Inc.
Microcontrollers
Servo Motor Controllers
Artificial Vision
Speech Recognition
Flex Sensors
www.imagesco.com
Tele: (718) 966-3694 Fax: (718) 966-3695

MaxSonar
Ultrasonic Ranging is EZ



www.maxbotix.com

Pololu
Robotics & Electronics
Save 10% on motor controllers with coupon code ELEKTORMC94
Robot chassis, wheels, casters, motors & servos
$49.95
Jrk USB motor controller with feedback
RP5 chassis $49.95
Controllers, sensors, cables, batteries & more!
Plastic SMT stencils & custom laser cutting
www.pololu.com

bob-4
basic overlay board for NTSC & PAL



NEW REDUCED PRICING
Automatic text scroll & crawl · 'TTL-232' & SPI control ports
Any size for custom fonts · Vector & bitmap graphics
DECADE ENGINEERING
www.decadenet.com

AP CIRCUITS
PCB Fabrication Since 1984
As low as... $9.95 each!
Two Boards
Two Layers
Two Masks
One Legend
Unmasked boards ship next day!
www.apcircuits.com
VISA MasterCard IPC MEMBER

www.elektor.com



Microcontroller modules
Communications modules
Support modules
Accessories
Kits available.
With BASIC On Board — development tools and compilers are no longer necessary.
Prototypes quickly and easily
Explore microcontrollers
BASIC ON BOARD !
Learn programming
Experiment
ATRIA Technologies Inc
www.AtriaTechnologies.com

TO BOOK YOUR SHOWCASE SPACE CONTACT STRATEGIC MEDIA MARKETING INC.
Tel. 1-978-281-7708
Fax 1-978-281-7706
Email ElektorUSA@smmarketing.us

products and services directory

SHOWCASE YOUR COMPANY HERE

Elektor provides you with more ways to promote your business with our Showcase section -- a permanent feature of the magazine where you will be able to further highlight your products and services.

- For just $715 ($65,00 per issue for eleven issues), Elektor will publish your company name, website address and a 30-word description.
- For $1100 ($100,00 per issue for eleven issues), we will publish the above plus run a 2-inch square, full-color image – i.e., product shot, screen shot from your website, company logo, catalog cover – or whatever you choose to showcase.

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

I wish to promote my company, please book my space:
• Text insertion only for $715 • Text and photo for $1,100

NAME: ..... ORGANISATION: .....
JOB TITLE: .....
ADDRESS: .....
.....
..... TEL: .....
PLEASE COMPLETE COUPON BELOW AND FAX BACK TO 1-978-281-7706
COMPANY NAME .....
WEB ADDRESS .....
30-WORD DESCRIPTION .....
.....
.....
.....
.....

MEMS TECHNOLOGY SUMMIT

MEMS Technology Summit
25 Years in Perspective

Lessons from the Past and Vision for the Future

October 19-20, 2010
Stanford University, Stanford, California

Register Online Today at www.memssummit.org

Founding Sponsor: InvenSense – Innovation in MEMS
Platinum Sponsor: SVTC
Gold Sponsor: BOSCH – Invented for life
Hosted by Stanford University

Silver Sponsors: CTI CONSULTING, finetech, sensonor, tegal, TEXAS MICROFACTORY, XACTIX, YOLE DÉVELOPPEMENT

Media Partners: MEMS Investor Journal, MEMS Trends, Micronews, NASA Tech Briefs, sensors, SMALLTIMES

Association Sponsors: MANCEF, MEPTEC

Going Strong

A world of electronics from a single shop!



Books

New models and applications

High-End Valve Amplifiers 2

Nobody has any doubt that valve amplifiers produce a remarkably beautiful sound. They have a lively, deep, clear, and expressive sound, and dynamically they do not appear to have any limitations. Menno van der Veen investigates, in a systematic theoretical approach, the reasons for these beautiful properties. He develops new models for power valves and transformers, thus enabling the designer to determine the properties of the amplifier during the design process. You will notice in this book that the author not only writes about amplifier technique, but tells about the way the development of valve amplifiers can have an influence on your daily life; even the usefulness of patents is discussed. Summarizing: new theories and solutions for perfect audio with valve amplifiers. Not only the professional and the DIY-er but everyone who wants to understand valve amplifiers will read this book with much pleasure.

420 pages • ISBN 978-0-905705-90-3 • $59.70

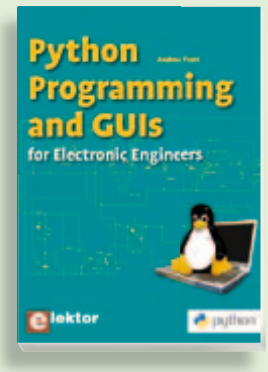


For beginners and experts

50 PIC Microcontroller projects

This book contains 50 projects for PIC microcontrollers such as a laser alarm, USB teasing mouse, eggtimer, guarding a room using a camera, mains light dimmer, talking microcontroller and much more. You can use this book to build the projects for your own use, but also as a studybook or reference guide. Several different techniques are discussed such as relay, RS232, USB, pulse width modulation, rotary encoder, interrupts, infrared, analog-digital conversion (and the other way around), 7-segment display and even CAN bus.

440 pages • ISBN 978-0-905705-88-0 • $58.10

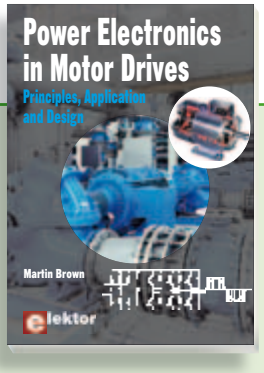


Get started quickly and proceed rapidly

Python Programming and GUIs

This book is aimed at people who want to interface PCs with hardware projects using graphic user interfaces. The programming language used is Python, an object-oriented scripting language. The book guides you through starting with Linux by way of a free downloadable, live bootable distribution that can be ported around different computers without requiring hard drive installation.

224 pages • ISBN 978-0-905705-87-3 • $47.60



Principles, Application and Design

Power Electronics in Motor Drives

This book is aimed at people who want to understand how AC inverter drives work and how they are used in industry. The book is much more about the practical design and application of drives than about the mathematical principles behind them. The detailed electronics of DC and AC drive are explained, together with the theoretical background and the practical design issues such as cooling and protection. An important part of the book gives details of the features and functions often found in AC drives, and gives practical advice on how and where to use these.

240 pages • ISBN 978-0-905705-89-7 • $47.60



Learn more about C# programming and .NET

C# 2008 and .NET programming

This book is aimed at Engineers and Scientists who want to learn about the .NET environment and C# programming or who have an interest in interfacing hardware to a PC. The book covers the Visual Studio 2008 development environment, the .NET framework and C# programming language from data types and program flow to more advanced concepts including object oriented programming.

240 pages • ISBN 978-0-905705-81-1 • $47.60



Use only free or open source software

ARM Microcontroller Interfacing

Learn to interface and program hardware devices in a wide range of useful applications, using ARM7 microcontrollers and the C programming language. Examples covered in full detail include a simple LED to a multi-megabyte SD card running the FAT file system. Interface to LEDs, transistors, optocouplers, relays, solenoids, switches, keypads, LCD displays, seven segment displays, DC motors, stepper motors, external analogue signals using the ADC, RS-232, RS-485, TWI, USB, SPI and SD memory cards. Also covered are methods to write programs to operate externally interfaced hardware devices, using timers and interrupts, porting FAT file system code for use with an SD memory card, programming the PWM to produce an audio sine wave, programming the PWM to speed control a DC motor and more. A chapter on more advanced ARM microcontrollers is included with an overview of some of the newest ARM microcontrollers and their features.

250 pages • ISBN 978-0-905705-91-0 • $47.60

More information on the Elektor Website:

www.elektor.com

Elektor US
PO Box 180
Vernon, CT 06066
USA
Phone: 860-875-2199
Fax: 860-871-0411
E-mail: sales@elektor.com

elektor



A must-have for audiophiles

DVD Masterclass High-End Valve Amplifiers

In this Masterclass Menno van der Veen will examine the predictability and perceptibility of the specifications of valve amplifiers. The DVD represents 3.5 hours of video material. Bonus elements on the DVD include the complete PowerPoint presentation (74 slides), scanned overhead sheets (22 pcs), AES Publications mentioned during the Masterclass. Not forgetting the bombshell: 25 Elektor publications about valves.

ISBN 978-0-905705-86-6 • $40.20



75 Audio designs for home construction

DVD The Audio Collection 3

A unique DVD for the true audio lover, containing more than 75 different audio circuits from the volumes 2002-2008 of Elektor. The articles on the DVD-ROM cover Amplifiers, Digital Audio, Loudspeakers, PC Audio, Test & Measurement and Valves. Highlights include the ClariTy 2x300 W Class-T amplifier, High-End Power Amp, Digital VU Meter, Valve Sound Converter, paX Power Amplifier, Active Loudspeaker System, MP3 preamp and much more. Using the included Adobe Reader you are able to browse the articles on your computer, as well as print texts, circuit diagrams and PCB layouts.

ISBN 978-90-5381-263-1 • $28.90

CD/DVD-ROMs



110 issues, more than 2,100 articles

DVD Elektor 1990 through 1999

This DVD-ROM contains the full range of 1990-1999 volumes (all 110 issues) of Elektor Electronics magazine (PDF). The more than 2,100 separate articles have been classified chronologically by their dates of publication (month/year), but are also listed alphabetically by topic. A comprehensive index enables you to search the entire DVD.

ISBN 978-0-905705-76-7 • $100.00



See the light on Solid State Lighting

DVD LED Toolbox

This DVD-ROM contains carefully-sorted comprehensive technical documentation about and around LEDs. For standard models, and for a selection of LED modules, this Toolbox gathers together data sheets from all the manufacturers, application notes, design guides, white papers and so on. It offers several hundred drivers for powering and controlling LEDs in different configurations, along with ready-to-use modules (power supply units, DMX controllers, dimmers, etc.). In addition to optical systems, light detectors, hardware, etc., this DVD also addresses the main shortcoming of power LEDs: heating. This DVD contains more than 100 Elektor articles on the subject of LEDs.

ISBN 978-90-5381-245-7 • $46.00



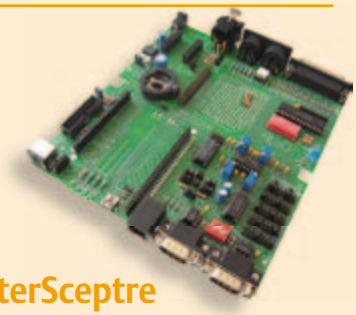
The Elektor DSP radio

(July/August 2010)

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

PCB, assembled and tested

Art.# 100126-91 • $240.40



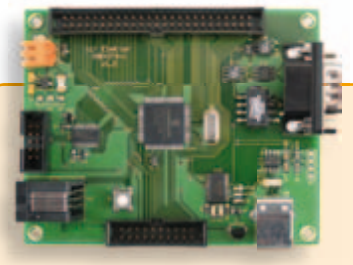
InterSceptre

(June 2010)

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

Kit of parts, contains PCB and components

Art.# 100174-71 • $187.10



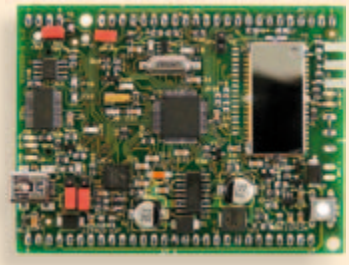
dsPIC Control Board

(May 2010)

This control board has been designed for incorporation into typical industrial electronics applications like controlling motors or adjustment of static up- or down-converters.The objectives were to obtain a board with a large number of pulsewidth modulation (PWM) generators, which enables us to control several motors and static converters at the same time. The cost of the control board needed to be as low as possible too. In addition, it must be possible to construct the board using a soldering iron, without requiring use of a reflow oven.

PCB, populated and tested

Art.# 090073-91 • $225.90



Reign with the Sceptre

(March 2010)

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

PCB, populated and tested, test software loaded

Art.# 090559-91 • $143.60

Kits & Modules

Product Shortlist

October 2010 (No. 22) $

+ + + Product Shortlist October: See www.elektor.com + + +

September 2010 (No. 21)

Elektor Project Case
100500-71 .... Predrilled Lexan sheets with standoffs 24.10

Digital Multi-Effects Unit
090835-31 .... EEPROM 24LC32 ..... 6.50
090835-41 .... ATmega8-16PU 13.40
090835-42 .... ATtiny2313-20PU 13.40
090835-71 .... Kit of parts including PCBs, programmed controllers and EEPROM ..... www.elektor.com

Dual Voltage/Current Display
100166-71 .... Kit of parts incl. PCB, item -41, LCD 100.00

July/August 2010 (No. 19/20)

The Elektor DSP radio
100126-41 .... ATmega168 PU 20.20
100126-91 .... PCB, assembled and tested 240.40

Daggerboard Position Detector
080307-41 .... PIC16F628A-DIL-18, programmed 12.90

PIC RJ-45 Cable Tester
090643-41 .... PIC16F72, programmed 12.90

3D LED Pyramid
090940-41 .... ATtiny2313-20SU, programmed 12.90

Digital Thumbwheel Switch
090538-41 .... ATtiny2313 dip20, programmed 12.90

Whistler: Electronic Trainer/Coach
100203-41 .... PIC16F88 DIP18, programmed 12.90

Solar Cell Battery Charger/Monitor
090544-41 .... PIC16F877A, programmed 26.70

Universal Timer with Zero Standby Current
090534-41 .... ATTiny2313, programmed 12.90

Tiny Timer
091044-41 .... ATtiny2313, programmed 12.90

Universal PWM Driver
090856-41 .... PIC16F628-1/P, programmed 12.90

Binary Clock
090187-41 .... PIC165F877-20/P DIP40, programmed 29.90

USB Tilt Sensor
070829-41 .... ATmega8-16AU (TQFP), programmed 12.90
090645-91 .... MMA7620 breakout board 13.80

Bench PSU for PC
090863-41 .... PIC16F616-I/P, programmed 12.90

Sailor's Battery Meter
090117-41 .... PIC16F690 DIP, programmed 12.90

Tiny Pulser
090444-41 .... ATTINY13-20P4, programmed 12.90

MicroMinimal Thermometer
090634-41 .... ATTINY13(A)dip8. programmed 12.90

Waterproof Bathroom Switch
090537-41 .... ATtiny13A, programmed 12.90

Lights Control for Model Cars
090834-41 .... Programmed controller ATtiny45 DIP-8 ..... 12.90

Modeller's Clock
090023-41 .... PIC18LF1320 I/P DIL18, programmed 12.90

Astrolamp
090550-41 .... ATTiny45 DIL8, programmed 12.90

ATM18-DIPATM18-DIP
090896-1 ..... Printed circuit board 16.00

Underfloor heating controller
100318-41 .... ATtiny25-20p4DUO8, programmed 12.90

RGB Synchronizing Fireflies
100358-41 .... ATTINY13(V), programmed 12.90

Scope Text
100327-41 .... Attiny2313 DIL20, programmed 12.90

Bestsellers

Books

1 ARM Microcontroller Interfacing
ISBN 978-0-905705-91-0 ..... $47.60

2 Power Electronics in Motor Drives
ISBN 978-0-905705-89-7 ..... $47.60

3 50 PIC Microcontroller projects
ISBN 978-0-905705-88-0 ..... $58.10

4 High-End Valve Amplifiers 2
ISBN 978-0-905705-90-3 ..... $59.70

5 Python Programming and GUIs
ISBN 978-0-905705-87-3 ..... $47.60

CD/DVD-ROMs

1 DVD The Audio Collection 3
ISBN 978-90-5381-263-1 ..... $28.90

2 Masterclass DVD High-End Valve Amplifiers
ISBN 978-0-905705-86-6 ..... $40.20

3 DVD LED Toolbox
ISBN 978-90-5381-245-7 ..... $46.00

4 DVD Elektor 1990 through 1999
ISBN 978-0-905705-76-7 ..... $100.00

5 DVD Elektor 2009
ISBN 978-90-5381-251-8 ..... $28.30

Kits & Modules

1 Elektor DSP radio
Art. # 100126-91 ..... $240.40

2 Reign with the Sceptre
Art. # 090559-91 ..... $143.60

3 InterSceptre
Art. # 100174-71 ..... $187.10

4 OBD2 Mini Simulator
Art. # 080804-71 ..... $135.50

5 dsPIC Control Board
Art. # 090073-91 ..... $225.90

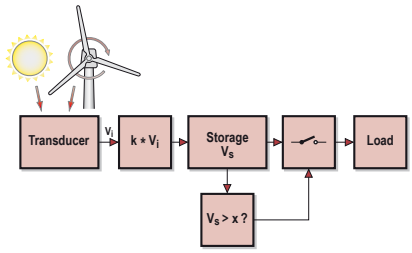
Order quickly and securely through
www.elektor.com/shop
or use the Order Form near the end of the magazine!

Elektor US
PO Box 180
Vernon, CT 06066
USA
Phone: 860-875-2199
Fax: 860-871-0411
E-mail: sales@elektor.com



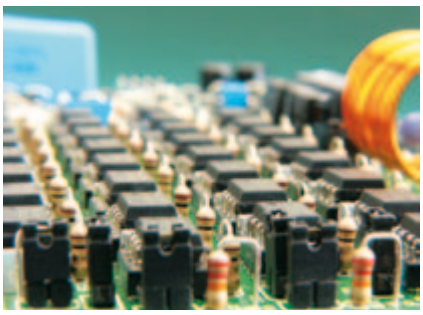
Mobile O_2 Meter with Minimod18

Nicely complementing the CO_2 Meter and Mobile CO_2 Meter projects recently published in Elektor we now present an O_2 (oxygen) Meter.
For divers and cave explorers it is absolutely essential to instantly know the current oxygen concentration in their air supply (from the cylinder) or in the ambient air (deep underground).
In this article we present suitable sensors for oxygen-level measurements, the way sensor signals are processed and, best of all, an oxygen meter based on the renowned Minimod18 board described in the January 2010 edition.



Energy Harvesting

Alternative energy sources are all the rage lately. In this article we present a number of ideas for powering circuits from solar energy, even under poor sunlight conditions. However, the less than constant and dramatically low voltages supplied by solar panels can be processed with the help of clever circuits, enabling voltages down to 200 mV to be used, and constant supply power to be guaranteed.



The 5532 OpAmplifier (2)

Have you ordered your NE5532's yet? They're cheaper by the hundred! In this the second and concluding installment on what's already known as "a remarkable audio amplifier" we'll be discussing the OpAmplifier's construction and performance, the latter to confirm (with graphs from our Audio Precision analyzer) that a top-notch design is on the table. For purists and other advanced audio boffins we also have guidance on configuring the amp for bridged operation and higher output powers.

Article titles and magazine contents subject to change; please check the Magazine tab on www.elektor.com

Elektor UK/European edition: on sale September 23, 2010. Elektor USA edition: published September 10, 2010.

w.elektor.com www.elektor.com www.elektor.com www.elektor.com www.elektor.com ww

Elektor on the web

All magazine articles back to volume 2000 are available online in pdf format. The article summary and parts list (if applicable) can be instantly viewed to help you positively identify an article. Article related items are also shown, including software downloads, circuit boards, programmed ICs and corrections and updates if applicable. Complete magazine issues may also be downloaded.
In the Elektor Shop you'll find all other products sold by the publishers, like CD-ROMs, DVDs, kits, modules, equipment, tools and books. A powerful search function allows you to search for items and references across the entire website.



Also on the Elektor website:

- Electronics news and Elektor announcements
- Readers Forum
- PCB, software and e-magazine downloads
- Time limited offers
- FAQ, Author Guidelines and Contact

Order Form 10-2010

Description	Price each	Qty.	Total	Order Code
LEDs 1 (Special Project) NEW	$16.00			
Elektor Personal Organizer 2011 NEW	$40.20			
DVD The Audio Collection 3 NEW	$28.90			
High-End Valve Amplifiers 2 NEW	$59.70			
ARM Microcontroller Interfacing NEW	$47.60			
Power Electronics in Motor Drives	$47.60			
50 PIC Microcontroller projects	$58.10			
	Sub-total			
	Shipping & Handling *(Airmail from Europe)*	$	20.00	
	Total paid			

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

Name/Company

Street & No.

City/State/Zip *Country*

Tel *E-mail*

EL10 *Date* – – *Signature*

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

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

Expiry date: _____

Verification code: _____

Send order form to:

Elektor US
PO Box 180
Vernon, CT 06066
USA

Phone: 860-875-2199
Fax: 860-871-0411
E-mail: sales@elektor.com
www.elektor.com

elektor

Order Form Subscription 10-2010

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

I would like:

- ☐ **Standard Subscription for $39.95 (11 issues)**
- ☐ **Plus Subscription for $54.95 (11 issues plus the Elektor Volume 2010 DVD-ROM)**



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

Name/Company

Street & No.

City/State/Zip *Country*

Tel *E-mail*

EL10 *Date* – – *Signature*

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

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

Expiry date: _____

Verification code: _____

Send order form to:

Elektor US
PO Box 180
Vernon, CT 06066
USA

Phone: 860-875-2199
Fax: 860-871-0411
E-mail: sales@elektor.com
www.elektor.com

ORDERING INFORMATION

To order contact customer service:

Phone: 860-875-2199
Fax: 860-871-0411
Mail: Elektor US
PO Box 180
Vernon, CT 06066
USA
E-mail: sales@elektor.com
On-line at www.elektor.com

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

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

COMPONENTS

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

PAYMENT

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

TERMS OF BUSINESS

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

SUBSCRIPTIONS (US & CANADA ONLY)

Subscription rates (1 Yr.)

Standard Subscription: $39.95
Plus Subscription: $54.95

Canada add $11 per year for postage

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

Elektor US
PO Box 180
Vernon, CT 06066
USA

E-mail: sales@elektor.com

Order subscriptions on-line at www.elektor.com/subs

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

For gift subscriptions, please include gift recipient's name and address as well as your own, with remittance. A gift card will be sent on request.
Subscriptions may be cancelled at any time for a refund of all unmailed issues.

Does your subscription expire soon?
Renew it online at www.elektor.com/renew

LEDs 1

Elektor Special Project

This special edition offers not only theoretical information but also shows how and where LEDs are applied nowadays. Additionally, this edition contains some tested electronic circuits for DIY.

Theory and applications:

- Control electronics and heat management for LED lighting
- LED projector technology
- Voltage converter with constant-current output for Power LEDs
- LED power and control unit on a single chip

DIY projects:

- Ambilight with Bluetooth
- Budget LED dimmer
- Computerised LED Christmas light
- Programmable LED lamp

And much more!



NEW

100 pages • $16.00

Elektor US
PO Box 180
Vernon, CT 06066
USA
Phone: 860-875-2199
Fax: 860-871-0411
E-mail: sales@elektor.com

elektor

Further information and ordering at www.elektor.com/shop

Index of Advertisers

AES . . . www.aesshow.com . . . 47

AP Circuits, Showcase . . . www.apcircuits.com . . . 13, 78

ARM TechCon . . . www.eetimes.com/armconference . . . 12

Atria Technologies, Showcase . . . www.AtriaTechnologies.com . . . 78

CES . . . www.CESweb.org . . . 35

Circuit Cellar . . . www.circuitcellar.com . . . 71

Decade Engineering, Showcase . . . www.decadenet.com . . . 78

DLP Design . . . www.dlpdesign.com . . . 13

EasyDAQ, Showcase . . . www.easydaq.biz . . . 78

Elsevier . . . www.newnewpress.com . . . 47

ExpressPCB . . . www.expresspcb.com . . . 11

EzPCB/V-Module . . . www.v-module.com . . . 53

Hameg Instruments, Showcase . . . www.haproelectronics.com . . . 78

Images Scientific, Showcase . . . www.imagesco.com . . . 78

Jameco . . . www.jameco.com . . . 88

Linx Technologies . . . www.linxtechnologies.com . . . 42

Maxbotix, Showcase . . . www.maxbotix.com . . . 78

MEMS . . . www.memssummit.org . . . 79

MikroElektronika . . . www.mikroe.com . . . 33, 57

NXP Contest . . . www.circuitcellar.com/nxpmbeddesignchallenge! . . . 3

Paia Electronics, Showcase . . . www.paia.com . . . 13, 78

Parallax . . . www.parallax.com . . . 19

Pololu Corporation, Showcase . . . www.pololu.com/maestro . . . 9, 78

Saelig, Showcase . . . www.saelig.com . . . 53, 78

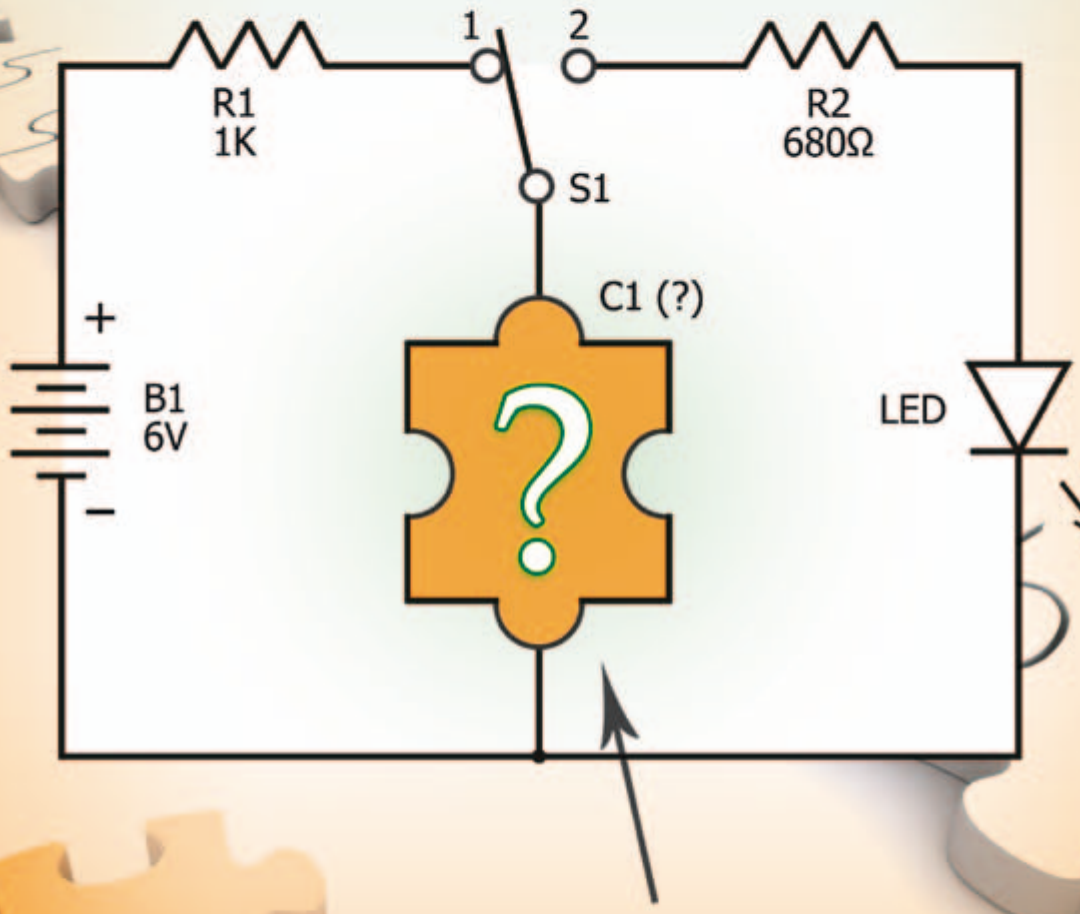
Showcase . . . 78, 79

SoC conference . . . www.SoCconference.com . . . 67

WIZnet . . . www.wiznettechnology.com . . . 2

Advertising space for the issue of 11 November 2010 may be reserved not later than 19 October 2010
with Strategic Media Marketing, Inc. - 2 Main Street - Gloucester, MA 01930 - USA – Telephone 1.978.281.7708 - Fax 1.978.281.7706 - e-mail: ElektorUSA@smmarketing.us to whom all correspondence, copy instructions and artwork should be addressed.

Can You Solve This?



What is the
missing component?



Electronics instructor Ollie Circuits planned to show his class of freshman electrical engineering students how to use a super capacitor as a memory back-up capacitor, but first he wanted to show how the students could make their own super capacitor and demonstrate its charge/discharge cycles with the simple circuit above. Most of the components were already on his workbench, the homemade super capacitor would be made from several layers of lemon juice-soaked paper towels interleaved between several layers of a mystery material to form a multi-layer stack. The stacked layers would then be sandwiched between the two copper-clad PC boards and held together with a rubber band. Ollie rushed to a nearby pet shop. What did he buy? Go to www.Jameco.com/solve7 to see if you are correct and while you are there, sign-up for our free full-color catalog.

1-800-831-4242 | www.Jameco.com

JAMECO® ELECTRONICS