October 2011

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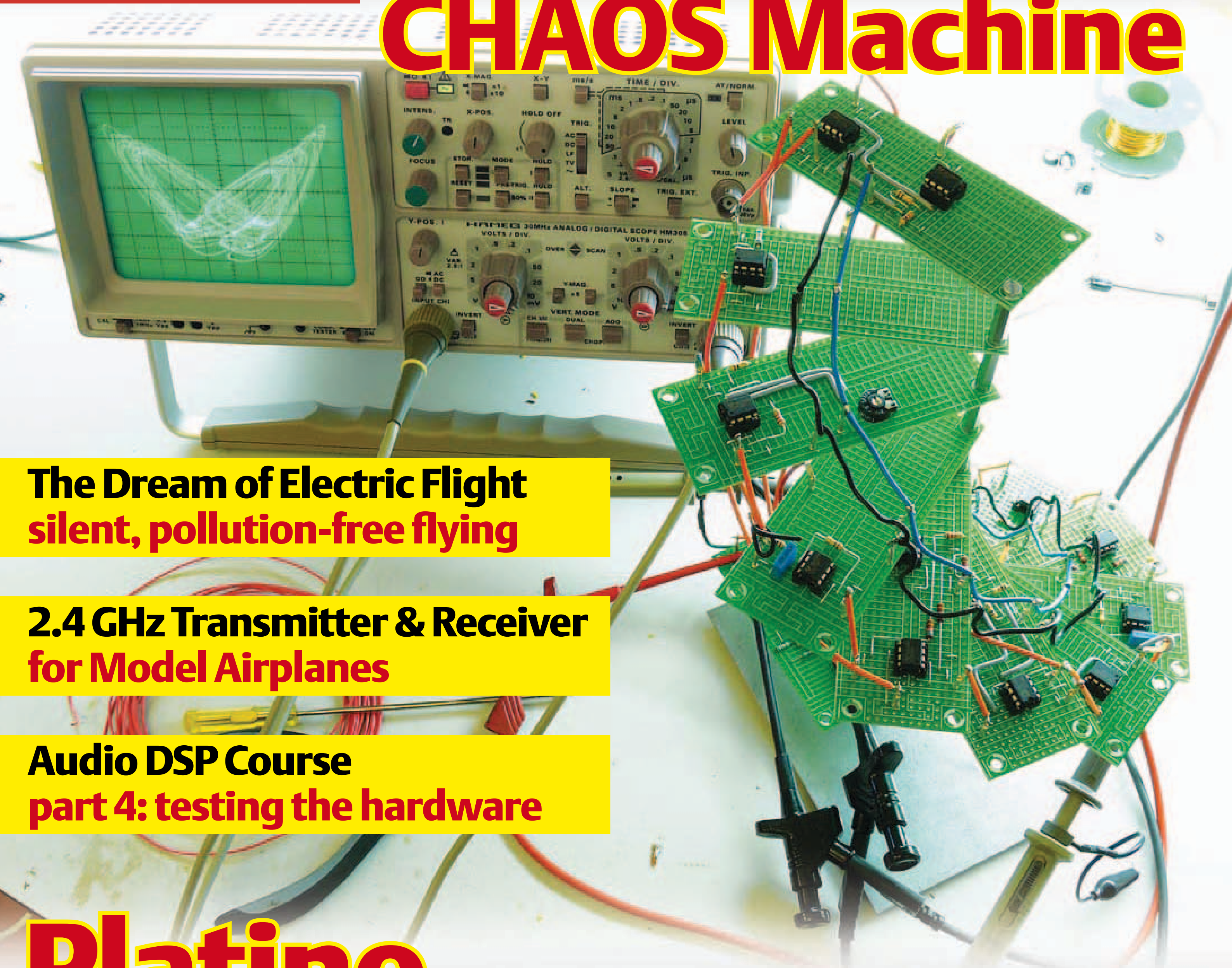

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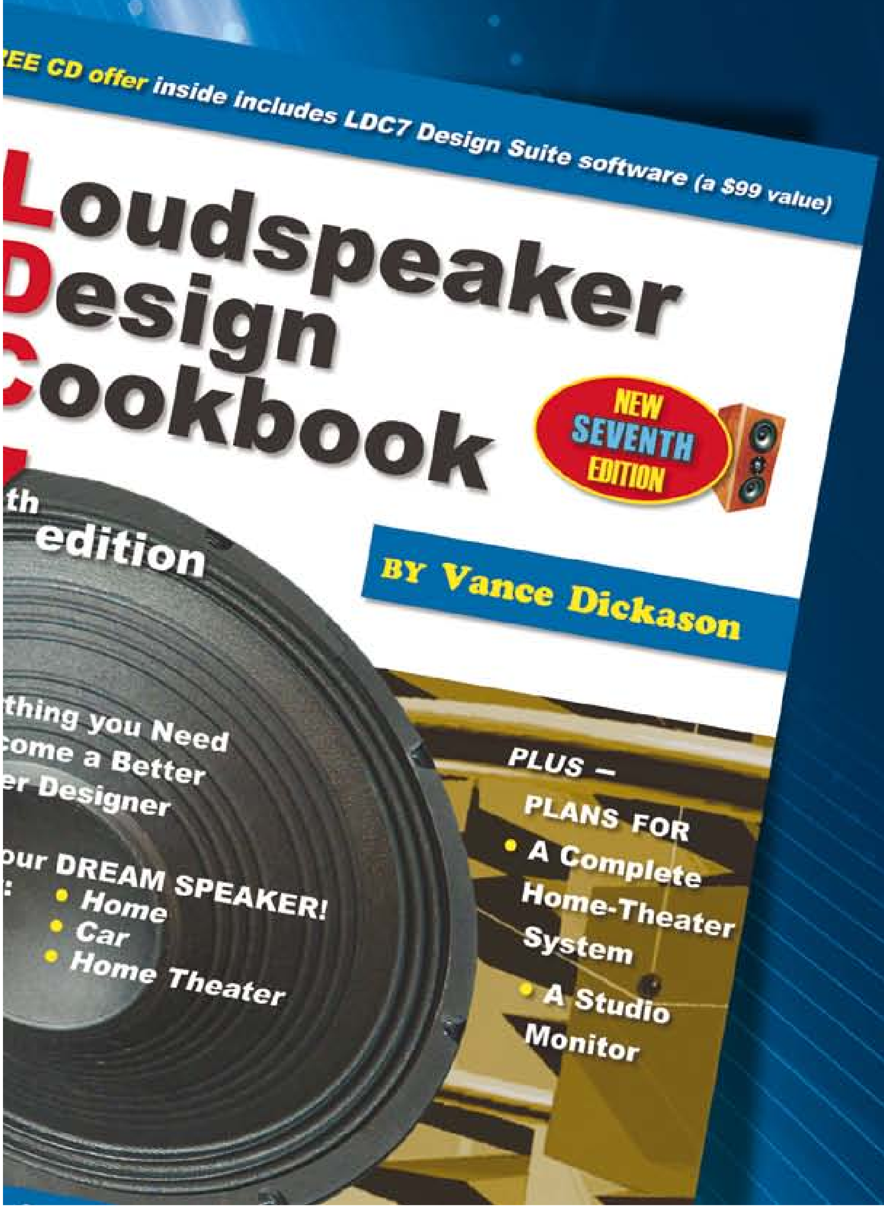

Back and better than ever, this 7th edition provided everything you need to become a better speaker designer. This newly revised edition now includes Klippel analysis of drivers, a chapter on loudspeaker voicing, advice on testing and crossover changes, and so much more! Ships complete with bonus CD containing over 100 additional figures and a full set of loudspeaker design tools.

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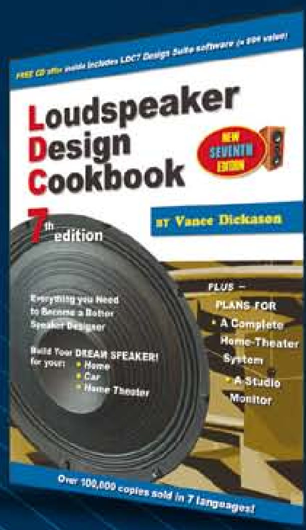
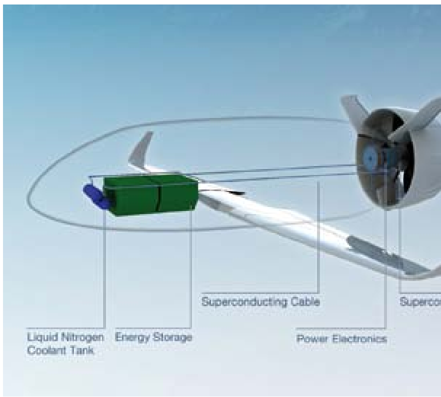


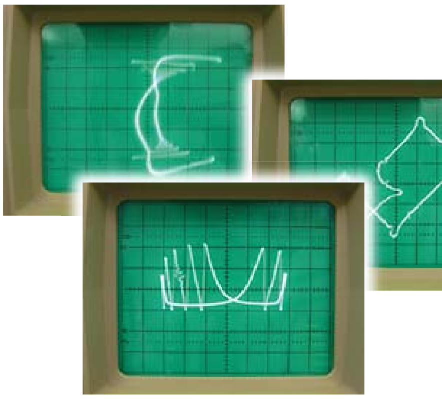
Beyond printed matter

Many of you will associate Elektor with the printed magazine of which the British English edition has been on circulation in newsstands, bookshops and in electronics retail stores since December 1974. In fact you are reading issue # 418 right now — on paper, and we intend to print quite a few more editions for you to browse, read, dog ear or blemish with the solder iron. However, over past few years Elektor has developed a number of activities that do not involve paper anymore, although we consider them part and parcel of our publishing activities in general. Apart from the blatantly obvious elektor.com website some of these activities may be unknown to you so I'll mention a few. To start with, there are our PCBs, DVDs, books, special editions, kits and modules. Elektor's PCBs — renowned for their quality — have been on sale since issue #1 but kits and modules are relatively recent additions and particularly useful to those of you dying to build our more ambitious projects but afraid or unable to source or handle the components used. Our first 'module' was the legendary GBDSO. Some of our recent kits are 'hybrids' meaning they come with the SMD components premounted on the board. From reader feedback we learned that many of you still enjoy soldering through-hole parts, so we decided to supply them separately with the kit for an hour or so of wielding the old soldering iron (low-power, mind you).
Elektor is also strengthening its 'e-vents' portfolio by staging webinars on successful publications. Our partners are companies as well as authors recognized as authorities in their field.
Our webmasters Patrick and Denis have created an Elektor channel on YouTube, www.youtube.com/elektorim. We have discovered that short movies (no matter how primitively made) on our techno stuff are a great way of pulling in not only newcomers of the MTV generation but also those now enjoying retirement and having rediscovered Elektor through successful Googling.
Everyone's more than welcome, hopefully there's something to delight you from our widening range of products either of the paper or the non-paper variety.

Enjoy reading this edition,
Jan Buiting, Editor

elektor





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October 2011
no. 34

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. 34, OCTOBER 2011 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.

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Get ready for the 'Elektor Academy Webinar Series in partnership with element14'

In response to requests from many enthusiastic readers out there, Elektor Academy and element14, the industry's leading online technology portal, have teamed up to bring you a series of five exclusive webinars (web seminars) covering blockbuster projects from recent editions of Elektor magazine.

In an Elektor Academy/element14 webinar, those who have registered to attend our online sessions not only get to see and hear leading authors and project designers exploring, discussing and elaborating on their projects, but also have an opportunity to enter into a debate on design and other technical aspects during the live Question & Answer (Q&A) slot after each presentation. Plus, every attendee receives an exclusive 10% discount off their next purchase with Farnell!

The first Elektor Academy/element14 webinar is titled '**Platino – an ultra-versatile platform for AVR microcontroller circuits'** and will take place on 13th October at 15.00 GMT (10.00 EST), live on element14.

Participation in these webinars is completely free! All you need to do is register via www.elektor.com/webinars to reserve your space. Places are limited so book soon to make sure you don't miss out.

Our future Elektor/element14 Webinar Series topics and times will be announced through Elektor's e-weekly newsletter as well as in our monthly publications and online so watch out for the next exciting episode!

www.elektor.com/webinars (110604-VIII)

elektor ACADEMY the school of electronics

element14

Wireless networking solution powered with energy harvesting system

Silicon Laboratories Inc. recently introduced the industry's most energy-efficient wireless sensor node solution powered by a solar energy harvesting source. The new turnkey energy harvesting reference design enables developers to implement self-sustaining, ultra-low-power wireless sensor networks for home and building automation, security systems, industrial control applications, medical monitoring devices, asset tracking systems and infrastructure and agricultural monitoring systems.

The market for energy harvesting devices is poised to grow exponentially this decade. IDTechEx forecasts that more than ten billion energy harvesting devices will ship by 2019 — a 20x increase over the roughly 500 million units that shipped in 2009. Although systems powered by harvested energy sources have existed for many years, developers have been challenged to implement wireless sensor nodes within very low power budgets. Silicon Labs has met this design challenge by creating a wireless energy harvesting system based on its Si10xx wireless microcontroller (MCU) family. The industry's most power-efficient, single-chip MCU and wireless transceiver solution, the Si10xx can perform control and wireless interface functions at ultra-low power levels.

In addition to being environmentally friendly and virtually inexhaustible, harvested energy provides a cost-effective, convenient alternative to batteries in many applications such as wireless networking systems. Batteries can be costly and inconvenient to replace, especially in large-scale wireless sensor node applications, and they are unreliable in extreme temperature conditions. Wireless sensor nodes often use batteries because they are placed in locations where it is not possible or convenient to run mains power. Energy harvesting simplifies these applications by eliminating the inconvenience of replacing batteries in inaccessible locations, while also reducing the quantity of depleted batteries for recycling or dumped in landfills.

The new energy harvesting reference design includes wireless network and USB software and a complete circuit design with RF layout, bill of materials (BOM), schematics and Gerber files. The design consists of three components:

- A solar-powered wireless sensor node that measures temperature, light level and charge level, using an Si10xx wireless MCU to control the sensor system and transmit data wirelessly and a thin-film battery to store harvested energy.
- A wireless USB adapter that connects the wireless sensor node to a PC for displaying sensor data; the adapter features Silicon Labs' Si4431 EZRadioPRO® transceiver with an MCU running USB-HID class software and EZMac® wireless software stack.
- A wireless sensor network GUI that displays data from up to four sensor nodes.

The thin film battery used in the energy harvesting reference design has a capacity of 0.7 mAh. In direct sunlight, the battery can be recharged fully in only two hours. While in sleep mode, the wireless sensor node will retain a charge for 7,000 hours. If the wireless system is transmitting continuously, it will operate non-stop

for about three hours, although it is designed to constantly recharge itself at an appropriate level to keep the thin-film battery from completely discharging.
Silicon Labs' energy harvesting reference design accommodates a wide range of harvested energy sources. An on-board bypass connector gives developers the flexibility to bypass the solar cell and tap other energy harvesting sources such as vibration (piezoelectric), thermal and RF.
The system is available and priced at $45.00.

www.silabs.com/pr/energyharvesting

(110582-IX)

Class-G headphone and Class-D speaker amplifiers balance audio power versus battery life

Designers of mobile devices, such as smartphones, tablets/multimedia internet devices (MID), and portable media players, are faced with the challenge of making the small speakers in their devices sound louder and better, while minimizing impact on battery life.

To meet this challenge, Fairchild Semiconductor developed the FAB1200 stereo Class-G ground-referenced headphone amplifier with integrated buck converter, as well as the FAB2200 audio subsystem with stereo Class-G headphone amplifier and 1.2 W Class-D mono speaker amplifier.
The FAB1200 features a charge pump which generates a negative supply voltage that allows the headphone output to be ground-centred and capacitor-free, eliminating up to two external capacitors. An integrated inductive buck regulator provides direct battery connection and adjusts the supply voltage between two different levels based on the output signal level resulting in reduced power consumption. The result of these features is reduced systems cost and extended battery runtime, while maintaining a high level of audio quality.
The device, available in a 16-bump, 0.4 mm pitch, 1.56 mm x 1.56 mm WLCSP package, offers excellent audio performance for better sounding audio headsets and is ideal for mobile handsets, tablets/MIDs, MP3 and portable media players.
The FAB2200 is an audio subsystem that combines a capacitor-free stereo Class-G headphone amplifier with a Class-D speaker amplifier. A proprietary integrated charge pump generates multiple supply rails for a ground-centred Class-G headphone output significantly reducing power dissipation when compared to Class-AB design implementations, while offering high power supply rejection ratio.
The filterless Class-D amplifier can be connected directly to a speaker without the need for two external filter networks, reducing the overall solution systems cost. The device also features Automatic Gain Control which limits the maximum speaker output levels to protect speakers without introducing distortion. It can also dynamically limit clipping as the battery voltage falls.
The FAB1200 and FAB2200 mobile audio ICs make handsets, tablets/MIDs, and other portable audio applications sound louder and better while reducing overall systems cost and minimizing the impact on battery runtime.
The FAB2200, available in a 25-bump, 0.4mm pitch, WLCSP package, is ideal for cellular handsets, notebook computers and tablets.

www.fairchildsemi.com/ds/FA/FAB1200.pdf
www.fairchildsemi.com/ds/FA/FAB2200.pdf

(110582-XII)

OC series antenna delivers higher gain

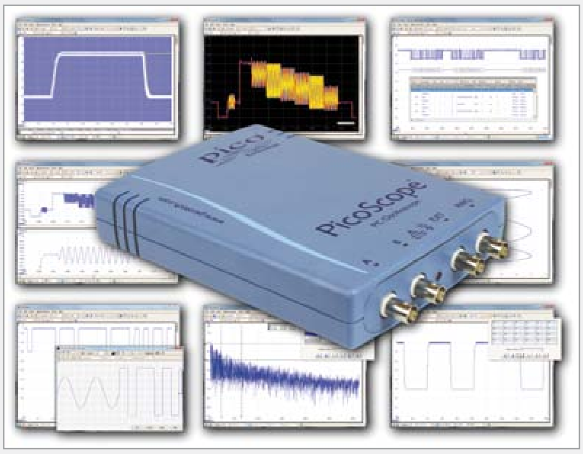
Antenna Factor is pleased to introduce the OC Series antenna. The 1/2-wave dipole antenna delivers higher gain than a standard whip antenna, increasing the range and reliability of wireless links. Using loaded coil technology, the OC Series antenna minimizes the length that would typically

be required to achieve omnidirectional gain. Its articulating base tilts 90 degrees and rotates 360 degrees. The antenna's internal counterpoise eliminates the need for an external ground plane and maximizes performance. Available in 916 MHz and 2.4 GHz, the OC Series antenna attaches with a standard SMA or Part 15 compliant RP-SMA connector. The antenna costs less than $7.00 in production quantities. Custom colours and logo options are available for volume OEMs.

www.antennafactor.com
(110582-XIV)

A digital oscilloscope for the analog world

The new PicoScope 4262 from Pico Technology is a 2-channel, 16-bit very-high-resolution oscilloscope (VHRO) with a built-in low-distortion signal generator. With its 5 MHz bandwidth, it can easily analyze audio, ultrasonic and vibration signals, characterize noise in switched mode power supplies, measure distortion, and perform a wide range of precision measurement tasks.



The PicoScope 4262 is a full-featured oscilloscope, with a function generator and arbitrary waveform generator that includes a sweep function to enable frequency response analysis. It also offers mask limit testing, math and reference channels, advanced triggering, serial decoding, automatic measurements and color persistence display. When used in spectrum analyzer mode, the scope provides a menu of eleven automatic frequency-domain measurements such as IMD, THD, SFDR and SNR. Its performance is so good that it rivals many dedicated audio analyzers and dynamic signal analyzers costing several times the price.

The PicoScope 4262 connects to any Windows XP, Vista or Windows 7 computer with a USB 2.0 port. You can use it with a PC to save space on your workbench, or connect it to a laptop to create a portable instrument that's perfect for field servicing and on-site work. As it is USB-powered, there is no need to carry a separate AC adapter. If you want to write your own application to control the scope or use it as a digitizer, Pico provides a software development kit, including example code, free of charge.

The PicoScope 4262 oscilloscope is on sale now, priced at only £750 including two probes, a carry case and a 5-year parts and labor warranty. Order from your local distributor or visit the Picotech website.

www.picotech.com (110604-II)

New enhanced AVR XMEGA family

Atmel® Corporation (NASDAQ: ATML), a leader in microcontroller and touch solutions, today announced additional unique features to the already-successful 8/16-bit AVR XMEGA microcontroller (MCU) family with the industry's lowest power consumption of 100 nA with 5µS wake-up time. The new Atmel AVR® XMEGA® family includes full-speed USB, the fastest and highest-precision analog systems, a Direct Memory Access (DMA) controller and the innovative event system that maximize real-time performance and throughput while reducing CPU load. This new family lowers overall system cost through higher integration, capacitive touch support, and ultra-low power consumption. The AVR XMEGA microcontrollers are designed for applications in the industrial, consumer, metering and medical segments.

The new AVR XMEGA MCUs integrate full-speed USB connectivity with unique functions that reduce overhead and provide higher data rates. Using the high-precision internal oscillator in the AVR XMEGA, designers can lower the system cost by eliminating the crystal oscillator traditionally required for full-speed USB. Atmel provides free software for all common USB device classes in the AVR Software Framework, which is a complete software package that includes drivers and communication stacks for AVR microcontrollers.

The AVR XMEGA family has unique high-precision analogue functions. The family includes two 12-bit analogue-to-digital converters (ADCs) with programmable gain stages that remove the need for external amplifiers. The ADCs operate down to 1.6V operating voltage, and have a combined sample rate up to 4MSPS. The two 12-bit digital-to-analog converters (DACs) also support systems that need fast and high-precision analog output. The DACs can drive high loads to reduce external driver component costs, while built-in current outputs enable embedded applications to remove external resistors or other constant current sources.

The Atmel AVR XMEGA family is the only 8/16-bit MCU in the market with DMA, Controller and Event System. Peripherals and communication modules can utilize

the DMA system to move data so the AVR XMEGA CPU has more idle time to save power or to perform other tasks. The innovative event system enables direct inter-peripheral signalling for short and 100% predictable response time without interrupt and CPU usage. Designers can now develop a solution with predictable real-time performance and data throughput even under a high system load. Other functions such as hardware AES and DES encryption and decryption ensure fast and low-power secure communication. Cryptography protects important intellectual software property during remote programming and firmware distribution. Atmel AVR XMEGA can also easily realize robust touch sensing interfaces through the Atmel QTouch® Library, enabling buttons, sliders, wheels or proximity for user interfaces.
All devices include the Atmel picoPower ultra-low power technology with true 1.6 V operation, accurate real time clock (RTC) operation and full data retention at the industry-leading current consumption of 500 nA.

www.atmel.com

(110582-XVI)

BASIC ON BOARD – programming – quick and easy

BASIC ON BOARD from Atria Technologies is a Basic interpreter that is pre-programmed on many of the ForeRunner microcontroller modules from ATRIA Technologies. BASIC ON BOARD is a derivative of the popular StickOS™ Basic developed by the talented software engineer Richard Testardi.

BASIC ON BOARD is the perfect tool to learn programming, explore microcontrollers, design prototypes, build home projects and even small products. To get started all you need is a terminal emulator.

BASIC ON BOARD enables access to many of the features of a microcontroller using built in commands, pin and register variables.

- Write text to a display: `lcd 1, "Hello World"`
- Read a 4x4 keypad: `on keychar do gosub KYPD`
- Create a timer interrupt: `on timer 1 do gosub clock`
- Write to an IIC device: `i2c start 0x68, i2c write t, i2c stop`

Common features such as console IO and string handling are available. With the popular HD44780 interface, a character

LCD can be directly controlled with a single command. A 4 x 4 keypad may be read as an interrupt. ForeRunner microcontroller modules with BASIC ON BOARD start at $24.

www.AtriaTechnologies.com

(110604-I)

It's a facebook for coders

Libstock is a community website created by mikroElektronika, allowing users to share their projects and libraries. It was created to provide the community with the right and necessary infrastructure.

Libstock is a powerful concept, encapsulating many useful features for easier navigation, flexibility in code presentation, and mechanisms to getting what you are seeking for, using categories, search, sorting and filters. Libstock allows you to stay in touch with your fellow contributors, to be notified of code changes, to discuss code implementation, but also express your wishes for future development. Libstock is far more comprehensive and user-friendly than any other embedded community website. It's the best place for code!

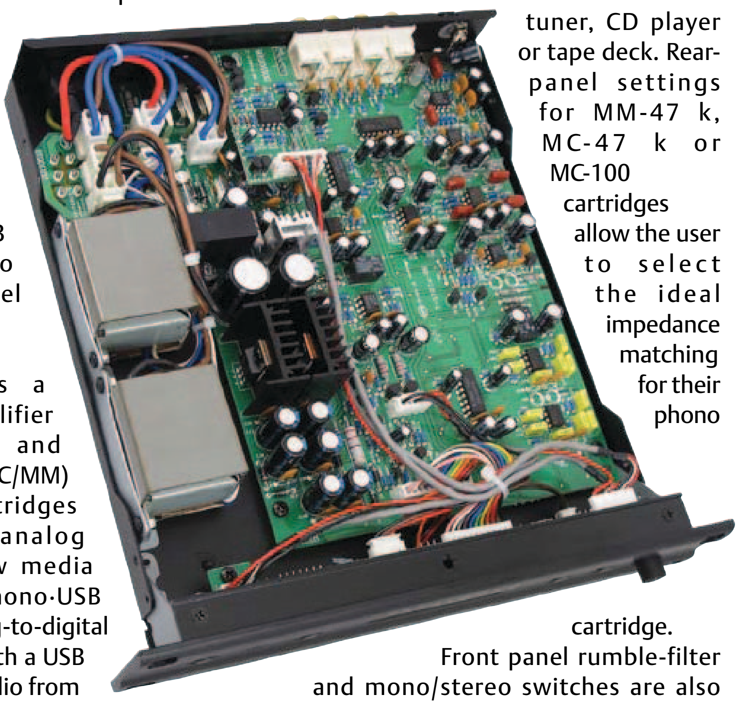
Libstock allows sharing of three major code types: Libraries, Projects and Visual TFT/GLCD projects. But within those types, we have allowed you to share whatever is necessary, or whatever you find suitable and helpful to the end user. For example, if you want to share your library, you can also provide examples, connections schematics, help files, datasheets, additional documentation, and even PCB designs if you like.

But Libstock is much more than that. It's like Facebook for coders! We can have our own profiles where we can put information about ourselves we find relevant, and which may boost confidence of others in our code. It will bring a face and personality to our communication.

www.libstock.com (110604-III)

Zphono·USB preamplifier

The Parasound Zphono·USB is a premium phono preamplifier with an A-D converter to translate vinyl LPs into digital audio for your Mac or PC via USB. RIAA EQ defeat capability for the USB output enables users to apply of more precise software-based equalization in their selected recording software. The Zphono·USB also provides two pairs of line level inputs.



Zphono·USB is a compact preamplifier for moving coil and moving magnet (MC/MM) phonograph cartridges and line-level analog sources. For new media applications, Zphono·USB also adds an analog-to-digital (A-D) converter with a USB port to transfer audio from vinyl LPs onto Mac and PC as digital media. Zphono·USB is the newest of the company's Z-Series family of half-rack-width components.

First of all, the Parasound Zphono·USB is a high-quality analog phono preamplifier engineered for the optimum in playback quality for vinyl LPs. Like its predecessor, the Zphono analog phono preamplifier, which continues in the line, Zphono·USB uses high quality parts and precision RIAA equalization to achieve extremely low levels of noise and distortion, and accurate frequency response.

For the digital realm, the Parasound Zphono·USB also includes an adjustable USB gain control and defeatable RIAA equalization to improve the quality of audio transfers from LPs to digital media. The USB gain control and USB clipping indicator are used to optimize the digital record-output levels for the optimum signal-to-noise ratio with all recording software programs. For those using sophisticated digital music software in their PCs or Macs, the rear-panel RIAA defeat switch allows users to bypass the internal hardware-based RIAA phono equalization in favor of software-based digital equalization. These capabilities are provided only for the rear panel USB digital output.

The Parasound Zphono·USB has a stereo input for an MC or MM phonograph cartridge, and two stereo line-level inputs to facilitate digital transfers of analog sources such as a tuner, CD player or tape deck. Rear-panel settings for MM-47 k, MC-47 k or MC-100 cartridges allow the user to select the ideal impedance matching for their phono cartridge.

Front panel rumble-filter and mono/stereo switches are also available to refine the quality of phono playback for older LPs and mono LPs.

There is a single pair of fixed-level line-level outputs and a headphone output. The Zphono·USB has dual power transformers and analog power supplies to minimize noise and an AC polarity reverse switch to combat hum issues related to power line polarity.

The Parasound Zphono·USB is the newest of many Z-Series components, each of which is one rack-space high and only one half rack-space wide. These Z-Series products are popular as stand-alone components and they can be easily rack-mounted using optional inexpensive adaptors.

The Parasound Zphono·USB will be available in the first week of September with a manufacturer's suggested retail price of $350.

Parasound's products are available from quality audio/video retailers, and select custom installation specialists.

www.parasound.com (110604-V)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www.pololu.com/wixel
NEW! Wixel Shield for Arduino
Pololu
Engage Your Brain

Versatile Board for AVR Micro

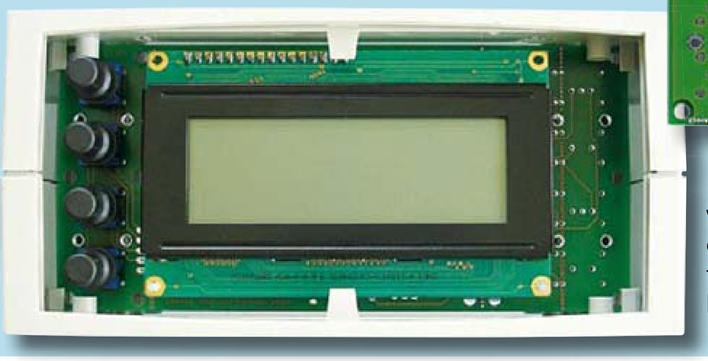
Platino[1], the greatest star of the support act

By Grégory Ester & Clemens Valens (France)

In electronics projects, the printed circuit board often only plays a minor role. Without the PCB, a circuit is definitely much more difficult to realize, but who can remember the PCB on which everything else depends, once everything is said and done? In order to rectify this injustice we have decided to give the leading part of this article to the circuit board. Ladies and gentlemen, please a warm applause for... Platino!

Biography

Platino was born on November 20, 2010 in the Netherlands; he is a versatile circuit board for circuits based on an 8-bit AVR controller. After several months of preparation this little brother of the J²B [2] met his first AVR microcontroller in June 2011. Because he did not yet feel properly prepared to brave the electronics jungle, he decided to optimize himself by taking his idol Arduino as an example. However, this carefree and innocent life was completely overturned by the chance meeting with a Bopla enclosure. It was love at first sight and they decided to continue together. The festive joining took place in July 2011 and you can be assured that they want many offspring.

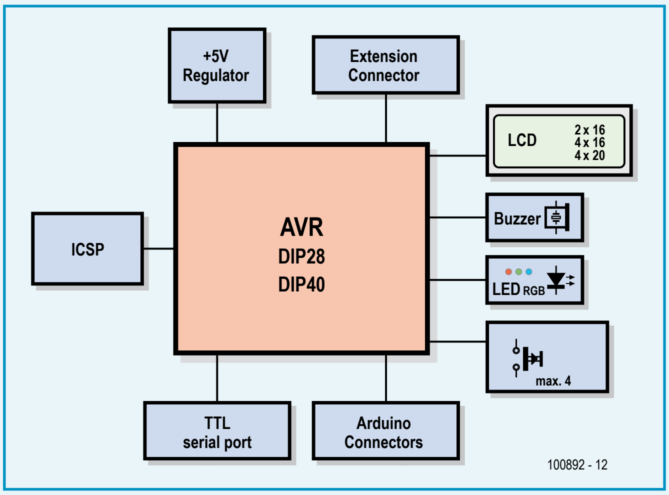


1. The name Platino is a playful reference to the French (and German) word 'Platine' meaning 'circuit board', with a slight wink at 'Arduino'.

controller Circuits

Elegant and fashionable

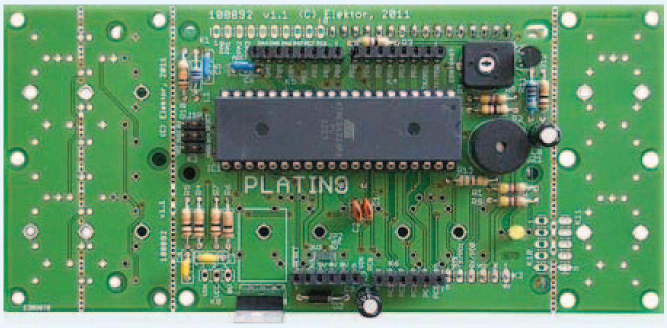
The time when we would dress ourselves exactly the same every day, such as Donald Duck or Tintin, has been long gone — Platino knows better. The modern circuit board is agile, adapting itself depending on necessity or circumstance. In a gloomy, dull environment Platino prefers to be adorned with a large LCD screen measuring 4 lines x 20 characters, but the moment the occasion presents itself Platino will resort to a scanty 2 lines x 16 characters. He does not fret that this will expose his beautiful circuit traces, quite the contrary! Platino is not prudish.



Even if you are a beautiful circuit board, without a sharp brain and a shrewd mind users will quickly become bored with you. Platino was therefore compelled to choose a microprocessor. Because his parents have always instilled the ethic of never doing a job by halves, Platino excels himself by offering accommodation to *all* AVR microprocessors with 28 or 40 pins, from the famous design studio and renowned manufacturer Atmel. In practice this amounts to all 8-bit AVR microprocessors in a DIP package.

Everybody knows the proverb “The coat makes the man”, and therefore the accessories complement in an elegant way the already fashionable appearance of Platino, who *adores* his tailor-made suit! He frequently turns over his collection of pushbuttons, by sometimes placing up to four of these jewels to the left, right or below his display. Platino is crazy about them, because they can be fitted with caps of different lengths, color or shape. It is true that these are a little bit more expensive, but when it comes to broadening the options Platino does not pinch a penny.

Another accessory favoured by Platino is the rotary encoder, which can be used to replace the functionality of two (or three even) pushbuttons. Up to two of these switches can be fitted at the same time!

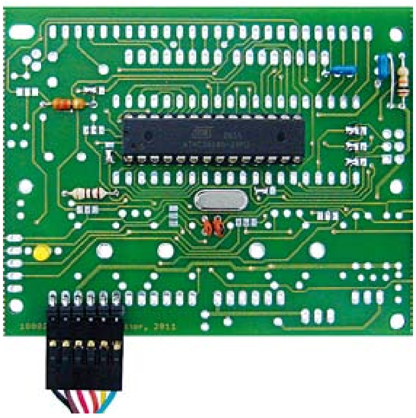


Platino likes to be the center of attention. He therefore has invested in a buzzer to ensure no one ignores him. To prevent him becoming hoarse he always uses the buzzer with a current-limiting series resistor (R2).

The mid-life crisis has not passed Platino either, so he adorns himself with a three-color LED. This can dazzle with perfectly white light, by suitably adapting the values of the resistors R1, R8 and R9, depending on the type of RGB LED chosen. He can also be green with fury or red with excitement, Platino has a mind of his own!

Lookalike

From a very young age, Platino has worshipped Arduino, the Italian star of fast embedded prototype development, who has been extensively studied by him. Although Platino is very much impressed, he is certainly not blinded and decided to adopt a few good aspects of his idol and to improve on certain weak points. As a result, he also takes the expansion connectors (K4 to K7) so that, like his example Arduino, he can adorn himself with *shields* (expansion boards), but in addition he also has expansion connectors with a more usual pitch (K1, K2, K9).



In contrast with Arduino, Platino can live without a USB/TTL adapter. He claims you can always resort to an external FTDI cable if you really must. Youthful arrogance? Maybe, but also cheaper. And Platino isn’t stupid either!

This cable also serves to program the microprocessor using the Arduino IDE, because Platino behaves himself exactly like Arduino. He assures us of a restart of the microprocessor via the IDE, without a *reset* button, thanks to resistor R13, which, remarkably enough, can also be a 0.1 µF capacitor. Platino can manage either solution. You have to realise that this works only if the microprocessor on the Platino has been programmed with an Arduino compatible programmer and a recent version of the IDE [3]. This is done via K3, using a standard AVR programmer.

Arduino has often been the victim of criticism regarding his limited options at times; that is why Platino decided not to tie himself to just one type of microprocessor. With an ATmega168 or ATMega324 Platino can play the lead role in a large number of *sketches*. And for the most demanding builders Platino has a convincing trump in hand: he can be fitted with an ATmega1284!

Platino can turn his hand to a three-color LED, but is also content with a simple LED, just like his idol. To achieve this you only need to connect R8 to RB5 via JP14. The LED will now flash when the microprocessor is programmed via the serial port. The *Blink* example from the Arduino IDE also works without any modification.

(100892)

Platino's outfit

An impeccable outfit is an absolute necessity for Platino. This is what he knows about his preferences for the parts:

Resistors

"Resistors are important, they can limit the current or apply a voltage. I prefer to use a 47 Ω for R2 and R3, 100 Ω for R13, 4.7 kΩ for R11 and, also a bit for convenience, 10 kΩ for R4 through R7, R10 and R12. R1, R8 and R9 are more difficult, that is because these have to be connected to the three-color LED. But 470 Ω is always a good middle-of-the-road choice".

"I use P1, my horizontal trimpot, to adjust the contrast of my LCD. I have one with a value of 10 kΩ".

Capacitors

"Capacitors are often denigrated to some backwater, but I nevertheless give them my attention. For C1 and C2 of the 16-MHz crystal I ask for a couple of niggling 22 pFs. High frequency noise works on my nerves. That is why I always carry C3, C4, C5. 100 nF is generally a good choice, but for C4 I prefer to take a 10 nF. This increases the bandwidth of the frequencies to be suppressed. The pitch is not important, 2.5 mm or 5 mm. When I fit IC3 then I also fit C8 and C9. C8 ensures the stability of IC3 and 1 µF gets the job done. Much the same for C9, but the often-made recommendation is to use one that is 10 x bigger. I therefore fit one with a value of 10 µF. Both have to be able to tolerate at least 16 V, C9 sometimes a bit more more. Preferably use a pitch of 2.5 mm".

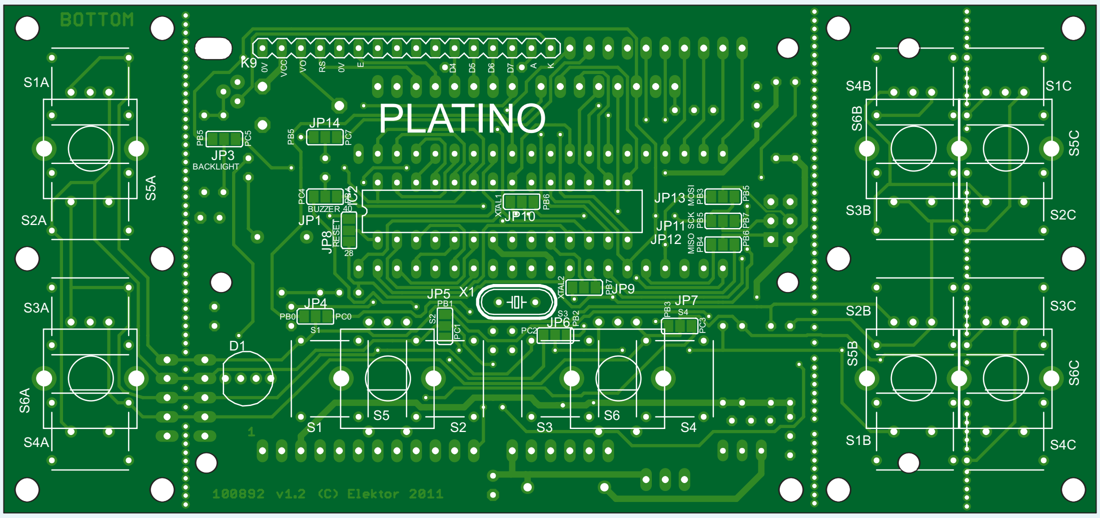
Inductors

"I have only one: L1. He takes care of the power supply for the analog to digital converter inside the microprocessor. C5 is there to assist him. 10 µH is a good value, but a wire bridge works well enough in most applications too."

Semiconductors

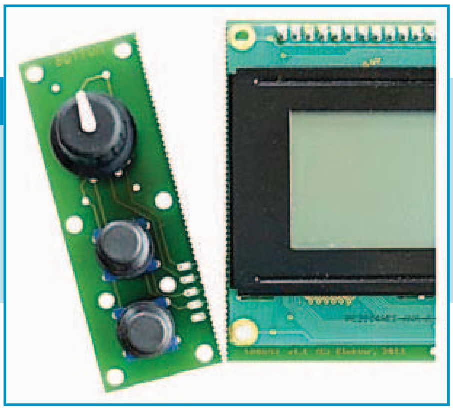
"I never use IC1 and IC2 at the same time, maybe that's possible.... to be investigated further... For standard occasions I prefer to take IC2, this one is easier to carry and cheaper. I therefore can make my selection from an ATmega48, an ATmega88, an ATmega168 or an ATmega328, which I mount on the solder side. IC1 has to be mounted on the component side, perhaps an ATmega164, an ATmega324, an ATmega644 and even an ATmega1284, which is more suitable for those special occasions. I only use those types that can use a 20 MHz crystal".

"If I feel the need to control the backlight of my display then I will fit T1. I don't have any particular preference as long as the transistor is able to switch a few hundred milliamps. A BC547C is



Unfaithful

Platino is very fond of his spacious Bopla housing but nevertheless has an eye for other enclosures. Platino is a jack of all trades and for convenience has a large number of mounting holes, but Platino remains changeable. He easily adapts by disposing of a few projecting parts, see the dotted lines... Thanks to connectors K10 and K11 he even has the option of taking advantage of his push buttons from a distance!



okay. Fitting a link in place of T1 (collector/emitter) is also an option".

"I sometimes do not have a lot of trust in an external +5-V power supply. In that case I will appeal to IC3, a +5-V voltage regulator. I'm already contented with the old, familiar 7805, although there are much nicer solutions these days. I also fit D2, a 1N5817 if the input voltage is not too high or an 1N4001 if this is above, say, ... 9 V. With D2 and IC3 I can handle voltages up to 18 V and I am protected against reverse polarity. I can also derive my power supply from the cable of the USB/TTL adapter. In that case do not feed me via V_{in}, otherwise IC3 can cause some trouble. Some of us might prefer not to fit the regulator at all in this particular arrangement".

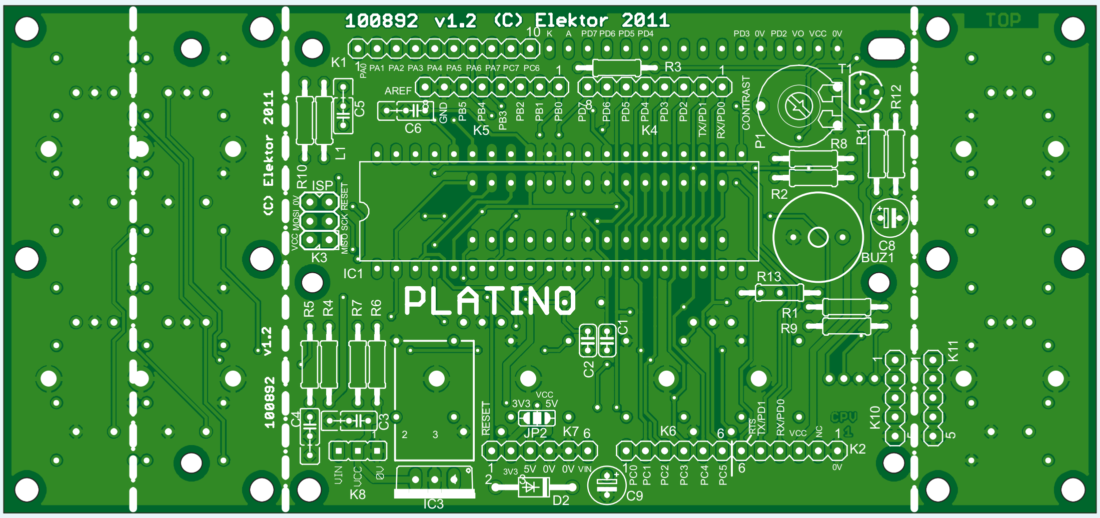
"D1 is my three-color LED with 4 connections. Kingbright makes models, such as the L-154A4SURKQBxxxx series, which are very agreeable to me. The COM-09264 from Sparkfun is also good".

Miscellaneous

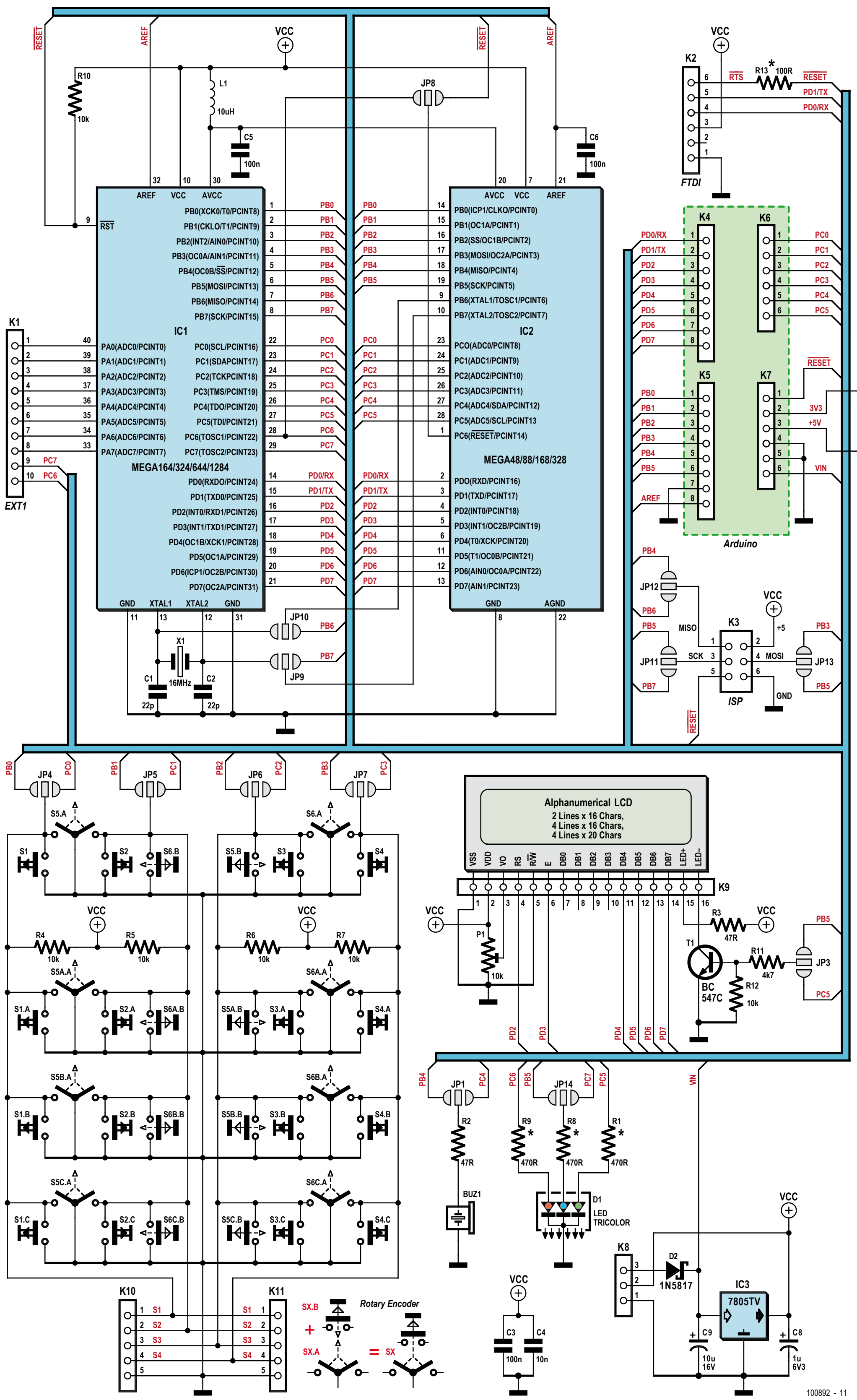
"My crystal is a standard 16 MHz, I carry it on my solder side to avoid contact with certain circuit board traces. My BUZ1 of 12 mm diameter has a pitch of 6.5 mm. Now the connectors. They are single row crimp connectors with a pitch of 0.1 inch (2.54 mm) except K3, this is a type with 2 x 3 contacts. K4 to K7 are female and offer a place for a shield. K1 and K9 may be either female or male. K1 has 10 contacts, K4 and K5 have 8, K6 and K7 have 6 and K9 has 16. K2 is a male model with 6 contacts (the right-angle version, very practical) and K8, also male, has only 3 pins. Finally I sometimes wear IC sockets for IC1 or IC2. IC2 requires a DIP socket with 28 pins and with a width of only 7.62 mm, and for IC1 a standard DIP socket with 40 pins".

"Yes, but what about my pushbuttons! Well, these are type 3FTL6 from Multimec, available from Farnell. My rotary switches are Alps type EC12E2424407 (with pushbutton switch) or EC12E2420404 (without pushbutton switch), also to be found at Farnell".

"I have a number of displays with different dimensions, 2 x 16, 4 x 16 or 4 x20. They are all suitable, provided they have a single row interface connector with 14 or 16 pins, to the left and above the display, with the condition that the connections correspond. The controller integrated into the display module needs to be compatible with the software libraries for the display driver, HD44780 is a standard when it comes to this".



The schematic diagram plays a secondary role to Platino in this article.



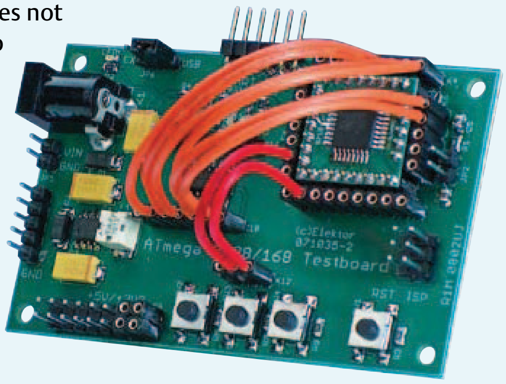
Platino to star in Elektor/element14 webinar

The family

Platino does not deny his heritage and proudly shows his descent from the ATM18 BASCOM-AVR/AVR-GCC lineage. When Platino provides accommodation to a 28-pin microprocessor, he does not have the use of the AD6 and AD7 signals that his little nephew the ATM18 [4] has, so they are not completely compatible. But if these signals are indispensable for a particular application then it is sufficient to replace the microprocessor with a type that has 40 pins. It is probably necessary to reconfigure a few ports or move a few wires because the vast majority of microprocessors has a port A, which the little microprocessor does not have.

In honour of a distant family member of the extended AVR microprocessor family of development boards, Platino has ensured that the control of the LCD is compatible with the Mikroelektronika libraries, which uses port D by default in 4-bit mode.

In spite of a few exceptions, Platino is a practical, modest and approachable circuit board who would love nothing more than to serve a broad audience. That is why everybody adores him.



Internet Links

[1] Platino: www.elektor.com/100892

[2] J²B: www.elektor.com/110274

[3] Arduino : www.elektor.com/080931

[4] ATM18: www.elektor.com/atm18

Function	Jumper	My choice
Buzzer BUZ1 on **PB4** or **PC4**	JP1	☐PC4 ☐PB4
Selection of power supply voltage from an Arduino *shield*: 5V or 3.3V.	JP2	☐3.3V ☐5V
Controlling the backlight via **PB5** or **PC5** Note: choosing PB5 here prevents the choice via *JP14*.	JP3	☐PB5 ☐PC5
S1 connected to **PB0** or **PC0**	JP4	☐PB0 ☐PC0
S2 connected to **PB1** or **PC1**	JP5	☐PC1 ☐PB1
S3 connected to **PB2** or **PC2**	JP6	☐PC2 ☐PB2
S4 connected to **PB3** or **PC3**	JP7	☐PB3 ☐PC3
Approval to connect **PC6** of IC2 (DIL28) to /Reset.	JP8	☐PC6
Approval to connect **PB7** of IC2 (DIL28) to the crystal. Always use in combination with JP10.	JP9	☐PB7
Approval to connect **PB6** of IC2 (DIL28) to the crystal. Always use in combination with JP9.	JP10	☐PB6
SCK-ISP : Connected with **PB5** when using IC2 Connected with **PB7** when using IC1	JP11	☐PB5 ☐PB7
MISO-ISP : Connected with **PB4** when using IC2 Connected with **PB6** when using IC1	JP12	☐PB4 ☐PB6
MOSI-ISP : Connected with **PB3** when using IC2 Connected with **PB5** when using IC1	JP13	☐PB3 ☐PB5
Connect with **PB5** for ''Arduino'' compatibility (see also *JP3*), otherwise with **PC7**.	JP14	☐PB5 ☐PC7

The Dream of Electric

From the electric airship (1884) to the Green Flight Challenge (2011)

By Ernst Krempelsauer (Editor, Elektor Germany)

The dream of silent, pollution-free flying is now a reality. The first type-certificated aircraft with electric propulsion has been in production now since 2004 and the Airbus parent company EADS has recently tabled a radical design concept for future commercial airliners powered by electricity.
We take a look at the emerging technology and the NASA-funded (now also Google) 'Green Flight Challenge' eco-aircraft competition, with prize money of 1.65 million dollars up for grabs it promises to be the most rewarding aviation contest yet devised.

(Image: EADS)

The fossil fuel debate invariably focuses on the motor car because this is where the biggest differences can be made. Up in the sky however there is also a quiet revolution going on. Electrically propelled flight actually predates (by almost 20 years) the Wright brothers first heavier-than-air flight. Back in 1884 the airship 'La France' lumbered through the sky propelled and steered by an electric motor driven by a battery.

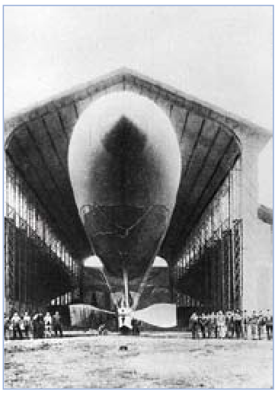


Figure 1. Pure innovation: The airship 'La France' in 1884, it was the first steerable airship, the first to have electric drive and the first to use Redox flow Batteries. Image: Wikimedia Commons/Photo (1885), 2001 National Air and Space Museum, Smithsonian Institution.

From electric airship to electric flight

The airship 'La France' that Charles Renard and Arthur Krebs built close to Paris (**Figure 1**) was powered by a 5.6 kW (later 6.3 kW) DC-Motor [1] from energy stored in a 435 kg zinc/chlorine flow battery. The battery which Renard invented was the first example of a 'Redox flow battery' [2] and was to be reinvented in the 1950s. It is still in use today to smooth demand peaks in power networks. After 'La France' made its last voyage the electric motor as a primary means of propulsion made an exit from our skies and 70 (noisy) years passed before it reappeared.
The model aircraft designer Fred Militky made many attempts to build electrically powered models before his 'Silentius' [3] was introduced in kit-form in 1960 by Graupner. The power to swing the large folding propeller was provided by a 2 to 4 V coreless motor-gearbox (Micro T 03/15) from Faulhaber drawing a current of 1.5 A, i.e. little

Flight

more than 5 W with an efficiency of just 70 %. Energy came from two sealed 2 V lead/acid batteries from Rulag. The 140 gram model can still be built from the plan and after 51 years the original motor is listed in the current Graupner catalog! [4]
We need to wait now until 1973 to witness the first 'heavier than air' manned electric flight; again the initiative came from Fred Militky.

E-Motorglider

In October 1973 Fred Militky became the first to pilot an electrically powered aircraft [5]. The flight took place in Wels (Austria) using a motorglider type HB-3 airframe (designed by Heino Brditschka). A 10 Kw Bosch DC motor [6] was shoehorned into the space normally filled by a four-stroke VW engine. Power came from a bank of VARTA NiCd rechargeable batteries weighing 125 Kg, giving sufficient energy to lift the aircraft up to 1500 feet for the 25 minute flight. This achievement was not matched until 1981 when a team working with the pedal powered Gossamer Condor covered one of the flimsy aircraft with solar cells to produce a craft powered by solar energy.

While electric drive using power derived purely from solar cells is still experimental, in combination with today's rechargeable cell technology it is a good solution for some applications. In particular together with a retractable motor/propeller it provides gliders with a self-launch capability, attaining sufficient altitude to allow several hours soaring. In addition it can be deployed to provide a boost between thermals and to assist the homeward leg to the airfield. Conventionally a small, low power (15 to 50 kW) two-stroke or Wankel motor with a tiny fuel tank would be used but the electric motor has a number of advantages: reduced noise and vibration, more reliable engine starting and running, no requirement for complex systems such as an electric starter, propeller brake or parking system to ensure the propeller retracts into the fuselage. For sure an electric motor provides a more elegant solution here. This is however not true of the energy storage system: a full 20 liter petrol tank stores enough energy to supply 175 kWh, a similar volume Li-Ion battery pack can only store around 5 kWh and is also much heavier. A modern motor and regulator unit can however achieve over 90 % efficiency and this, despite the relatively poor energy density of rechargeable cells is sufficient for the needs of a glider. Given the advantages of electric drive its success will depend on cost.
The first commercial electric motorglider (the AE-1 Silent) with retractable propeller built by Air Energy [7] of Aachen (Germany) began development in 1991 and made its maiden flight in 1997. In 1998 it became the first electric aircraft to gain type certification (with 12 m (40 feet) span and 195 kg empty weight it qualifies in the ultra light category). The motor produces 13 kW and weighs 8.5 kg, The Li-Ion batteries weigh 35 kg and store 4.1 kWh.
The first high power electric glider was the 'Antares' from Lange Aviation [8], which was also employed by DLR as a test bed (**Figure 2**) for their research into fuel cell technology [9]. The Antares has been in production since 2004 and was the first to use the EM42 electric motor developed by EASA (at the time it was the only one available). The EM42 is a brushless DC motor with a rotating outer casing. It measures 25 cm in diameter and 27 cm long, operating from 190 to 288 V producing 42 kW (peak) and drawing 160 A. Weighing in at 29 kg (plus around 10 kg for the control electronics installed in the fuselage) the production version operates at an efficiency of over 90 % giving a maximum torque of 216 Nm. The motor and electronics [10] were developed at the HTA (University) in Biel Switzerland (now renamed BFH TI Bern) between 1996 and 1998. A useful feature of the stepper motor operation is that it allows the prop to be exactly positioned before the unit is retracted.

Figure 2. The Antares 20E from Lange Aviation — shown is the DLR-Version with hydrogen tank and fuel cell in pods slung beneath the wing. Image: DLR.

Energy is stored in 72 type VL41M Li-Ion cells made by SAFT [11]. Each individual cell is rated at 44 Ah at 3.7 V; in series they produce 266 V and 12 kWh. With this amount of power on tap the Antares climbs to 1000 m (3300 ft) in around four minutes and after 13 minutes has reached its maximum of 3000 m (10,000 ft)! Assuming no assistance from any thermals, this altitude is sufficient for over 1.5 hours flying time covering a distance of 150 km (93 miles). The electronic system provides motor control, battery supervision (including telemetry via GSM modem) and a built-in battery charger (nine hour recharge cycle from 230 VAC or 115 VAC). The SAFT cells are good for over 3000 cycles and can be expected to last around 20 years at 20 °C. The batteries have a guaranteed availability up until 2031.
This power drive technology from Lange has also been used to provide a self-launch capability for the high-performance two-seater Arcus sailplane designated the Arcus-E and produced by the German company Schempp-Hirth Flugzeugbau [12], its first flight was in 2010.
The prize for the first two-seater electric aircraft must however go to the Taurus Electro from Pipistrel [13]. Based in Slovenia the company first flew this craft in 2007. The production version has been flying this year and is provisionally classed as an ultralight aircraft.

Flying with a fuel cell

Around ten years ago two teams, one from NASA and the other from Boeing set out to develop an aircraft electrically powered by fuel cells. At the Aero 2003 event held in Friedrichshafen, Germany the motor-glider Super Dimona was presented as a test bed for Boeing fuel cell with a test flight programmed for the 17th December 2003 (100th anniversary of powered flight). In fact it wasn't until March 2008 that the first manned flight powered by a fuel cell occurred. The available power was an issue with the design and meant that the craft could only sustain level flight. A Li-Ion battery pack was added to provide the extra power necessary for take-off. A complete flight powered by a fuel cell alone was not achieved until July 2009 with an Antares-E-motorglider described in this article, Provided by the company DLR as a research platform the aircraft was designated Antares DLR-H2 [27] featuring an external hydrogen tank and 25 kW fuel cell unit slung beneath the wings in two pods. The Antares DLR-H2 achieved a speed of 170 km/h (105 mph) and 750 km (465 miles) range during a five hour flight when it set a new altitude record of 2558 meters (8392 feet).

Since 2010 work has progressed with its successor the DLR-H3 [28].

This is again based on the Antares-E and features 4 wing pods and a non-retractable tail-mounted pusher prop. With its 23 m (75 ft) wing span this new design promises a range of around 6000 km (3700 miles) and a flying time of 50 hours with a 200 kg payload. (Image: DLR).

The drive system uses an external rotor motor providing 40 kW start and 30 kW continuous power. The battery pack contains 128 or optionally 192 LiPo 10 Ah cells giving 4.75 kWh or 7.1 kWh (battery weight 42 kg or 55.6 kg). The Taurus will form the basis for Pipistrel's entry into the 'Green Flight Challenge' aircraft competition.

Experimental

From the motor assisted parachute to the electric helicopter from Sikorsky we have witnessed a leap of interest in electrically powered aircraft over the last ten years mainly brought about by the introduction of novel new materials and improved motor/battery technology. Many of the designs are a result of 'electrifying' an existing aircraft, mostly either amateur or ultralight aircraft. A team from Turin university took a two seater ultralight aircraft type Alpi 300 and fitted it with a 62 kW electric motor and managed to set a world speed record for electrically powered craft of 250 km/h (155 mph) [14] which still stands today. Flight times are however limited to just 15 minutes. The helicopter manufacturer Sikorsky have an ongoing project Firefly [15] where the conventional power plant of a (Hughes/Schweizer 300) helicopter has been replaced by a 140 kW electric motor. Power is supplied from a bank of Li-Ion rechargeables. Cessna have collaborated on a conversion of one of their C172 (the most produced four seater aircraft in the world) light aircraft to demonstrate electric flight possibilities (at least for a few minutes anyway) [16].

There have also been a number of new designs specifically intended for electric flight: the two-seater Yuneec E430 [17] from China (**Figure 3**) and the single seat Elektra One (**Figure 4**) from the German design company PC-Aero [18]. While the Yuneec is designed as a passenger motorglider, the Elektra One is more compact and employs efficient aerodynamics to conserve energy. See **Table 1** to compare their specifications. Tian Yu the founder of Yuneec has for many years specialized in the supply of electric model aircraft and their components. Only recently has he branched out into full-scale versions.

Green Flight Challenge

To encourage teams working on sustainable flight technologies NASA (and now Google) are sponsoring to the tune of 1.65 million dollars the Green Flight Challenge (GFC). The contest designed by

Figure 3. The Yuneec E430 is the first electric aircraft from China developed by a model aircraft manufacturer. Image: Yuneec.

Figure 4. Elektra One from PC-Aero for the Green Flight Challenge (GFC). Uses solar panels on the hangar roof to recharge. Image: PC-Aero, Copyright Shahn Sederberg.

CAFE (Comparative Aircraft Flight Efficiency Foundation) [19] will take place from the 25th September until the 3rd October 2011 in Santa Rosa California.

The competition rules do not stipulate any particular method of propulsion. Team aircraft must fly 200 miles (322 km) in less than two hours using the energy equivalent or less than 1 gallon of petrol or 33.7 kWh (the equivalent energy) per occupant. Everyone seated in the aircraft counts as a passenger so for a two-seater the upper limit of fuel consumption is 2.36 l/100 km (100 MPG) while a single-seater is allowed just 1.18 l/100 km (200 MPG)!
The equivalents for electric aircraft are 21 kWh for a two-seater and 10.5 kWh per 100 km (62 miles) for a single-seater.
Thirteen teams have qualified for the competition (**Table 2**), dem-

Table 1. Comparison of Elektra One and Yuneec E430

	Elektra One	Yuneec 430
Number of seats	1	2
Wing span	8.6 m (28 ft)	13.8 m (45 ft)
Empty weight (no batteries)	100 kg	171.5 kg
Battery weight	100 kg max	83.5 kg
Empty weight (incl. batteries)	200 kg max	255 kg
Payload	100 kg	175 kg
Max. weight	300 kg	430 kg
Max. power	16 kW (22 HP)	40 kW (54 HP)
Battery	LiPo	LiPo
Capacity	n.a.	100 Ah
Battery voltage	n.a.	133.2 V
Cruising speed	160 km/h (100 mph)	95 km/h (60 mph)*
Max endurance	> 3 h	ca. 2 h*
Operating range	500 km max	ca. 190 km*

** Provisional figure*

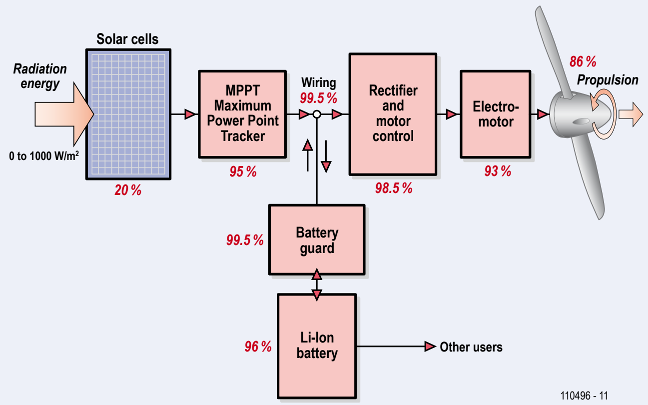
Table 2. The Green Flight Challenge Teams and aircraft

No.	Team	Aircraft (name)	No of seats	Wingspan	Max power	Power source
1	Einar Enevoldson PC Aero (Germany)	Elektra 1	1	8.6 m (28.2 ft)	16 kW (21 HP)	electric
2	Gene Sheehan Feuling GFC (USA)	Team Feuling GFC	1	5.1 m (16.7 ft)	16 kW (21 HP)	electric
3	Gregory Cole Windward Performance (USA)	Goshawk	2	15.5 m (51.0 ft)	n.a.	electric
4	Lawrence Speer Green-Elis (France)	Greenelis PXLD	2	10.8 m (35.5 ft)	30 kW (41 HP)	Biodiesel (Smart-Diesel)
5	Mike Stude Michael Stude (USA)	Wings of Salvacion	1	5.1 m (16.7 ft)	32 kW (44 HP)	ethanol
6	Richard Anderson Embry-Riddle Aeronautical University/Stemme (Germany)	EcoEagle (Stemme S10)	2	23 m (75.0 ft)	100 kW (136 HP)	Biofuel-hybrid (Rotax 914F)
7	John W. McGinnis Synergy (USA)	Synergy	6	9.8 m (32.0 ft)	142 kW (193 HP)	Biodiesel
8	Greg Stevenson GSE-Aerochia (USA)	Econo-Cruiser 3000	2	14.7 m (48.3 ft)	15 kW (20 HP)	Biofuel-hybrid
9	Ira Munn IKE Aerospace (USA)	SERAPH	1	4.6 m (15.0 ft)	30 kW (41 HP)	Biodiesel-hybrid
10	Eric Raymond e-Genius/University of Stuttgart (Germany)	e-Genius	2	16.9 m (55.4 ft)	60 kW (82 HP)	electric
11	Jim Lee Phoenix Air (Czech republic)	PhoEnix (Phoenix)	2	14.4 m (47.3 ft)	44 kW (60 HP)	electric
12	Scott Sanford Yuneec (China)*	Yuneec E 1000	3	17.0 m (56.0 ft)	120 kW (163 HP)	electric
13	Jack Langelaan Penn State University/Pipistrel (Slovenia)	Taurus G4 (Taurus)	4	21.0 m (69.1 ft)	145 kW (197 HP)	electric

** contestant witdrawn, see text*

Solar powered flight

The history of solar flight [29] started began with unmanned aircraft. The 10 kg Sunrise I built by Ray Boucher of California first flew in 1974. A later model achieved an altitude of 5000 m in 1975. In Europe by 1976 Fred Militky had made the first flight of a remotely controlled solar powered aircraft. The pedal-powered Gossamer Condor and Albatross designed by the legendary Paul MacCReady really paved the way for solar powered manned flight. In 1980 a reduced size version of the Albatross named the Gossamer Penguin was covered in solar cells and an electric motor installed. Power was marginal so MacCready's son piloted the test flights. When the sponsors asked for an adult pilot to be used before publicity photos were taken the call went out for a pilot weighing around 95 pounds (43 kg). Janice Brown fitted the requirements and happened to be



an experienced commercial pilot. In the first official 'manned' solar flight she piloted the craft over a three kilometer course in 14 minutes. The next milestone was when MacCready's 14 m wing span Solar Challenger flew from Paris to London in July 1981.

In Germany the design professor Günther Rochelt flew his ultra-light solar electric motorglider Solair 1 on a flight lasting almost six hours in 1983 (with assistance from thermals). Using a similarly designed solar glider named Sunseeker Eric Raymond took two weeks to fly across America in 1990. Both of these designs use a motor rated at 2.2 kW which is an order of magnitude less than the 14 kW motor used for the Icaré 2 built by Stuttgart University which went on to win the Berblinger contest in 1996. More recently we have seen the impressive four-engine Solar Impulse [30] designed by Bertrand Piccard and André Borschberg of Switzerland. With this design it should be possible to circle the globe using just the energy collected by its solar cells [31]. The design of energy supply for continuous solar operation must consider many factors as shown in the figure.

Taking in to account the efficiency of the complete system we can expect that of all the energy falling on the PV solar collectors surface (on a summer's day approximately 500 W/m²) only around 13 % will end up driving the propeller. The principle loss in the system is suffered by the solar cells which can only achieve around 20 % efficiency at best. Energy needs to be stored in rechargeable cells during daylight for use over the next 24 hours. As a consequence a large surface area is necessary to accommodate the cells and act as an aerofoil. The relatively low power yield dictates that the airframe

must be as light as possible but still flyable with the available low engine power. If we assume a solar radiation figure of 250 W/m² over a 24 hr period, the power available to the motor, taking in to account losses in the batteries of 12 % will only be 30 W per square meter of solar cell area. The solar cells mounted on the wing and tail plane of the Solar Impulse cover a surface area of 200 m² giving a power of 6 kW (8.2 HP) available to the motor. This has been calculated to keep the 1.6 ton aircraft aloft both day and night at a speed of around 70 km/h (43 mph) (For comparison the first aircraft made by the Wright brothers in 1903 had 12 HP).

Shortly after its first flight in 2009 the Solar Impulse prototype set records for a solar powered craft by achieving an altitude of 9000 m and a 26 h flight time.

onstrating a real mix of propulsion units and aircraft configurations: from 1 to 6 seater, 5 to 23 m (16 to 75 ft) wing span, 15 to 145 kW (20 to 197 HP) power units mostly choosing electric but also biofuel hybrids, ethanol and biodiesel. Entrants using biofuels (biodiesel/ethanol) are at a disadvantage so the requirements for this category has been relaxed and a 'biofuel prize' introduced [20].

All participating teams require an American team leader; six of the thirteen teams are based in Europe. Sadly the only Chinese team to qualify (Yuneec E1000) has since withdrawn following a mishap during trials. While the European entries such as the Elektra 1 and Greenelis are derived from motorgliders, entries from the US such as the 'Synergy' (**Figure 5**) and 'Seraph' (**Figure 6**) look quite futuristic. There are also some quite radical looking motorized gliders (**Figure 7**).

The best chance of success must go to the electric entrants with two or more seats. A team from the institute of aircraft design at Stuttgart university [21] under the leadership of Prof. Rudolf Voit-Nitschmann have already tested their two seater e-Genius (**Figure 8** and **Table 3**) in June 2011 and achieved an average speed of 164 km/h (102 mph) over a distance of 341 km (212 miles) demonstrating a fuel consumption of just 46 kWh (13.5 kWh/100 km) equivalent to 1.5 l/100 km (157 MPG) or 310 passenger miles per gallon (PMPG), exceeding the GFC requirements by 55 %, that's impressive!

Figure 5. The 6-seater Synergy will take part in the GFC powered by its 142 kW (193 HP) bio-diesel motor.
Image: CAFE Foundation Blog.

Figure 6. This single-seater Seraph using a biodiesel hybrid engine is one of the more unconventional entrants for the GFC.
Image: CAFE Foundation Blog.

The future for E-Flight

Basically the limitations of airborne electric propulsion are the same as those faced by terrestrial vehicles: We need better batteries! With efficiencies around 90 % for motor and control subsystems, there is little room left for improvement. Battery technology at the moment is sufficiently developed to make self-launching glid-

Internet Links

[1] http://rbmn.free.fr/Ballon_photos_10.html

[2] www.poweringnow.com/technology/history

[3] www.modellflugsport.ch/upload/museum/geschichte/modelle/Silentius.pdf

[4] www.graupner.de/de/products/a1899b43-43cd-4cea-8e22-e05d381420e6/1725/product.aspx

[5] www.flightglobal.com/pdfarchive/view/1973/1973%20-%202921.html

[6] www.airventure.de/historypics/Emose1.jpg

[7] www.airenergy.de/index.html

[8 www.lange-aviation.com

[9] www.dlr.de/tt/desktopdefault.aspx/tabid-4935/8219_read-13587

[10] http://ecweb.redcor.ch/fachtag-energie/referate/referate/ws2_2_andreavezzini_light.pdf

[11] www.saftbatteries.com/Produit_Large_VLM_cell_range_301_62/Language/en-US/Default.aspx

[12] www.schempp-hirth.com/index.php?id=nimbus-4dm1

[13] www.pipistrel.si/plane/taurus-electro/overview

[14] www.skyspark.eu/web/eng/index.php

[15] http://blog.cafefoundation.org/?p=1438

[16] http://blog.cafefoundation.org/?p=1422

[17] http://yuneec.com

[18] http://www.pc-aero.de

[19] http://cafefoundation.org/v2/gfc_main.php

[20] http://cafefoundation.org/v2/pdf_GFC/2011_06_30_GFC_Prize_Structure.pdf

[21] http://www.ifb.uni-stuttgart.de/index.php/forschung/flugzeugentwurf/hydrogenius

[22] http://yuneec.com/paramotor.html

[23] www.flightdesign.com/index.php?page=presentation

[24] www.elektor.de/elektronik-news/hybrid-elektrisches-flugzeug.1871506.lynkx

[25] http://www.pipistrel.si/plane/panthera/overview

[26] www.eads.com/dms/eads/int/en/press/documents/Dossiers/Downloads/EADS-Brochure_VoltAir_English.pdf

[27] www.dlr.de/tt/desktopdefault.aspx/tabid-4935/8219_read-13587

[28] www.dlr.de/desktopdefault.aspx/tabid-6216/10226_read-26189

[29] www.solarflugzeuge.de (UK: www.asl.ethz.ch/research/asl/skysailor/History_of_Solar_Flight.pdf)

[30] www.solarimpulse.com

[31] www.mp.haw-hamburg.de/pers/Scholz/ewade/2009/EWADE2009_Ross_Paper.pdf

Figure 7. Pipistrel from Slovenia has combined two Taurus motorgliders together with a 145 kW electric motor to make this twin-fuselage entry for the GFC. Taking advantage of the 'per passenger' calculation of fuel allowance. Image: Pipistrel.

Table 3. The e-Genius specs:	
No of seats	2
Wing span	16.9 m (55.4 ft)
Payload	180 kg
Max. weight	850 kg
Power continuous/peak	60/100 kW (82/136 HP)
Motor configuration	Water cooled permanent magnet synchronous motor
Motor dimensions	27 kg/25 cm/28 cm
Prop diameter	2.2 m (7.2 ft)
Batteries	Lithium-Ion/56 kWh
Motor, battery and controller weight	336 kg
Motor controller efficiency	> 90 %
Cruising speed	140 to 235 km/h (87 to 146 mph)
Max. climb rate at 850 kg	4.5 m/s (15 ft/s)
Flight duration	4 h approx
Range	> 400 km (250 miles)

ers and motorized parachutes [22] a practical proposition. With further development like the E-Genius and the Elektra 1 it is likely that a market will open up for passenger motorgliders and ultralights. Linked together with solar PV modules fitted to the aircraft hanger (PC-Aero/SolarWorld), transport trailer (Taurus-G2/Pipistrel) or a wind turbine (Arcus-E/Windreich) to charge the batteries. The dream of emission-free flying using totally renewable resources is now reality.

An aircraft using hybrid technology is also conceivable such as the design proposal by Flight Design [23] and EADS/Siemens/Diamond-Aircraft [24] which have already been demonstrated.

The next step can only come when improvements to battery technology make it possible. The Slovenian manufacturer Pipistrel has the vision and faith to have designed not only a hybrid passenger aircraft but also a pure electric version called the Panther [25]. The water-cooled 145 kW electric motor is already used in the GFC Taurus-G4 (Figure 7).

Scaling things up a bit the Airbus mother concern EADS has proposed an electric ducted fan unit to power future commercial aircraft. This VoltAir concept [26] published in May gives a optimistic glimpse into what may be the future for air travel. The design envisions a system using easily interchangeable Lithium/air batteries with an energy density of 1000 Wh/kg. The electric engine employs super-conducting materials cooled with liquid nitrogen (**Figure 9**). With a projected 7-8 kW/kg the power plant would have a better power to weight ratio than contemporary turbo prop designs. It could be within the next 25 years that we at last realize the dream of quiet, emission-free, economical and more comfortable long-haul flying compared to the ecological nightmare of our present day technology.

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Figure 8. Originally the 'Hydrogenius' this fuel cell concept e-Genius from Stuttgart University is a very efficient electric flyer competing in the GFC contest. Image: e-Genius-Team, IFB University Stuttgart.

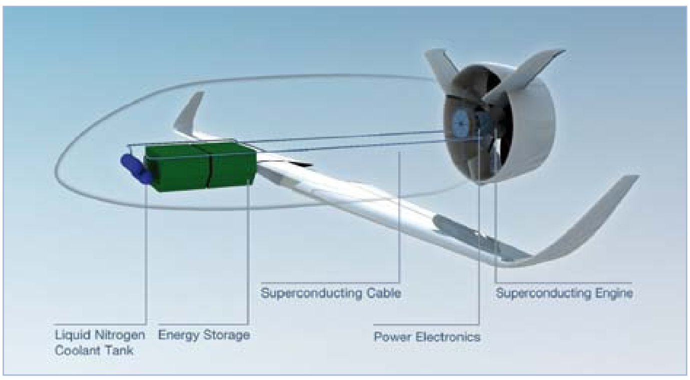

Figure 9. A look into the future according to EADS (Airbus parent company). Using super conducting materials, liquid nitrogen and (much) better batteries, condensation trails will be just a faint memory. Image: EADS.

Groping in the Dark

Webcam conversion to night-vision camera?

By Thijs Beckers (Elektor Netherlands Editorial)

Cameras with night-vision capability are not all that cheap. Webcams are. Can you modify such a webcam so that it becomes suitable as a night-vision camera? Several Internet sites claim that this can be done. We will put some these claims to the test.

There is a nearly limitless supply of these on the Internet: tutorials for converting all kinds of (electronic) devices. This time our eyes were drawn to converting a cheap webcam into a camera with *night-vision* capability, that is, a camera which is still able to see in complete darkness. The phrase 'in complete darkness' is however a little deceptive in this case. To illuminate the field of view of these cameras an infrared floodlight is used, which operates at a wavelength that is not visible to the human eye (all electromagnetic radiation above 780 nm).

Anyhow, we were very curious whether this would be possible with any arbitrary webcam. According to the tutorials, you have to remove the IR filter that is in the camera, so that infrared light will now also register on the CCD of the camera. So, time to get cracking.

Not too expensive

For our 'test' we 'borrowed' two webcams from our colleagues. Preferably as cheap as possible. We had a Sweex WC002 and a König Computer CMP-Webcam75 at our disposal, neither more expensive than $30. As a consequence, the quality of the images is not that great, but that was to be expected. The CMP-Webcam75 had the biggest CCD and also the highest resolution: the camera can supply up to 1290 x 960 pixels. Displaying the image with the same resolution on the laptop screen resulted in the 'best' picture. By the way, the webcam is offered on several web sites as a 'webcam with night-vision'. But don't be fooled: the four built-in *white* LEDs are barely sufficient to illuminate your face when you're directly in front of the camera, while chatting and the like. Anything further away than about 1 meter remains practically invisible to the unmodified camera.

Results before...

After installing the accompanying drivers for these webcams, we decided to test the cameras before making any modifications, so that we could clearly establish any differences brought about by the modifications. In the basement we found a place were we could work that was practically completely dark, which was therefore perfect for our test location.

First we looked at the images with the lights still on (**Figure 1**). On the left is the picture from the CMP-Webcam75, which is set to 640x480 and on the right the picture from the WC002, set to a resolution of 352x288. For clarity we stretched the latter picture to the same size as the König webcam. Although the Sweex claims that 640x480 is possible, this is not the case at 30 frames per second... Both drivers are at their default settings.

To be able to see something in the dark with these cameras we used

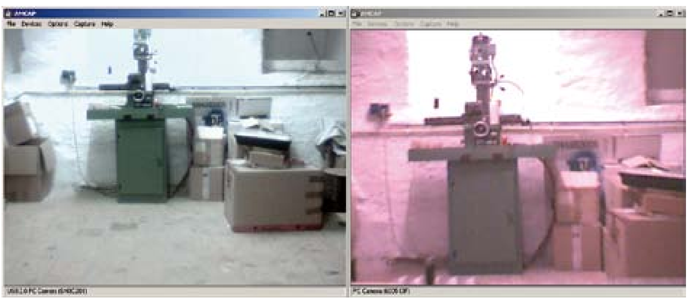

Figure 1. With the lights on both cameras show a (not all that high a quality) image.

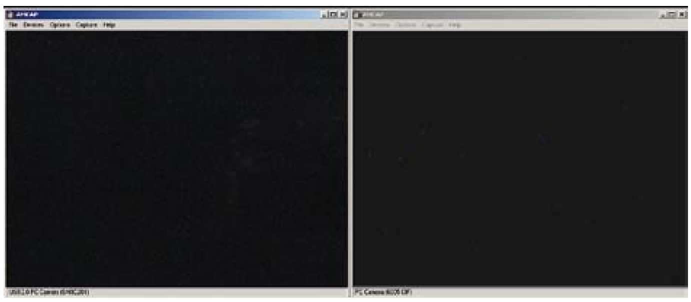

Figure 2. Without lights the image of both cameras remains black.

a few individual IR LEDs and a — somewhat older, but nevertheless still very well functional — IR floodlight with 28 IR LEDs from Conrad Electronics.

Neither of these webcams were able to see anything in complete darkness, despite the fact that the infrared LEDs were turned on (**Figure 2**). Some image noise and the odd lost red, blue or green pixel were the only things visible on the laptop screen. Only when we pointed the IR LEDs directly into the lens could we see that they were actually turned on. It was not possible to recognize any objects at all in the dark.

From this it appears that both cameras have a built-in IR filter. So, open them up, because that has to come out.

...and after modification

The lenses are relatively easily removed from the cameras. The Sweex camera is simply snapped together and with the König the lens can be unscrewed easily. At certain angles it was possibly to see a red gleam on both lenses: the IR filter. With the Sweex lens we suspected that this could be a coating on the outside of the lens. Attempts to remove the coating, even with a strong cleaning solution, proved to be unsuccessful (the plastic of the lens was melted by the solvent, but unfortunately not the coating). The other lens was different. Here it appeared that on the inside there was a real glass filter. After some careful fiddling (it still had to look nice for the camera) we were able to remove the glass and had the IR filter in our hand (see **Figure 3**). And now the proof is in the pudding: was the camera with the modified lens more sensitive to IR light, and if yes, was it actually able to see anything in complete darkness?

Figure 4 shows the picture after modification, on the left the König and on the right the (unmodified) Sweex. We were quite impressed with the difference! Even with only three IR LEDs it already became clear what objects there were in the dark room. And not only the outlines! It was even possible to read the text on the removal box at a distance of about 15 feet. The result with the IR floodlight was even better (**Figure 5**). Movement detection is easily possible. We would even dare to suggest that it would be suitable for a security camera at home.

We do however have to make a marginal note: we noticed that the focus for the modified lens with IR illumination was different from the focus for normal lighting. When we switched the lights on after we had focussed the König lens with IR light, we obtained the picture of **Figure 6** on our screen. It was hard to find the correct focus for the König webcam. This 'trick' is therefore not all that suitable if you want to be able to use the camera both at night and during the day. But because the webcams are so cheap, even the purchase of a pair — one for during the day and one for at night – is still considerably cheaper than a real night-vision camera.

The conclusion is therefore that if the IR filter can be removed, then the webcam is perfectly suitable as night-vision camera, but the IR filter is not easily removed with all cameras.

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Figure 3. With the König lens the removal of the IR filter was quite easy to do.

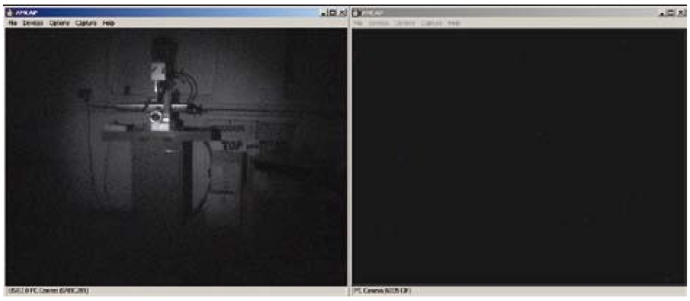


Figure 4. Using only 3 IR LEDs a nice picture already begins to form with the modified camera. The camera with IR filter is still groping in the dark.

Figure 5. The IR floodlight from Conrad makes everything clearer still. People are easily recognizable in complete darkness.

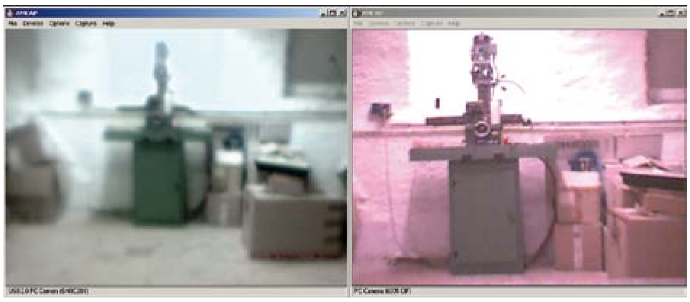


Figure 6. Using the modified camera during both the day and night is unfortunately not very practical: the focusing has to be redone every evening and morning, and by hand.

2.4 GHz Transmitter and Receiver for Model Airplanes

ZigBee technology for model construction

By Michel Kuenemann (France)

For a number of years now, remote radio control systems for models that operate in the 2.4 GHz band have been available. This technology is highly robust against interference and offers the option of telemetry which was not permitted with the older technology which, depending on the country, uses the low VHF 27 MHz, 35 MHz, 41 MHz or other allocated bands. The project described here offers the option of effortlessly expanding a lower VHF system with 2.4 GHz SHF technology. Because this is a fully open system, it can, to a large extent, be adapted to suit your own needs.

Figure 1 shows the block diagram of the system.

Transmitters for remote model control have a connector which includes the standardized PPM-signal (*Pulse Position Modulation*), which contains the information about the channels that are being controlled by the transmitter. This connector is normally used when training new pilots or for connection to a flight simulator on a PC. In our application this signal is connected to a separate enclosure which contains a 2.4 GHz transmitter. This enclosure also contains a battery and an LCD, which turns it into an autonomous subsystem. In this design the pilot can continue to use the transmitter for 35/41 MHz with older model airplanes but also have the option of switching to 2.4 GHz operation quickly and easily.

The receiver built into the model airplane consists of a circuit board to which are connected one or two receiver batteries and the servos. An important advantage of the 2.4 GHz technology is that the relatively long wire antenna, which was often a source of problems with model airplanes, is no longer necessary. This project is an open, experimental system which includes the following communication interfaces: serial (UART), CAN-bus and I²C-bus.

Technology

The design and implementation of a well-performing transmitter- and receiver-module operating at 2.4 GHz is unfortunately outside the reach of most enthusiasts and even many professional electronics engineers. Fortunately, a large number of modules are available commercially, which makes this 2.4 GHz technology readily accessible. We chose the recently introduced module MRF24J40MB made by Microchip [2]. This standardized module is compact, generates enough RF power and, moreover, is affordable. It is therefore an ideal choice for our project. A PIC18LF2685 microcontroller, clocked at 24 MHz, provides effortless control of the various peripherals.

To simplify the realization of this project, the design decision was made to use only one PCB and one program for both the transmitter and the receiver. By fitting a jumper, the board is configured to operate as a transmitter. Without this jumper the board functions as a receiver.

The schematic

The PCB contains all the power supplies that are necessary to satisfy the various requirements of both the transmitter as well as the receiver (**Figure 2**).

The transmitter is powered from a separate lithium-polymer (LiPo) battery. For

A few remarks and warnings

This system has been tested successfully by the author over a period of many months and in different model airplanes, both with electric motors and with combustion motors. The transmitter range in the open field was measured at more than 3000 feet. There was no interference observed with other radio systems and with other model fliers at 41 MHz or 2.4 GHz.

This is however still an experimental project, where you yourself have to carry the responsibility for the implementation and use. The MRF24J40MB radio module from Microchip is officially approved in Europe (ETSI), the US (FCC) and Canada (IC).

The RF output power is 100 mW.

With this system the use of LiPo batteries is recommended. Note that these can explode or cause fire when subjected to excessive mechanical force or when exposed to excessive currents. If you prefer not to use this type of battery then there is absolutely no problem to power the transmitter from three R6 size NiMH cells, and the receiver from NiMH battery packs of four or five cells, which are available from model hobby shops.

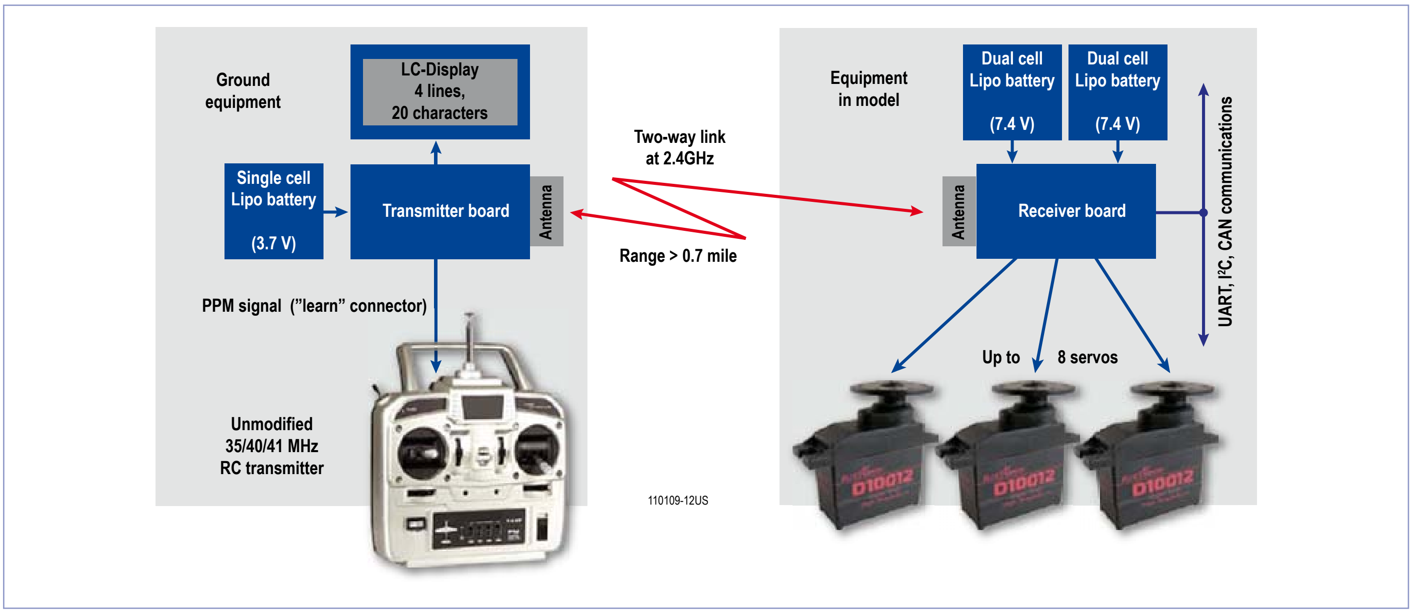


Figure 1. Design of the system.

this purpose the board contains a charger, which charges the battery with a constant current of about 200 mA, without ever exceeding the maximum voltage of 4.2 V. The circuit for the charger is built around an LM317 (U4), where a BC848 (T3) together with shunt resistor R20 take care of the current control. This module can charge a 1000 mAh battery in a few hours. The on/off-switch of the transmitter connects the battery with the charger when the transmitter is switched off. The charging circuit is compatible with any mains adapter that can supply at least 9 V_{DC} at 250 mA. Using a battery with a capacity of 1000 mAh the transmitter can be operated for more than 15 hours continuously.

The power supply for the receiver has the unusual feature of being redundant with the use of two separate batteries. This means that if during the flight there is a defect in one of the batteries the receiver will con-

Technical characteristics

- Transmission of 8 proportional channels
- PPM-modulation, compatible with all transmitters for 35/40/41 MHz
- Existing transmitter does not have to be modified
- Receiver with dual power supply and linear regulator for one or two LiPo batteries
- Remote voltage measurement of the receiver batteries
- Receiver compatible with BEC power supply
- Remote signal strength measurement of the receiver (RSSI)
- Remote current measurement of the receiver with calculated energy use in mAh
- LC-display at the transmitter for indicating the parameters
- Audible alarm signal at the transmitter
- Open communication interfaces: UART, CAN, I²C
- ZigBee technology
- Range of more than 3000 feet in the open field, verified by the author
- Reaction delay 20 ms

tinue to operate without any noticeable interruption. This 'switch-over' between the two batteries is done simply with two diodes. This type of circuit is often used in fault-tolerant systems (aviation) and is very reliable. This high reliability level can only be reached if the voltage supplied by both batteries is checked before the flight. Otherwise a latent defect in a battery will inevitably lead to a crash of the airplane if the second power source runs flat or becomes faulty during the flight. The use of two receiver batteries is not mandatory, but is certainly strongly recommended when flying one of the more expensive model airplanes.

The measurement interfaces for the battery voltage are made from two voltage dividers R21-R22 (battery A) and R29-R31 (battery B). In the schematic you can also see that voltage divider R21-R22 is also used for measuring the voltage of the transmitter battery.

The linear regulator MC33375 (U6_1) supplies the voltage of 3.3 V, which is necessary for the microcontroller and the 2.4 GHz module, as we will see later on.
The charge pump ICL7660 (U5) inverts the 3.3 V voltage rail and turns it into a negative voltage, which is necessary for the proper operation of the LCD-module that is used in the transmitter. The LT1764A linear regulator supplies a voltage of 6 V at up to 3 A for powering the servos of the airplane. A shunt of 10 mΩ (R23) together with amplifier LTC6106 (U7) form the measuring interface for the current that the servos draw during the flight.

The power supply line VCAN, which is protected by a fuse, supplies the power for any optional expansion boards.

In models with an electric motor drive, the energy for powering the receiver and the servos is generally supplied by the electronic speed controller for the drive motor, via a circuit which is called the BEC (*Battery Eliminator Circuit*). Compatibility with a BEC power supply is obtained with the aid of a BAT54J diode (D4), which passes the power supply voltage for the servos to the 3.3 V regulator.

Connector CN14 is intended for the connection of the on/off-switch for the radio in the model airplane. This switch works opposite compared to a standard power supply switch: the receiver is powered when the switch is **open**. Because the unintentional closing of a switch is much more unusual compared to the unintentional opening of it, this circuit actively contributes to the reliable operation of the model.

The PIC18LF2685 microcontroller (U2) is, with its 96 KB flash memory, 3 KB RAM and CAN-bus a heavyweight within the range of microcontrollers in 28-pin packages. The microcontroller is clocked with the aid of a 24 MHz crystal, which makes a short software loop time possible, as well as accurate timing for the control pulses to the servos. Ports RA0 to RA3 are configured as analogue inputs and are used for measuring the battery voltages, the VCAN voltage and the current consumption of the servos.

The MAX3054 IC (U1) is a fault-tolerant CAN transceiver with a maximum speed of 250 Kbits/s. This part is optional and you only need to fit it if you intend to use this interface. Connector CN2 is for connecting the CAN-bus and also contains the power supply voltage VCAN which allows multiple expansion cards to be connected in a *daisy chain* configuration.

Connectors CN3 and CN4 are available for your own expansion circuits. Whether a jumper is fitted on CN5 determines the functionality of the board: no jumper = receiver; with jumper = transmitter.

Ports RC1 and RC2 are used for the I²C-bus, which in the receiver mode are used to control the servos and in transmit mode to drive the LCD. Both these ports and the 3.3-V power supply voltage are connected to CN6 and J1. Connector J1 is compatible with the pocket terminal from the April 2009 issue of Elektor [3].

RC6 and RC7 are used for the serial connection (UART) with a signal level of 3.3 V. This

Open project

Even if you are not interested in model construction, you are free to 'hack' this project for home-automation or robotics applications which are based in ZigBee or a CAN- or I²C bus. The generously sized program memory of the microcontroller offers space for the most complex algorithms. Creative model builders can use this project as the basis for experimenting with an automatic pilot or for exotic aircraft such is multi-rotor helicopters.

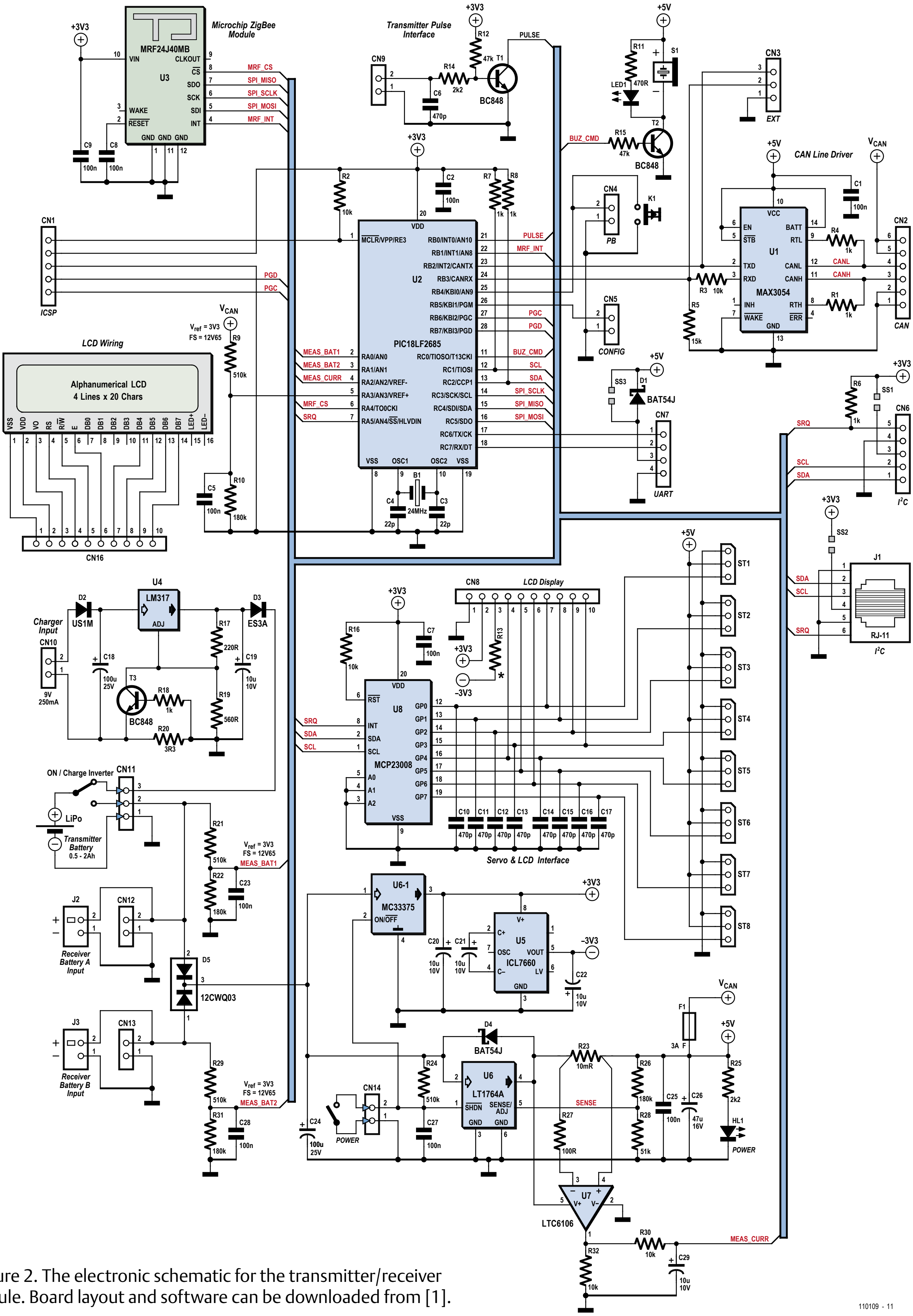


Figure 2. The electronic schematic for the transmitter/receiver module. Board layout and software can be downloaded from [1].

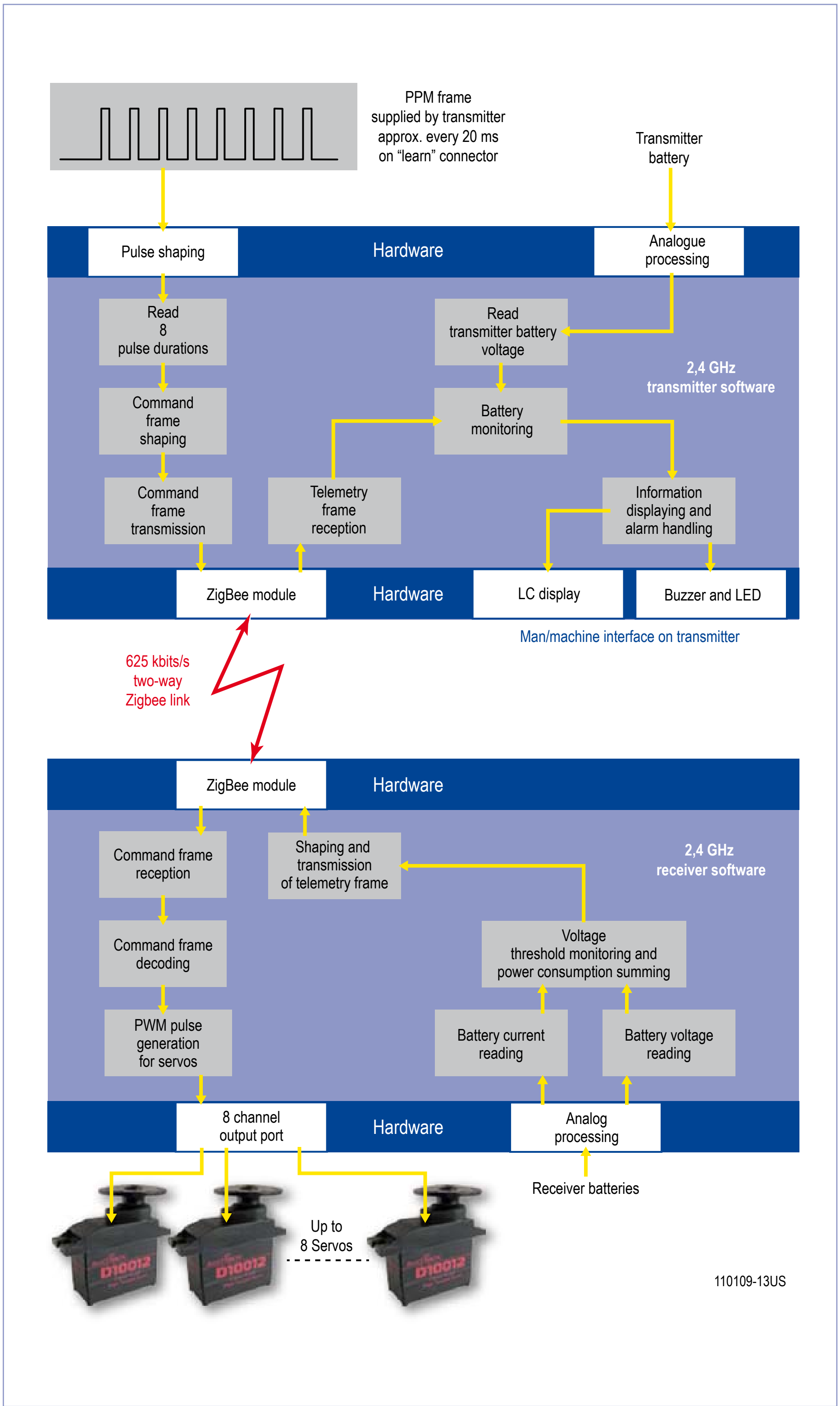


Figure 3. Overview of the different software modules.

communications port, together with the 5 V power supply voltage, is present on connector CN7.

The MCP23008 IC (U8) contains an 8-bit port expansion for I²C. In the receiver mode this part can be used to drive up to eight servos directly, which are connected to eight connectors ST1 to ST8. In the transmitter mode this part forms the interface to a standard LCD module with 4 lines of 20 characters each.

The MRF24J40MB module (U3) provides for 'radio wave' transmitting and receiving of the command frames. This module is fitted with a standard SPI interface and is powered from 3.3 V. The output power of 100 mW is in harmony with regulations set in most countries, but check for yours.

The buzzer, driven by T2, is mainly intended in receiver mode to alert the pilot that one of the measured values is outside its adjustable limit. In the receive module you can replace the buzzer with LED1.
Transistor T1 is the interface for the PPM signal from the transmitter, which enters on connector CN9.

The software

The embedded software is written in C, the complete source code of which you can download from the Elektor website [1]. Its most important characteristic is that it is 'real-time'. It is called this because there is a strict synchronization with the received PPM frames supplied by the transmitter. These frames follow each other at a high rate of about fifty per second. This immediate ability to respond is always present to give the pilot a good feeling of control.
In practice, this system has a delay of less than 4 ms between the end of the PPM frame and the beginning of the command to the first servo in the airplane by the receiver.

Figure 3 shows the most important elements of the programs which are used in the transmitter and the receiver.
For the interested reader, we make the additional remark that the program uses a multitasking kernel, which was written by the

Display line	Measured quantity	Measuring range	Measuring resolution	Unit	Alarm threshold
1	Tx Batt.	0 – 12.65	10 mV	V	< 3.8 V
1	Tx RSSI	0 – 99	1	%	Not applicable
2	Rx Batt. A	0 – 12.65	10 mV	V	< 7.6 V
2	Rx Batt. B	0 – 12.65	10 mV	V	< 7.6 V
2	Rx RSSI	0 – 99	1	%	Not applicable
3	Rx current	0 – 3300	3 mA	mA	Not applicable
3	Rx usage	0 – 9999	1 mAh	mAh	Not applicable
4	Batt. drive voltage (future expansion)	0 – 25.00	10 mV	V	TBD
4	Batt Drive current (future expansion)	0 – 200	1	A	Not applicable
4	Batt. Drive usage (future expansion)	0 – 9999	1	mAh	Not applicable

Table 1: Overview of the measured quantities and their characteristics.

author. This part of the software is essential for obtaining the 'flow' and reaction speed that is required for this application. The kernel and accompanying services are described in a (French language) file that is included with the software package.

Construction and test

You have to work carefully when soldering the MCP23008 and the LTC6106, because these have a pin pitch of only 0.635 mm. The LCD-module in the transmitter is connected via 10 wires to CN8. If your microcontroller is not already programmed then you can do this via the ICSP-interface (CN1) and a programmer from Microchip or one that is compatible with it (ICD2, PICKit or similar).
Resistor R13 determines the contrast of the display. The value depends on the exact type of LCD that is used.
Once everything is mounted, visually check the quality of the soldering, put jumper CN5 on the board and connect a power supply voltage 4.2 V to pins 1 and 2 of CN11. LED HL1 will now light-up briefly and the current consumption has to be around 60 mA. The buzzer will initially sound two short beeps and a welcome message appears on the display. Check whether the power supply voltage is correctly indicated on the first line of the display. Now lower the power supply voltage to 3.8 V. After about 20 seconds the buzzer will sound about 20 short beeps and on the fourth line of the display there will be the message 'No PPM signal'. Connect the trainings connector of your transmitter to connector CN9, switch the transmitter on and check that the error message goes away.

Figure 4. This is what the display shows when powering the transmitter from 4.2 V and the receiver from two 8.4 V batteries.

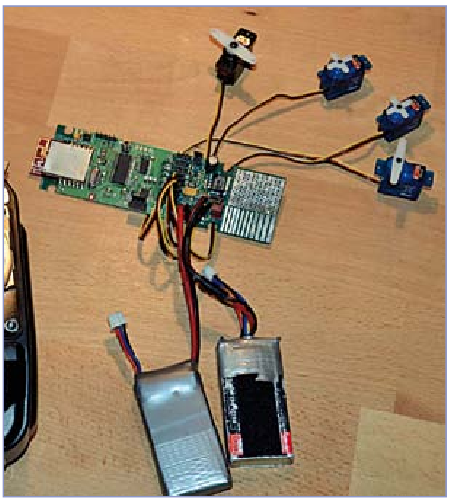


Figure 5. Author's prototype connected to four servos and two LiPo batteries.

The only thing left to test is the battery charger. Connect a voltage of 9 V to CN10 and limit the current to 1 A. Check whether the voltage on pin 3 of CN11 does not go above 4.2 V. Connect pin 3 of CN11 to ground and check that the current drawn by the circuit does not exceed 250 mA.
At this stage a large number of the vital components of your transmitter have been tested. The 2.4 GHz module will be tested in the next step.

In the same manner, assemble and test a second board, where you replace the buzzer with LED1. You can also omit the components for the battery charger. First test the board in transmitter mode. Then remove the LCD module, remove the configuration jumper CN5 and connect a power supply voltage of 8.4 V, first via CN12 and then via CN13. After the power supply is attached,

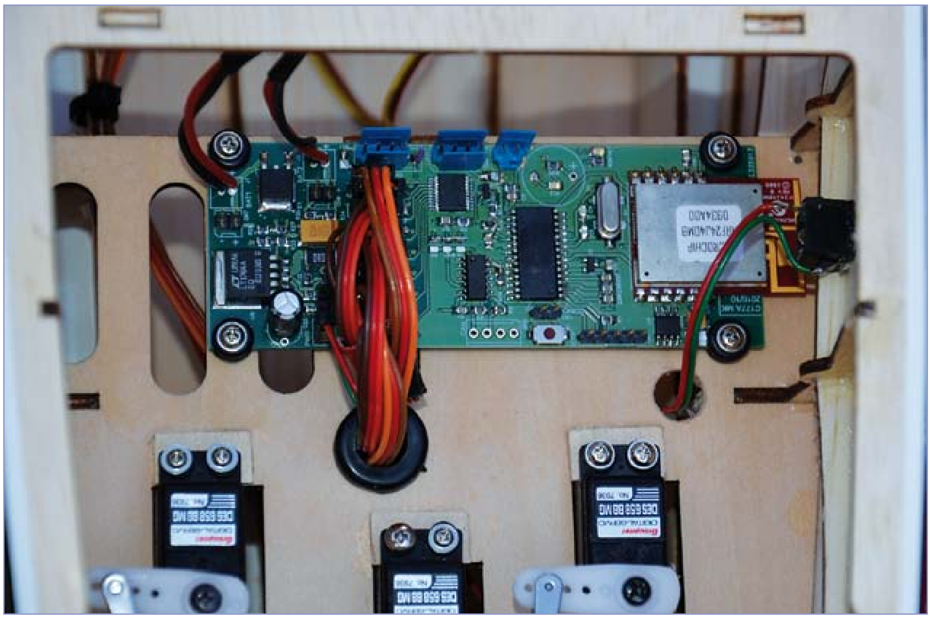


Figure 6. The built-in receiver.

LED1 will begin to flash excitedly (at about 20 Hz) at the beat of the reception of the command frames. The display should now look like that shown in **Figure 4**. **Table 1** shows an overview of the measured quantities and their characteristics.

The fourth line of the display, which is not used at the moment, is intended for telemetry information from the main drive battery of an electric model. But this may be a subject for a future article in Elektor.

If you power the receiver from just one battery then you can ignore the voltage reading from the battery which is not connected. Check that the receiver switches off when connector CN14 is shorted. For both batteries check also that the alarm sounds when the battery voltage drops below 7.6 V. Check that the measured values for the voltage and current from the receiver are correct and then connect a few servos to the receiver (**Figure 5**). Move the control levers on the transmitter and check the movement of the servos.

The transmitter board, the display and the battery now need to be mounted in a non-screening plastic enclosure that you can attach to your transmitter in a clever way. Provide a switch with a mechanical latch (for safety) and a charging connector. If you would like to attach a small whip antenna to your transmitter housing then you can replace the MRF24J40MB module with an MRF24J40MC.

Before you build the system into a model airplane (**Figures 6 & 7**), take the time to once more carefully check all solder connections and all power supply voltages. If you have even only the slightest amount of doubt then make sure that it is removed before you take off.

(110109)

ure 7. The author's Christen Eagle with 2.4 GHz receiver built in.

Internet Links

[1] www.elektor.com/110109

[2] 2.4 GHz modules from Microchip: www.microchip.com/wwwproducts/Devices.aspx?dDocName=en027752

[3] www.elektor.nl/080253

[4] ZigBee network analyser – ZENA: www.microchip.com/stellent/idcplg?IdcService=SS_GET_PAGE&nodeId=1406&dDocName=en520682

[5] Website of the author: http://breakinbench.free.fr/

Sinewave Inverter with Power Factor Correction

By Michael Kiwanuka (UK)

Power inverters are used to generate AC powerline voltages like 230 VAC or 115 VAC in the field, using high capacity 12 V or 24 V vehicle batteries. They come in a wide variety of output powers (anything between 15 and 1,000 watts) and quality of the AC output voltage (anything from abominable to pure sinewave). Some models even have output voltage regulation. Few however combine power factor correction (PFC) with 'pure-sine-wave-out', hence a suggested design appears in this article, along with a light theoretical background.

Into the circuit

With reference to circuit diagram in **Figure 1**, IC2 and crystal Q1 form a 4.096 MHz high frequency clock. The Type CD4060 14-stage binary divider together with IC3, a Type CD4017 Johnson counter, scale down the basic clock frequency to a 50 Hz square wave. For 60 Hz output, the quartz crystal frequency has to be changed accordingly.

The clock signal is then processed by IC5 and IC6.A which with their associated networks that together form a soft start unit. IC6.B with its twin-T filter network selects the 50 Hz (or 60 Hz) fundamental frequency which by Fourier analysis is a pure sine wave.

The next component in the chain, IC6.C, acts as Schmitt trigger transforming the basic high frequency unipolar signal into a symmetrical square wave signal. This is integrated and mixed with the 50 Hz sine wave from the notch by IC6.D.

IC13 and associated components is a comparator which compares a DC signal with the output of the comparator to give a pulsewidth modulated signal which in turn drives IC14, a Type IR2104 half bridge driver. The half bridge proper consists of power FETs T2–T3 and T4–T5, the latter being optional for higher output powers when required.

The half bridge topology drives the primary of a 9 V 16 A power transformer to give a 230 V (or 115 V) rms output voltage with a rated power of 100 VA. A 100 µH inductor (Bourns 23000L; for vertical mounting) is inserted in series with the primary. Capacitors C11 and C25 are connected across the secondary of the transformer to filter out the high switching frequency. Note that we call the 9-V winding 'the primary' and the 230-V (115-V) winding 'the secondary' and not the other way around as is customary with AC power transformers.

The secondary's inductance of the transformer doubles as a power factor correction (PFC) element when driving energy saving lamps, which tend to have a leading power factor (see **inset**).

In terms of additional components seen in the circuit, IC16 is used as a level detecting network for the batteries. IC17A, IC17B and FETs T6-T7 form a battery charger with an

Power factor correction and the Osram lamp

The power factor of a typical Osram energy saving lamp is 0.6 capacitive (i.e. leading). For a 21-watt lamp, the I/P power S1 = 21/0.6 = 35 W. The 'VA' value Q1 can be calculated vectorially as:

$Q1 = \sqrt{(35^2 - 21^2)} = 28$ VA

Let the power factor = 0.9 after correction, then

S2 = 21 / 0.9 = 23.3 VA

$Q2 = \sqrt{(23.3^2 - 21^2)} = 10.1$ VA

Hence Q_a (amount to be corrected) = 17.9 VA leading

Now, for the transformer's secondary inductance,

$L_s = V^2 / (2\pi \times 50 \times 17.9) = 9.45$ H

From measurements, $L_p = 12.32$ mH.

$L_s = n^2 L_p = 9.49$ H, for n of 28 as deduced from knowledge of the number of turns on the transformer. Hence the inverter transformer provides a PF correction of 0.9.

Note. Readers' Projects are reproduced based on information supplied by the author(s) only.
The use of Elektor style schematics and other illustrations in this article does not imply the project having passed Elektor Labs for replication to verify claimed operation.

100 watts, 24 VDC to 230 VAC (115 VAC) rms pure sine wave out

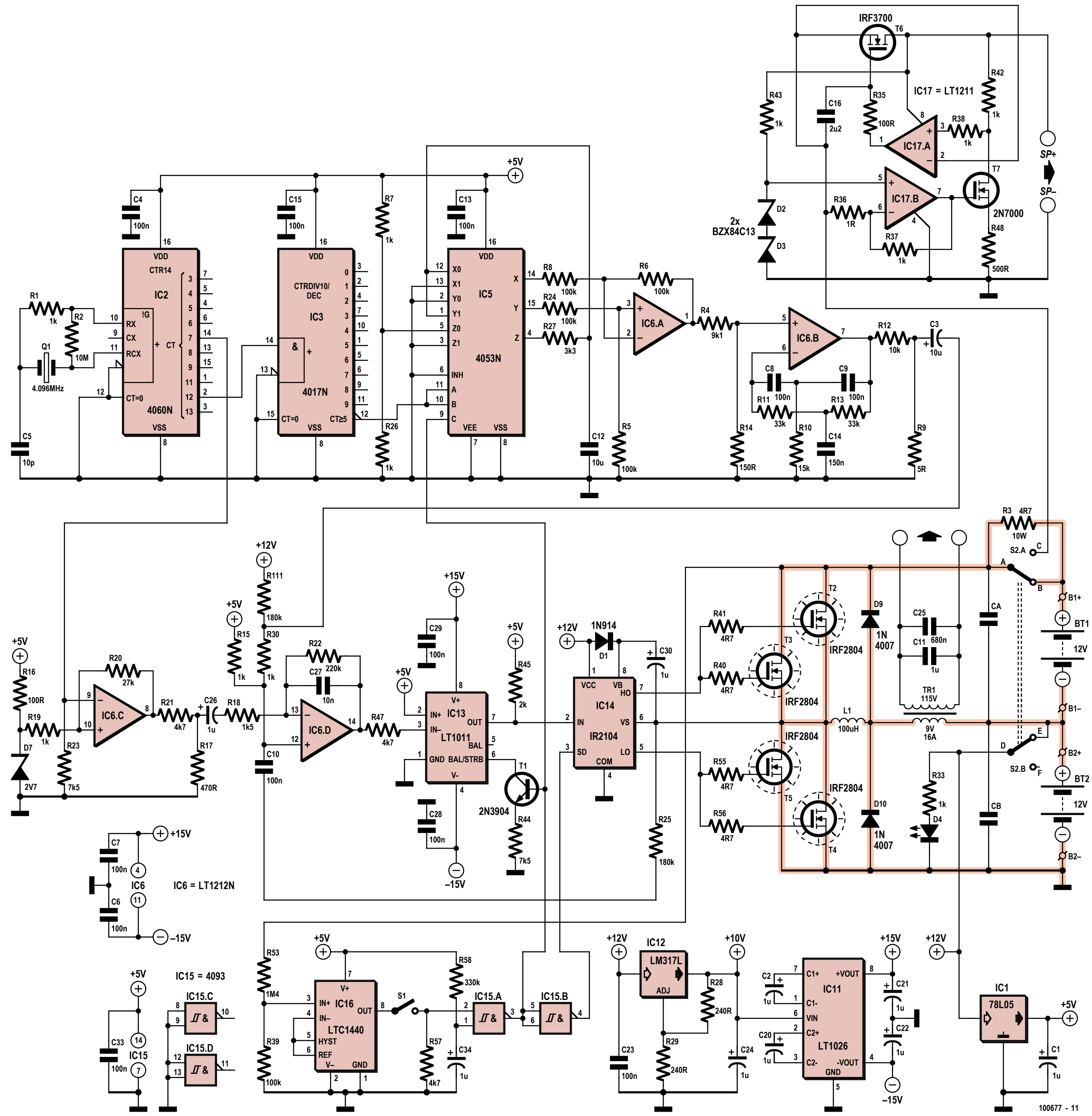
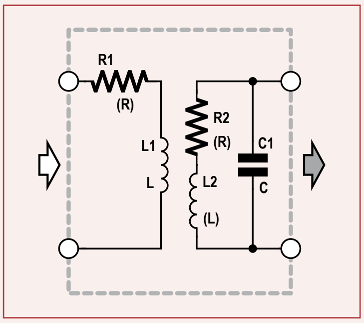


Figure 1. The circuit diagram of the power inverter is rather elaborate due to the use of standard integrated circuits and transistors (from Farnell) rather than dedicated converter ICs.

The output filter



The output filter is configured to pass a band of frequencies beyond which the signal is greatly attenuated. This may be achieved by connecting a capacitor across the secondary winding as shown in the circuit diagram.

It can be shown that the input impedance looking into the primary terminals is given by:

$$Z_1 = R_1 + jX_1 + Z_2$$

$$Z_1 = R_1 + jX_1 + \frac{(\omega M)^2 R_2}{R_2^2 + X_2^2} - j\frac{(\omega M)^2 X_2}{R_2^2 + X_2^2}$$

With the secondary resonating at ω_o we have

$$Z_1 = R_1 = jX_1 + \frac{(\omega_0 M)^2}{R_2}$$

Thus just above ω_o, I_{pr} is proportional to $1/\omega$.
Now consider ω considerably higher than ω_o

$$Z_1 = R_1 + j\frac{X_1 - (\omega M)^2 X_2^2}{R_2 + X_2} + \frac{(\omega M)^2 R_2}{R_2^2 + X^2}$$

At a second resonance

$$X_1 - \frac{(\omega M)^2 X_2}{R_2^2 + X^2} = 0$$

$$X_2^2 - \frac{(\omega M)^2}{X_1^2} X_2 + R_2^2 = 0$$

$$X_2 = \frac{(\omega M)^2}{2X_1} \pm \tfrac{1}{2}\sqrt{\frac{(\omega^2 M^2)^2}{X_1^2} - 4R_2^2}$$

But $X_1 = X_2(N_1/N_2)^2$ and remembering the expression for Q as well as noting $L_1/L_2 = (N_1/N_2)^2$, we have (for Q>>1):

$X_2 = k^2 R_2 Q$

For the transformation from series to parallel we have
$R_2 = R_p/Q^2$, where R_p is the resistance in the primary and R_2 that in the secondary.

Either $X_2 = 0$,

or $X_2 = \dfrac{R_p k^2}{Q}$

or $X_2 = k^2 R_2 Q$

Thus at a second transition, substituting X_2 and noting that the imaginary part is zero

$$Z_1 = R_1 + \frac{(\omega M)^2}{R_2 \times (1 + k^4 Q^2)}$$

Therefore I_{pr} is roughly proportional to $1/\omega^2$ for $\omega >> \omega_o$, which is very desirable.

output voltage of 25–26 V. IC11 and IC12 form a ±15 V symmetrical supply for the operational amplifiers, and IC1 is a standard 5 V regulator for the logic. Schmitt trigger gates IC15A and IC15B form a power on reset (POR). Capacitors CA and CB are ‘off board’ parts because of their size — their value has to be established experimentally. The prototype of the inverter worked best using two Evox/Rifa 22,000 µF, 25 V electrolytic, aluminum can capacitors with stud/nut mounting.
The thicker lines in the circuit diagram indicate PCB tracks, pads and connectors suitable for carrying DC currents up to 32 A.

Practical matters

The introductory photo shows an early prototype of the inverter, which is being developed further aiming to go into actual production. The power FETs in the bridge are secured to a Type SFP100 heatsink which acts as the top side of the case. Two nuts on the side panel secure the large electrolytics CA and CB, which are electrically isolated using special materials the author is willing to share.

A circuit board was designed by the author and the artwork files (silk screen and copper track) may be downloaded from [1], along with tooling data for a Type KOH10-KOR2-160-ME-SL enclosure from Fischer Elektronik (UK distributor: Dau Components Ltd.). PCB tracks carrying high current (refer to circuit diagram) should be strengthened by soldering 1.5 mm² c.s.a. (approx. 16 AWG) massive copper wire along their paths.

(100677)

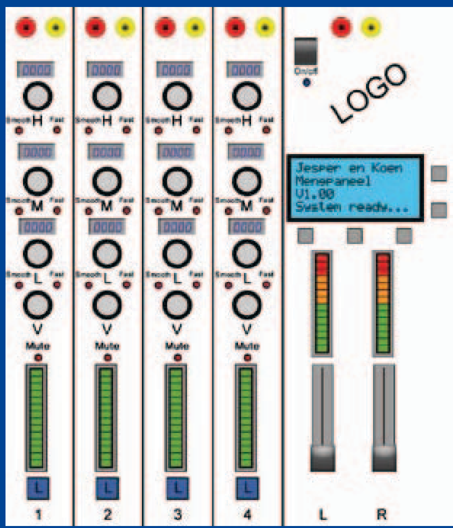
Internet Link

[1] www.elektor.com/100677 (PCB design and case drilling data)

Mixed results

By Koen Beckers (trainee, Elektor Labs) & Jesper Raemaekers

Koen Beckers, a trainee at Elektor Labs told us about a project he carried out along with fellow student Jesper Raemaekers while studying Electrical Engineering at Leeuwenborgh College in Sittard, the Netherlands.



“At school we had to carry out a project that let us put theory into practice and which would prepare us for all those things that you can’t learn from theory alone. We were allowed to choose the subject ourselves. Because both of us were involved with audio as a hobby, we decided to design a four-channel mixer. We’ve used an LM1036 to process each audio channel. This is an IC that has a tone control, balance and a volume control built in. This replaces a large amount of analog electronics that would otherwise be required and the IC is very easy to drive using four control voltages. Three of those voltages are generated by three potentiometers that are connected to the internal voltage regulator of the LM1036. The fourth voltage is taken from a DAC (MCP4921) followed by an opamp that increases the voltage to the right level. This was necessary because the maximum output voltage of the DAC was 5 V and the LM1036 required a voltage of 5.4 V to be fully driven.

The signal level is shown on a row of LEDs that are driven by an LM3914, which is connected to the output signal of the DAC. The image at the top shows one of the first drawings we made when we started this project.

We calculated that we would use something in the order of 100 LEDs which means that the supply should be able to source at least 2 A (20 mA per LED). We considered using a 78S05, but the temperature of the regulator could end up very high. A minimum of (7 V–5 V) × 2A = 4 W will be generated inside the IC. When the voltage at the input of the regulator isn’t 7 V but becomes 15 V, which is desirable for opamps, it could well mean the end of this IC!

In order to get round the heat problems we could have changed to a switch mode supply. However, this was something we wanted to avoid since the design of a good switch mode supply for audio applications was beyond our abilities, and a ‘bad’, simple switch mode supply was likely to cause too much noise and interference.

The best solution for us was to use a linear regulator after all, and to make sure that the current was kept within certain limits. During several tests it became apparent that we would never require the full 2 A since not all LEDs would ever light up together. Because of this, it was possible to use a standard 7805.

As we progressed with the design of the printed circuit board (using Cadsoft Eagle), and we wanted to design a compact board for each channel, we found out that we wouldn’t be able to make (etch) these at school. We therefore asked (and obtained) permission for the boards to be made by the Elektor PCB Service.

Once the design of the printed circuit board was complete we had it produced and then populated it. Unfortunately, the board wouldn’t work at our first attempt. We found out that the symbol that we used for an opamp in Eagle didn’t make it clear which connection was for V_{cc} and which was for ground. Because of this, we blew up four opamps before we discovered what exactly was happening. An incorrect connection of the supply isn’t the first thing you’d think of when you’ve just checked that the supply voltage has the correct value.

The photograph shows the completed prototype. The black plastic panel is a laptop stand that was for sale very cheaply at IKEA and which was perfectly suited for our project.

The original intention was to build a four-channel mixer where all the possible settings of the LM1036 were controlled using a DAC and rotary encoder (with the current settings shown on 7-segment displays) and using motorized slide potentiometers for the volume control. Unfortunately, this didn’t come within our budget and we had to scale down the design to one DAC, which was driven by a rotary encoder with the help of an ATmega88. The college originally gave us a budget of € 100. We exceeded this monumentally despite scaling back the design on a regular basis.

All in all this project gave us some good experience and we learnt a few things about electronics and programming whilst working on something that we enjoyed.”

(110601)

E-LABs INSIDE

Verification of radiation meter

By Thijs Beckers (Editor, Elektor Netherlands)

Prompted by the design of the radiation detector in the June 2011 edition ('Measure Gamma Rays with a Photo Diode', [1]) we were invited to test our sensor in the Nuclear Physics Laboratory at the University of Namur in Belgium, not too far from Elektor Labs. Research & development engineer Aurélien Nonet had sent us an enthusiastic email about the article in which a cheap sensor was used (at the university they usually work with sensors which, together with the necessary accessories, cost around €200,000 a piece). Aurélien had offered us to test our sensor with calibrated radioactive samples and possibly also compare it with their conventional detectors.

So on July 12, there I was, together with author Burkhard Kainka and his measuring circuit, on the steps of the Laboratoire d'Analyses par Réactions Nucléaires [2]. After a warm welcome we were given an extensive tour of the partly underground lab — where to my amazement a complete 2-GeV particle accelerator was installed: the Altaïs (Accélérateur Linéaire Tandetron pour l'Analyse et l'Implantation des Solides). With this particle accelerator, atoms are shot at samples so that materials can be tested. For example, nitrogen atoms are fired at samples. During the collision various types of radiation are released (mainly X-rays and gamma radiation) which are accurately measured. From this you can then obtain information about the material shot at. But the accelerator is also used for medical research (the fight against cancer).

And now some measuring!

After the tour, a few calibrated radioactive materials were retrieved from the vault to see what our (ridiculously!) cheap sensor would be capable of. Initially things weren't going so well with the measurements. But after some more experimenting and using different samples we were making progress. The counter in the circuit was incrementing, a sign that radiation was being measured. The sensitivity of the sensor proved to be not particularly high (something we, incidentally, already knew). Only when using samples with a sufficiently high energy (expressed in electronvolt, eV) did our circuit react.

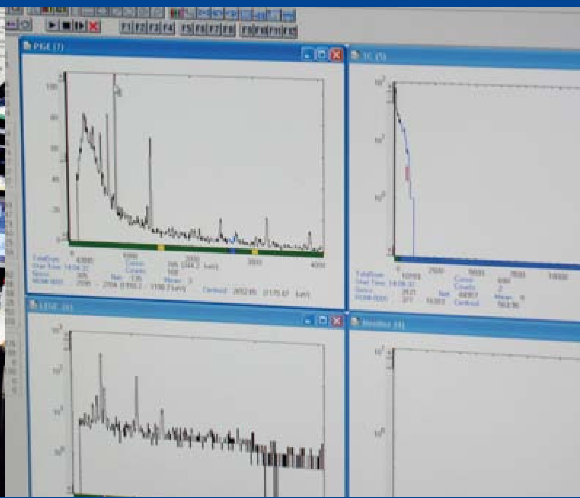
To enable the sensor to measure radiation, it has to be completely shielded from any form of light. A tin that used to contain hand lotion worked extremely well. The plate containing the radioactive material was fastened with a little putty and the lid was put back on the tin to create a completely dark measuring environment. The first tests were positive, although the professional sensors costing tenths of thousands of euros are (of course) much more sensitive.

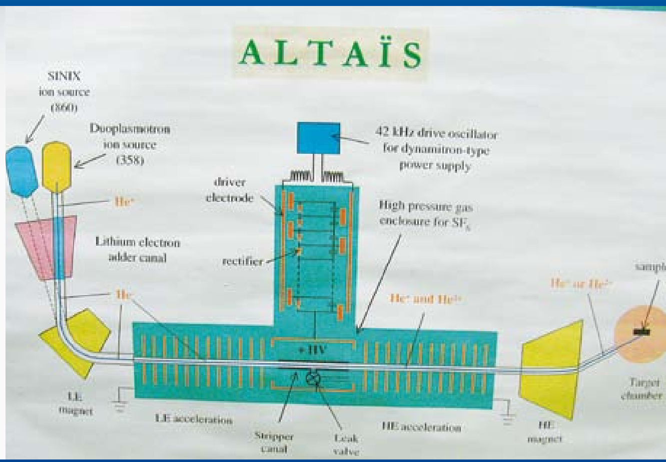
For this occasion or circuit was provided with a coax output, which made the (amplified) signals from the sensor available to the outside world. Using this coax output the circuit could be connected to the measuring equipment in the nuclear physics lab. After some adjusting and twirling of knobs (the output voltage from the professional sensor with amplifier is much higher) we did succeed in getting a picture on the PC. The professional software running on the PC translated the sensor signals in readable measurement values and charts showing the radiation characteristics of the radioactive material in front of the sensor. Everybody was enthusiastic. The cheap sensor really does work! An example of a measuring result:

Measurement of gamma radiation using a BPW34 as a sensor.
Sample: 137 Cs (Caesium), 661 keV Gamma.
Result: Good sensitivity for gamma radiation, also through the aluminum shell around it. There is no clear energy spectrum because the blocking layer in the diode is too small. Only a small part of the energy is absorbed in the blocking layer, the remainder of the radiation exits on the opposite side. With this the direction depends on the distance traversed through the sensor. Conclusion: The BPW34 is very suitable for use in counter applications for gamma radiation.

A second sensor

Because the response to the June 2011 article had been so great, Burkhard continued his experiments and he had a second type of sensor with him. This one was based on the BPX61. Using this sensor he succeeded in measuring the weaker alpha radiation also. Our visit to the university was of course an excel-





lent opportunity to verify this with professional equipment. A few results:

Alpha radiation measurements with a BPX61
Sample: 244 Cm (Curium), 5.8 MeV Alpha.
The radio active sample is placed in a light-proof enclosure, close to the sensor. The measured pulse amplitude is a good measure for the amount of energy of the radioactive particle hitting the sensor. In this respect the BPX61 is a fully fledged alpha detector. Experiments with different distances between the sensor and sample indicate that with increasing distance the energy has dropped to 0 after about 5 cm.
Sample: 239 Pu (Plutonium), 5 MeV
The sample generated 210 mV at the output of the measuring amplifier. At a spacing of 1 cm between sample and sensor the signal was still 190 mV.
Conclusion: The BPX61 is not only suitable for counter applications, but also for alpha spectroscopy.

Measuring beta radiation?

Whether or not we can also measure beta radiation with our cheap sensors is a question we were unfortunately unable to answer unequivocally. The Namur lab does not normally work with this form of radiation and the available radioactive samples generated relatively little beta radiation. We were unable to establish any clear signals resulting from beta radiation. So this question remains open. If you have an idea or suggestion (or have a complete nuclear physics laboratory at your disposal), then do not hesitate to contact us! You can use Jan's editorial address for this: editor@elektor.com.

DIY

If you would like to get started yourself, but do not have access to a laboratory or have insufficient financial support to justify a trip to Japan, then an old-fashioned watch with illuminated hands is a good alternative. Even when the hands do not give off any light any more they still emit more than enough radiation. However, note that for alpha radiation you will have to make a small hole in the glass. That is because this radiation is so weak that it is blocked by the glass.
By the way, Elektor is planning to publish an improved version of the radiation meter, complete with printed circuit board and detailed description of the sensors. Keep an eye out for this in the magazine in the coming months...

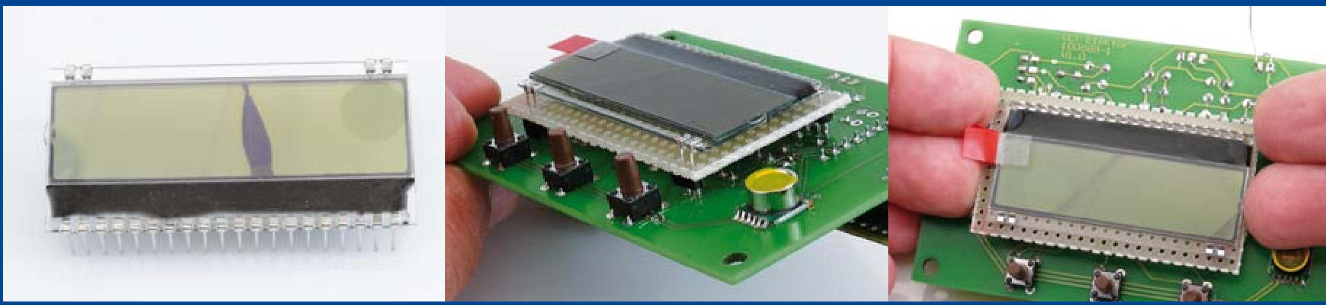
(110605)

Internet Links

[1] www.elektor.com/110372
[2] www.fundp.ac.be/en/sci/physics/larn/page_view/presentation.html



Very handy, this display



By Luc Lemmens & Thijs Beckers (Elektor Labs/Editorial, The Netherlands)

For prototypes of projects that require a display, we often reuse the same (type of) display in the lab. Since there are a number of standard displays that are often used it doesn't really make much sense to get a new display from the storeroom for each new project, whilst a large number are gathering dust in the prototype box. Anyway, it makes sense to reuse displays. This is all very well as long as there is a decent (sturdy) board and header on the display. On those occasions when we need to get a new display from the storeroom, the first thing we do is to attach a header onto it.
However, for some displays this isn't so easy, for example with the DOGM displays made by Electronic Assemblies. These basically consist of a piece of glass with a few thin pins attached to it for the necessary electrical connections. It's not very strong and it certainly isn't made to be reused. Several have come to an untimely end in the lab when we removed them from the board (see photo) and we certainly won't be the only ones to whom that has happened.
However, we have now come up with a solution, although it appears quite simple. All you have to do is put a piece of experimenter's board between the (mother) board and the display. There isn't even a need to solder the display onto it. The pins of the display simply stick through the experimenter's board and can make a good connection with the main board, since the pins are usually long enough. When you need to remove the display, you pull the experimenter's board instead of the fragile glass of the display. The experimenter's board spreads the force over the whole display and it stops the glass from breaking. It's all very simple really...
It is of course also possible to solder the display onto the experimenter's board. In addition, you could add some sturdy headers to the experimenter's board. Moreover, if the connections of the headers also correspond with the normal pin-out of the LCD you end up with a universal display module.

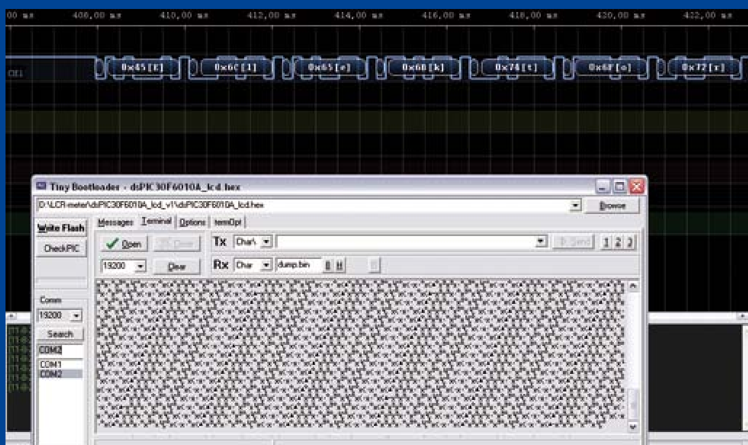
(110506)

Recalcitrant little bits

By Raymond Vermeulen (Elektor Labs)

While testing a project something strange happened (see illustration). The terminal showed nonsense, but the logic analyzer properly displays 'Elektor' in ASCII. The latter also indicates that the UART is operating at 4800 baud instead of the 19200 baud that I had programmed (at least that's what I thought), a difference with a factor of 4. The change I had made in my code was a fourfold increase in the clock speed of the dsPIC. The conclusion I had to arrive at is that the clock speed was not being changed. But why not? The inspiration came, and where else, in the shower. In a hobby project I used an ATmega32u4 with a bootloader whose only limitation was being unable to program the fuse bits. "That's not going to be..." I was thinking. But yes, the bootloader I used in my dsPIC cannot program the configuration bits either. Experienced programmers would have realized that long ago, but everyone has their off-days...
(The solution is to use a 'real' programmer, such as the ICD3).

(110613)



E-LABs INSIDE

Wheelie GT

Gear tooth sensing improves handling

By Günter Gerold and Uwe Hofmann (Germany)

It's been over a year since we introduced the Elektor Wheelie (a self balancing single axle vehicle). Now the GT modification described here senses the speed of each road wheel to give better stability and improved performance over uneven terrain.

Up until now the Elektor Wheelie control system used an accelerometer and a tilt sensor to sense movement of the vehicle's footplate. The tilt angle and the rate of change of the tilt angle are used in a control system which drives two motors to keep the vehicle stable. Leaning forwards tilts the plate forwards and produces an acceleration response from the control system; leaning backwards has the opposite effect. The regulation is applied to both motors equally. A pot sensing left/right tilting of the control lever adjusts the current to the drive motors thereby allowing the Wheelie to turn corners.

The control system does not have any information on the rotational speed of the wheels so it cannot compensate for any load variation on individual wheels. When a wheel hits an obstacle the control system reacts by increasing drive to the free wheel, producing an unwanted turn. Off-road capabilities of the original Wheelie are therefore somewhat limited.

To solve this problem we have added rotation sensors to each of the two wheels. Now the control system can sense the wheel speed and adjust power to the individual motor, helping it to overcome obstacles.

The gear tooth sensor

A good way to measure the rotational speed of a gear wheel is to use a gear tooth sensor. This device (**Figure 1**) uses a magnet and a Hall-Effect sensor to measure magnetic field strength. When the device is placed close to the teeth of a rotating gear wheel the disturbance caused by each tooth moving through the field can be detected by the Hall-Effect sensor which outputs a sawtooth waveform. The ATS665 detector from Allegro includes a signal conditioning circuit with an amplifier and comparator (**Figure 2**); this generates a more useful square wave output signal. These sensors were originally developed for use in vehicular ABS systems and drive control.

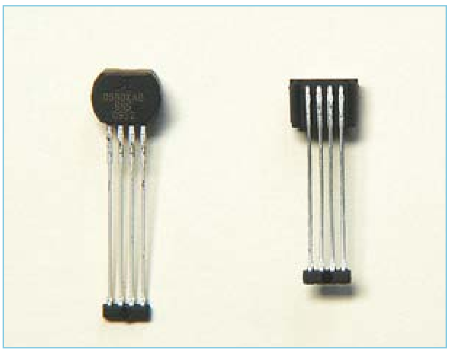


Figure 1. The gear tooth sensor consists of a permanent magnet and a Hall-Effect element to sense the magnetic field.

The Elektor Wheelie uses a direct drive system with the final drive gear wheel connected directly to the road wheel. This configuration makes it simple to fit this type of sensor to the gearbox. This non-contact form of revolution sensing is very reliable, is not subject to wear and can be completely sealed from the environment. A small PCB (**Figure 3**) has been designed for mounting the sensor together with the other three components shown in the circuit in **Figure 4.** The board greatly simplifies the job of fitting the sensor to the gearbox. The newer ATS667 from Allegro can be substituted for the ATS665 shown in the circuit diagram.

Evaluating the data

The ATMega8 in **Figure 5** evaluates the speed impulses received from the two sensors connected to K3 and K4. Connector K1 provides an I²C interface between the ATMega8 evaluation board and the existing ATMega32 (pins 22 and 23) on the Wheelie main board.

The sensors output 60 impulses for each revolution of the road wheel. A method of measuring speed by counting the number of impulses in a given time window does not give sufficient resolution especially when the Wheelie is traveling at low speeds. It is better to measure the time between impulses i.e. the time it takes for two gear teeth to pass the sensor. A free running timer is used to measure this period, the firmware keeps track of the timer overflows to calculate the time interval. The evaluation board configures itself as an I²C slave. When a request is received from the ATMega32 main board the evaluation board responds by returning the values.
The values sent are the reciprocal of the wheel speed. The ATMega32 first calculates the speed in km/h then the individual wheel speeds are summed and the value used to scale the control lever sensitivity.
The speed reading could also be used in the development of a speedometer for the Wheelie or as one of the operating parameters transferred over a telemetry link.

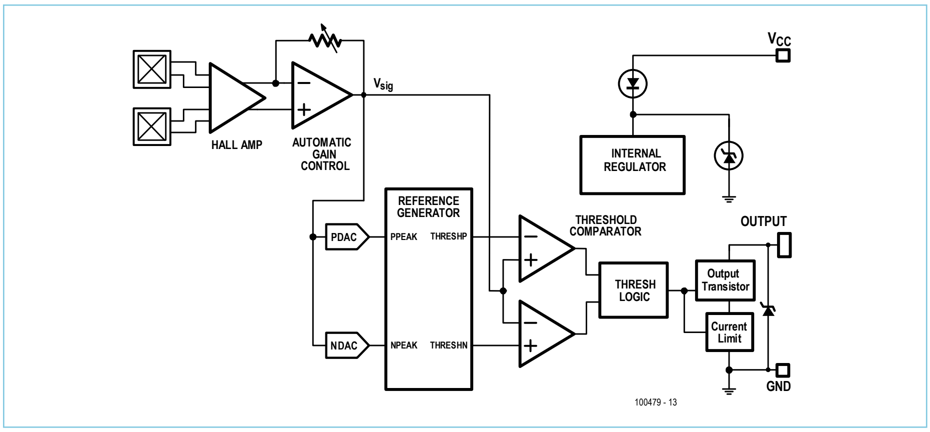


Figure 2. The ATS665 sensor contains an integrated amplifier and comparator.

COMPONENT LIST

Sensor board

Resistors
R1 = 10kΩ

Capacitors
C1 = 100nF

Semiconductors
IC1 = ATS665 (or ATS667, see text)

Miscellaneous
K1 = 3-pin pinheader
PCB no. 100479-2*

*A kit of parts containing signal processing board (100479-1), two sensor boards (100479-2) and all components is available from the Elektor Shop, order code 100479-71.

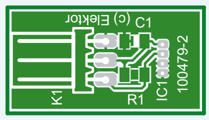


Figure 3. A small PCB simplifies the job of fitting the sensor to the gearbox.

Fitting the components

The complete additional parts required to implement the GT modifications consists of a evaluation PCB to take the ATMega8 microcontroller and two small PCBs on which the sensors are mounted. The evaluation board (**Figure 6**) contains no SMDs and is not at all difficult to assemble. The sensor PCBs however have two SMD components (R1 and C1) which need to be soldered on the track side of the board. The Hall-effect

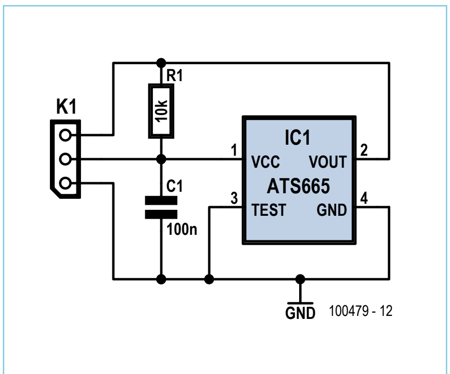


Figure 4. Circuit diagram of the sensor PCB.

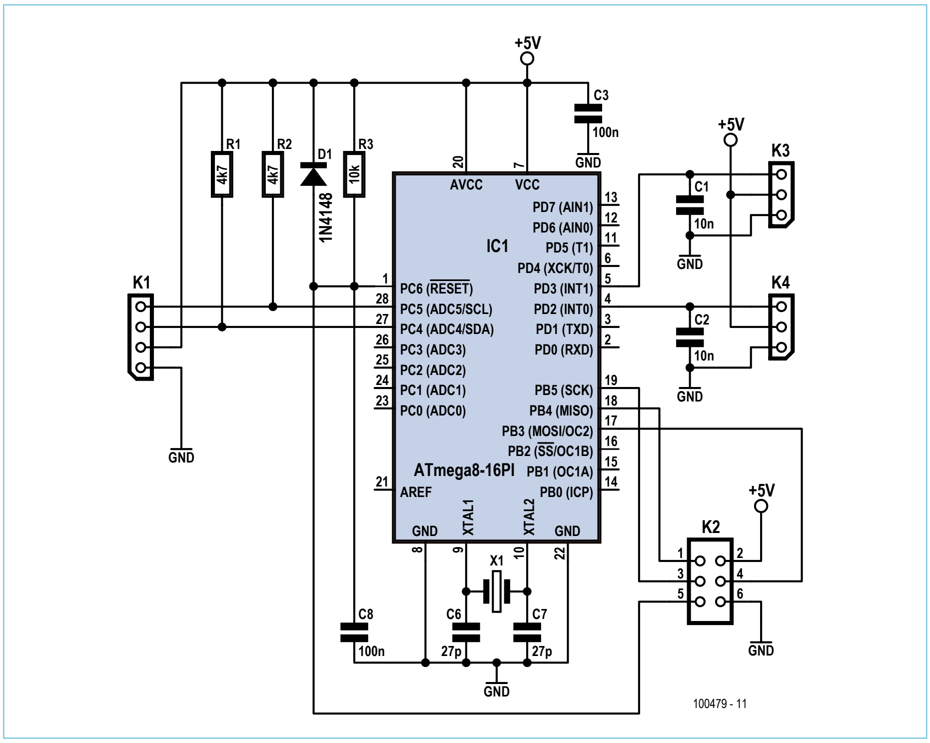


Figure 5. The evaluation board ATMega8 processes both gear tooth sensor signals.

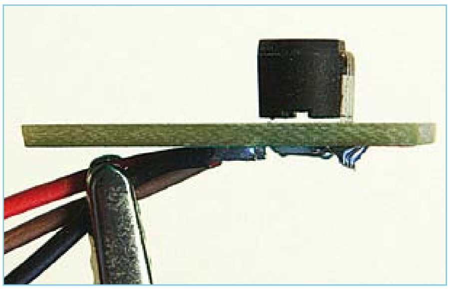


Figure 7. Mounting the sensor on the small PCB.

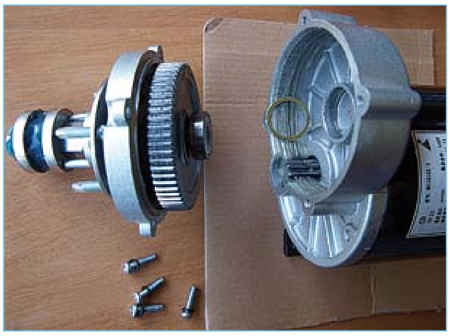


Figure 8. Release the four bolts and carefully remove the casing which holds the stub axle and the final drive gear wheel.

Figure 9. The correct hole position from the casing edge.

Table 1. Connections between the ATMega8 PCB and the Wheelie main board

ATMega8 signal processing board	Connection to the Wheelie main board
K1/Pin 1 (GND)	K3/Pin 5 (GND)
K1/Pin 2 (+ 5 V)	K2/Pin 2 (+ 5 V)
K1/Pin 3 (SDA)	IC7/Pin 23 (SDA)
K1/Pin 4 (SCL)	IC7/Pin 22 (SCL)

COMPONENT LIST

Signal processor board with ATMega8

Resistors
R1,R2 = 4.7kΩ
R3 = 10kΩ

Capacitors
C1,C2 = 10nF
C6,C7 = 27pF (or 22pF)
C3,C8 = 100nF

Semiconductors
D1 = 1N4148
IC1 = ATMega8-16PI, programmed)

Miscellaneous
X1 = 16MHz quartz crystal
K1 = 4-pin pinheader
K3,K4 = 3-pin pinheader
K2 = 6-pin (2x3) pinheader
PCB no. 100479-1 *

* A kit of parts containing signal processing board (100479-1), two sensor boards (100479-2) and all components is available from the Elektor Shop, order code 100479-71.

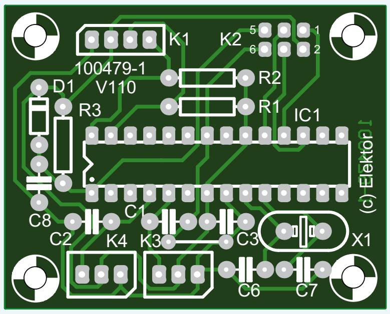


Figure 6. The evaluation board is wired to both sensors and the Wheelie main board.

sensor is mounted from the other side of the board and soldered on the track side. The legs are first bent flat along the body of the sensor (**Figure 1**) and then pushed through the board and soldered to the pads on the track side. Note that a small gap should be left between the sensor and PCB (**Figure 7**), This allows the sensor to be fixed to the PCB using epoxy adhesive. The lead ends can now be cropped close to the solder joints on the PCB. Finally a short length of heat shrink sleeving over the sensor will prevent any possibility of the leads shorting to the gearbox casing. Connections to the board can be made by soldering the three wires directly to the pads of K1. This is more robust and removes any reliability issues of a connector at K1.

Construction

The most time-consuming part of this modification will be fitting the rotation sensors into the two motor gearboxes. The greatest challenge is drilling one hole in the gearbox aluminum casing — and get it right first time round!
Firstly undo the four screws holding the gearbox cover in position then pull the cover off complete with the stub axle and large gearwheel (**Figure 8**). The housing will be filled with grease. The ball race housing contains a spring washer which will most likely adhere to the ball race as you pull it out of the housing. Keep this washer safe, you will need it later during reassembly.
The position of the hole to take the sensor can now be marked on the casing, it is 11.5 mm (0.45 inch) away from the edge of the casing **(Figure 9** and **Figure 10)**. Use a center punch to mark the point; it will prevent the drill from wandering. Before drilling it will be necessary to clean the grease away from the area where the hole will be drilled. Lay some paper kitchen towels or clean rags on the bench to catch any swarf. Debris which does find its way into the casing can be removed with a pair of tweezers (the more meticulous types out there will no doubt remove all the grease, flush out the housing after drilling and re-pack with grease).
Once the position has been marked and double checked make a pilot hole through the casing using a 3 mm (1/8 inch) drill. Check the position of the hole again before drilling through with a 9 mm (3/8 inch) drill. The sensor PCB (with its cables attached) can now be permanently fixed to the casing using two-pack epoxy glue (with the sensor chip positioned into the hole). Be sure to degrease and abrade this area of the case before gluing. Once the glue has set the hole **(Figure 11)** will be completely sealed by the PCB **(Figure 12)** and the sensor will be close enough to the gear teeth to generate impulses when the cog turns. Any debris remaining in the gearbox housing must be carefully removed before re-greasing the gear wheels and reassembling the housing (don't forget the spring washer).

Wiring

Three-core cables are used to connect the sensor PCBs to the ATMega8 PCB.

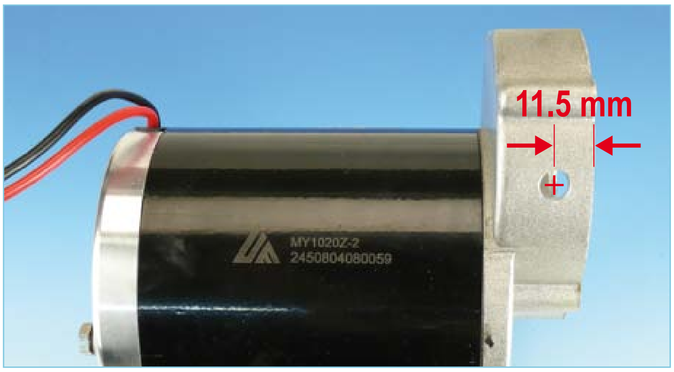


Figure 10. The motor before...

A four-way flat band cable connects to K1 of the ATMega8 PCB and to the points specified in **Table 1** on the existing main board in the Wheelie.

Software and Updates

The firmware for the ATMega8 fitted to the evaluation board can be downloaded for free from the Elektor Website. The direct link is: www.elektor.com/100479.
A commented source file is included in the download folder for this article along with the Hexfile.
The Elektor shop stocks the complete kit to convert the standard Wheelie to the Wheelie GT including a pre-programmed ATMega8.
It will also be necessary to upgrade the existing ATMega32 main board firmware in the Wheelie so that it can handle data from the evaluation board. The new firmware (hex and source code) is available for free download from www.elektor.com/100479.
Some hardware modifications will also necessary to the main board for Wheelies using the GT sensors:

1. Replace the three 470 µF capacitors C1, C2 and C3 with better spec 1000 µF capacitors (use low ESR types e.g. the Panasonic FM series).
2. Change R14 to 47 kΩ and add a 100 nF capacitor between IC7/Pin34 (ADC6) and ground (solder it between the correct leg of R14 and ground)

The improvement in stability of the Wheelie GT version (especially in off-road situations) can be seen on one of the author's YouTube videos; search for guenter1604.

(100479)

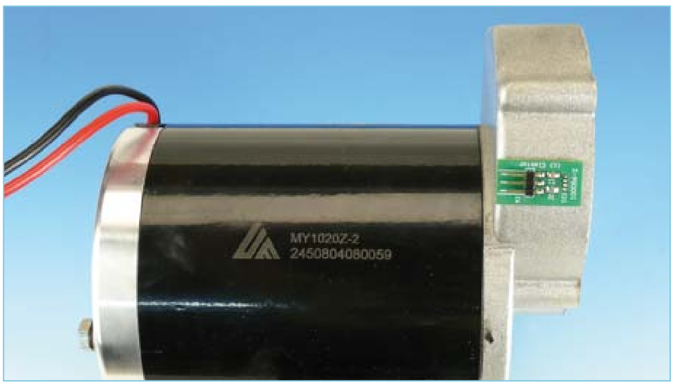
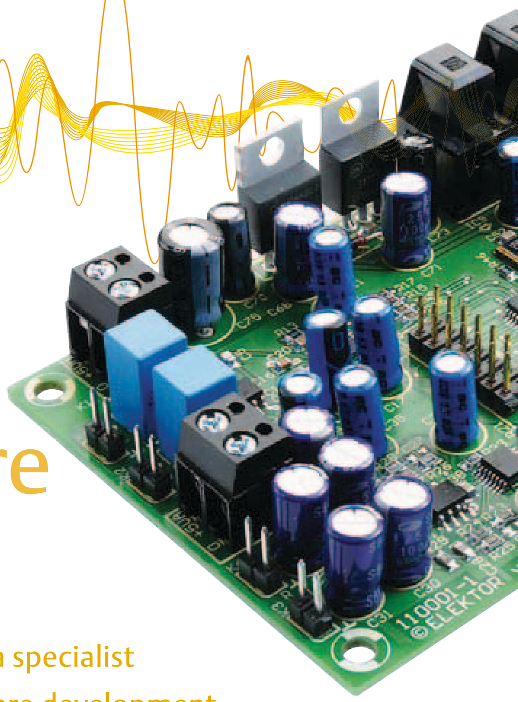


Figure 11. ...and after fixing the sensor PCB

Audio DSP Course (4)

Part 4: testing the hardware



By Alexander Potchinkov (Germany)

In the previous installments of this series we have got to know the DSP as a specialist device for processing audio signals digitally. We have also looked at software development environments and their functions and introduced the DSP board that accompanies this course. Now we will install the development software and test the hardware. We have a choice between a traditional development toolchain built from separate components, including two different debuggers, and an integrated development environment. To test the hardware we will use a few small DSP programs, which we have of course made freely available to readers.

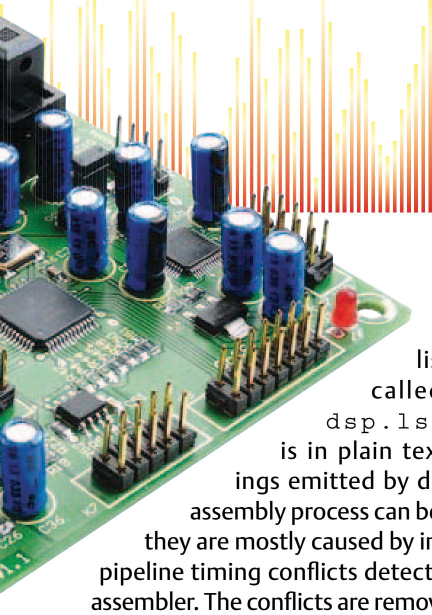
Two software development environments (SDEs) are available to us: Suite56 and Symphony Studio. We need to make a decision between them as they employ different adaptors to connect the DSP device to the debugger software. They also differ considerably in the range of facilities offered and in complexity, with corresponding differences in the time it takes to get to know them. Rest assured that the programs in this course and all programs developed by readers can equally well be assembled and used in conjunction with either of the two SDEs. Programs that appear as separate entities in Suite56 appear as plug-ins in Symphony Studio, and so the differences between the two SDEs are more in terms of how they are used than in terms of what they can actually do: many of the underlying programs are the same. One significant distinction (though not important for the purposes of this course) is how the DSP5672x family of dual-core DSPs are handled: in Symphony Studio these are supported directly. Below we will look at both of the SDEs and illustrate their use with the help of our first test program, whose source code is in the file `tst_dsp.asm`. We will look at how the program is assembled and how it is loaded into the DSP. The remainder of the article will examine this test program and four others in more detail.

If you do not decide to plump immediately for the more modern Symphony Studio environment, it is possible to practice editing, assembling, simulating and (to a limited extent) debugging code using both systems without using an adaptor. You can then decide which environment you prefer and only then obtain the corresponding adaptor.

Suite56

The Suite56 software comes in the form of a self-extracting file `DSP563000_TOOLS.exe` of about 8.9 MB. It comprises a number of rather elderly components: the assembler `asm56300.exe`, the simulator `sim56300.exe` (or `gds56300.exe` in the Windows version) and the debugger `gui56300.exe`, which works in conjunction with a parallel port adaptor. If you do not have a parallel port adaptor, a different debugger must be used in place of the one provided in Suite56. One attractive possibility with an 'intuitive' user interface is `evm30xw.exe` (which works with a USB adaptor) made by Domaintec rather than Freescale. It can be extracted from a compressed file available from the Domaintec download area [1]. From now on we will assume that you will be using the Suite56 assembler and simulator and the Domaintec debugger. The advantages of this combination are its transparency and that it is easy to learn; the disadvantages are that the programs are, as mentioned above, showing their age, and that the debugger appears not to run under 64-bit operating systems. The author uses these separate software tools, however, as he has found that they make for quicker development.

Once the software has been obtained from Freescale and from Domaintec, installation is a simple and quick process. The Domaintec debugger is called with the option `-cx`, where `x` is the number of the (virtual) COM port assigned by the Windows operating system to the adaptor when it is connected. If no DSP system is connected, the software can be run in 'demonstration mode' (using the `-D` option) for evaluation purposes. The first step is to assemble the test program by entering the command `asm56300 -a -b -l tst_dsp` into the command window. This generates the 'cld' file `tst_dsp.cld`, which contains the object code, and the (often extremely



useful) listing file called `tst_dsp.lst`, which is in plain text. Warnings emitted by during the assembly process can be ignored: they are mostly caused by instruction pipeline timing conflicts detected by the assembler. The conflicts are removed by the addition of no-operation instructions to the program, which the assembler will do automatically. When you become a more experienced hand at DSP programming, you will want to reorganize the program so that the no-operation instructions are replaced wherever possible by instructions that do useful work. The object code file contains everything the DSP device needs to run. The debugger is now started up and the following sequence of commands given.

`force r`	(force reset of the DSP)
`load tst_dsp.cld`	(load the object code into the DSP)
`go 0`	(run the program starting from address 0)
`force b`	(put the DSP into the debug state)
`disp x:$200`	(display the content of X memory starting at address $200)
`disp y:$200`	(display the content of Y memory starting at address $200)

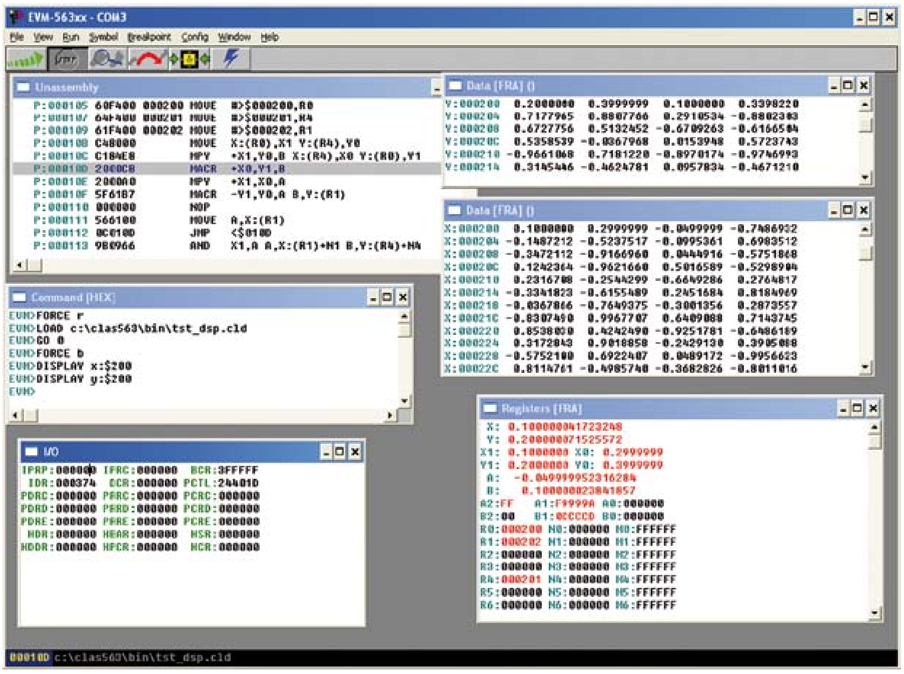


Figure 1. User interface presented by the Domaintec debugger.

And that's all there is to it! **Figure 1** shows how the debugger user interface looks after the last of these commands is executed. The left-hand part shows the DSP program, the debugger commands and the DSP I/O registers; the right-hand part displays the selected areas of X and Y memory and the contents of the DSP's registers. We have selected fractional display mode ('[FRA]') for the values in the memory and register displays: alternatively, the values can be shown in decimal, hexadecimal or binary, or in graphical form.

It is possible to make the DSP switch to the debug state to allow access by the debugger from within the program itself, using the assembler instruction `debug`. This has the same effect as issuing the command `force b` from within the debugger as shown above.

Symphony Studio

Symphony Studio integrates an assembler, a simulator and a debugger along with a C compiler and more besides. It is based on the open-source integrated development environment Eclipse, which was originally developed for writing Java programs. It is a considerably more modern-looking product than Suite56. Eclipse is used as the basis for many other professional development environments for other processors: it is clearly highly worthwhile to learn how to use this system, which is on the way to becoming an industry standard. The biggest advantage offered by Symphony Studio is its support for team working, including file synchronization and version control. It also works perfectly well on 64-bit versions of Windows. On the downside the user interface is complex and there is a large number of configuration settings. If, because of a bad configuration setting, the program does not react to a command quite as you expect, it can be very difficult to work out what is wrong. Also, many operations are not particularly intuitive.

The Eclipse interface is based around specific components, views, editors and perspectives. Wikipedia contains an informative description, from which we have summarized some of the information below, adapted where necessary to the particular configuration used by Symphony Studio.

A 'view' is a small window dedicated to a particular function. Examples of views in Symphony Studio are the 'navigator' and the project directory structure display. These views can be rearranged at will by dragging: they can be arranged in the form of tabs, activated by a click of the mouse,

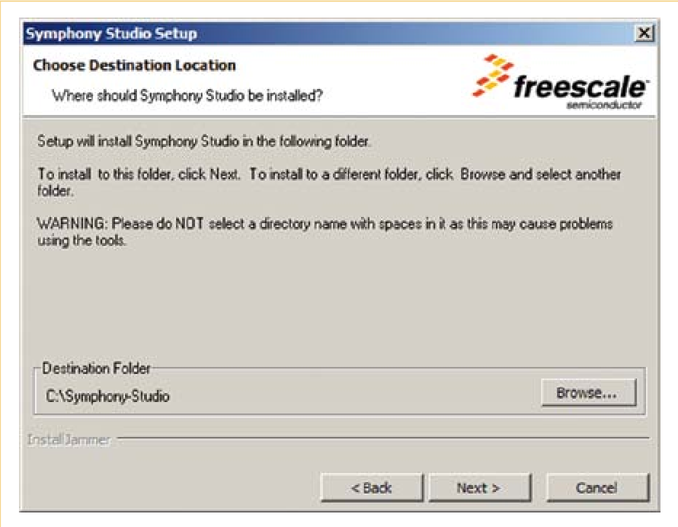


Figure 2. Installation path.

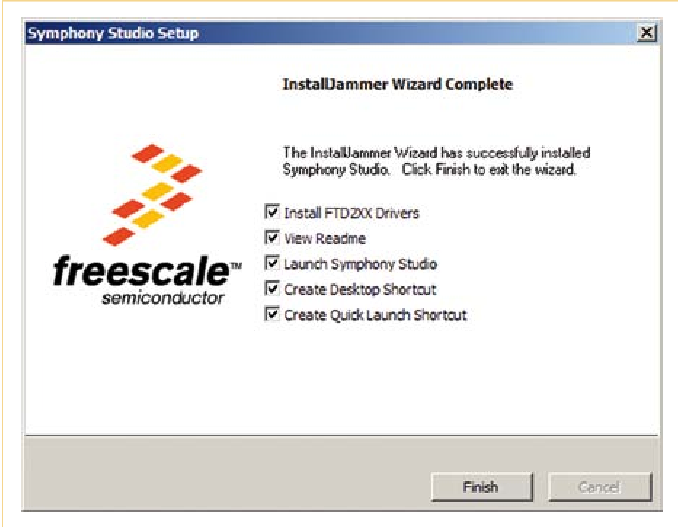


Figure 3. Installation options.

in the form of permanently displayed windows, or as ‘fast views’, which appear as icons on bars that can be placed almost anywhere. Clicking on the icon makes the view appear. ‘Editors’ are used to display source code, with syntax highlighting. A ‘perspective’ is a complete arrangement of menus, icon bars, views and editors. The arrangement is highly configurable, and user-defined perspectives can be saved and loaded. Symphony Studio includes two perspectives, the ‘C/C++’ perspective for setting up and working on projects and for assembling source code, and the ‘Debug’ perspective in which the simulator and the debugger can be used. The user can switch between the two perspectives using a ‘toggle switch’ in the upper right corner of the user interface. The simulator and debugger are both considered as debug tools, differing essentially only in whether they require the presence of a DSP board. This is a sensible decision, and a consequence of it is that the simulator does not have a perspective to itself.

We will now look at how to install Symphony Studio and run it on a small example program. The steps given are by way of example only: there are other ways to achieve the same effects, and it will probably take you a little while to find the workflow that you find most comfortable. Freescale offers a manual [2] and application notes [3] with more detailed information.

One step at a time

After registering on the Freescale website the Symphony Studio software (`SYMPHONY_STUDIO_IDE.zip`, approximately 55 MB) can be downloaded and then installed. Since it uses the Eclipse envi-

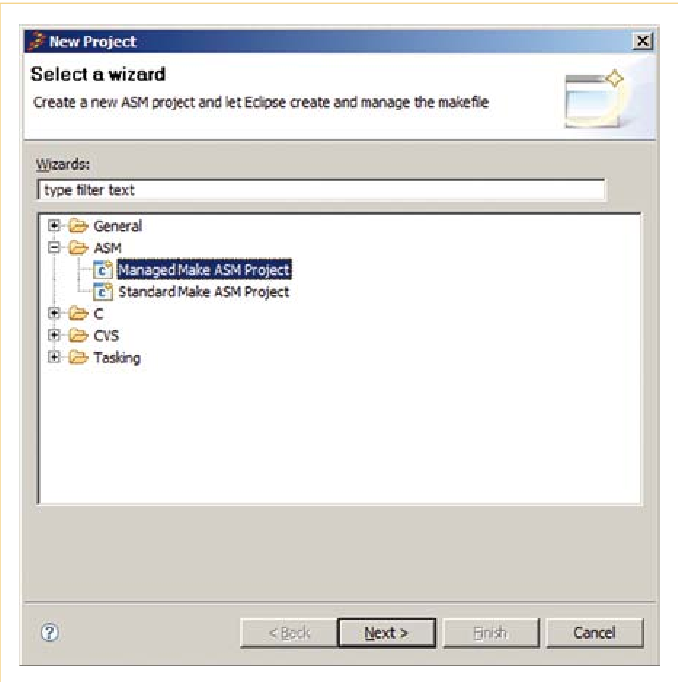


Figure 4. Starting a new project.

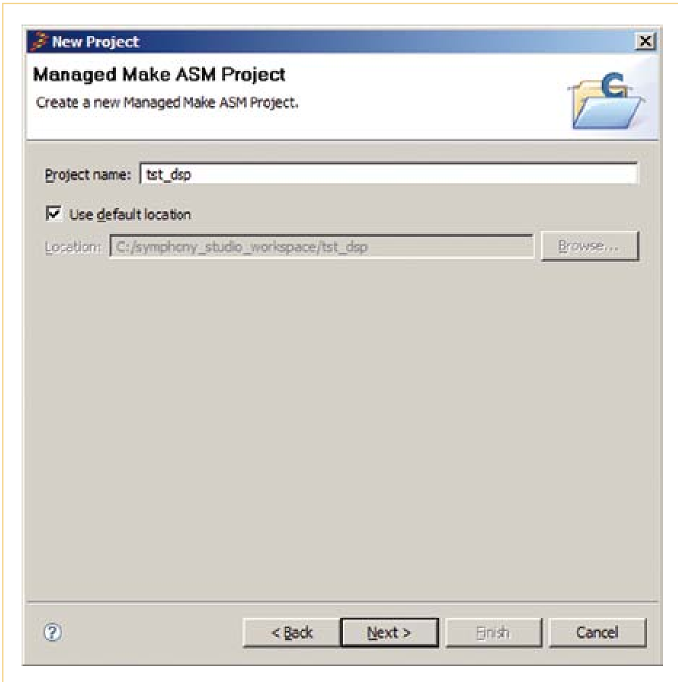


Figure 5. Giving the project a name.

ronment, the Java Runtime Environment (JRE), version 1.5 or later, is also required. If the JRE is not already installed it can be obtained from [4]. **Figure 2** and **Figure 3** show two dialog boxes from the installation process. Note in particular that the FTDI driver must be installed (do not untick the check box in the dialog shown in Figure 3!) as it is needed to use the USB adaptor. When first run the welcome screen appears: click on the 'workbench' icon on the right-hand edge. In the window that now appears click on 'Open Perspective' towards the top right and then select 'C/C++ Perspective'.

In Eclipse software is always developed in the form of 'projects'. We can create and initialize a new project by clicking on File -> New -> Project -> Managed Make ASM Project. **Figure 4** shows the 'New Project' window. Give the project a name, for example the name of the test program, as shown in **Figure 5**. We now need to specify the type of project: **Figure 6** shows the settings that we need. The project is set up in 'build automatically' mode, which means that whenever the source code is changed and the edits confirmed by a `Save' command, the assembler will automatically be invoked. The next step is to specify the directory for the source code, by clicking on File -> New -> Source Folder. **Figure 7** shows the how the project subdirectory is entered: we have simply called it `src`. The subdirectory is now set up, and we can use Windows Explorer to copy the source code file `tst_dsp.asm` and paste it into the prepared subdirectory `...\tst_dsp\src` in the 'Project' window ('View Project'). We can open the source code file using 'Open File' in an editor. Under 'File' click on 'Refresh', which will cause the assembler to be run on our source code. Alternatively, we can make a trivial change to the source code and then the assembler will be invoked when we tell the editor to save the file. The assembler will produce a listing file, which we can load into an editor from the 'Project View'. **Figure 8** shows the appearance of the C/C++ perspective with the program source code displayed, including color highlighting of keywords, along with the listing file `tst_dsp.lst`. On the left-hand side in the 'Project View' we can see the directory structure of the project, including a subdirectory called 'debug', about which more later.

Debug perspective is used for simulation, loading code into the DSP, and debugging. In the SDE plug-ins such as the simulator and debugger are called 'External Tools', which reflects the fact that they are separate programs independent of the Eclipse environment. In order to use one of the external tools, a connection must be established to it. This gives a way for data to be transferred to and from it, and for it to be configured. In this case data communication is done over a TCP/IP port. Configuration depends on the hardware that is connected: Symphony Studio knows about the Freescale Soundbite board, the special-purpose DSP56371 signal processor, and the DSP56300 family, to which our DSP56374 belongs. To configure the debugger for our hardware take the following steps.

- Switch to the Debug perspective (upper right corner of the window) and click on the drop-down menu item Run -> External Tools -> External Tools.
- Select the external tool 'OpenOCD GDB Server'.
- Press the 'New Launch Configuration' button, which looks like a piece of paper

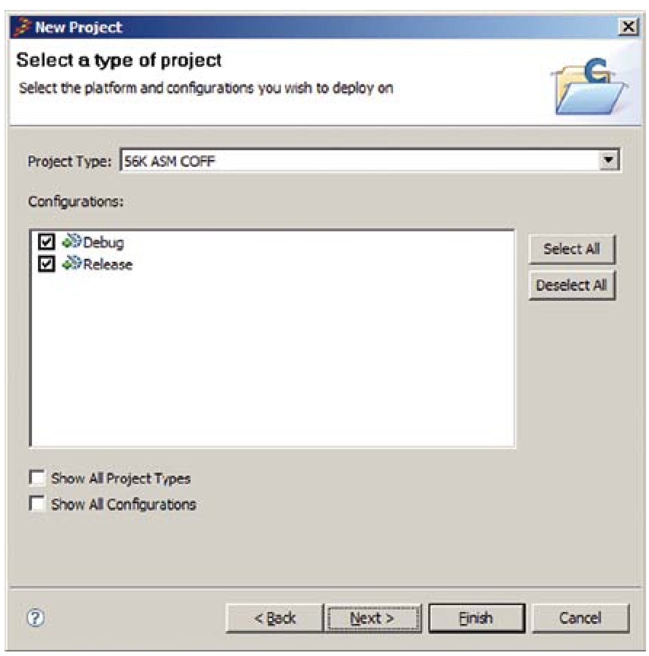


Figure 6. Selecting the project type.

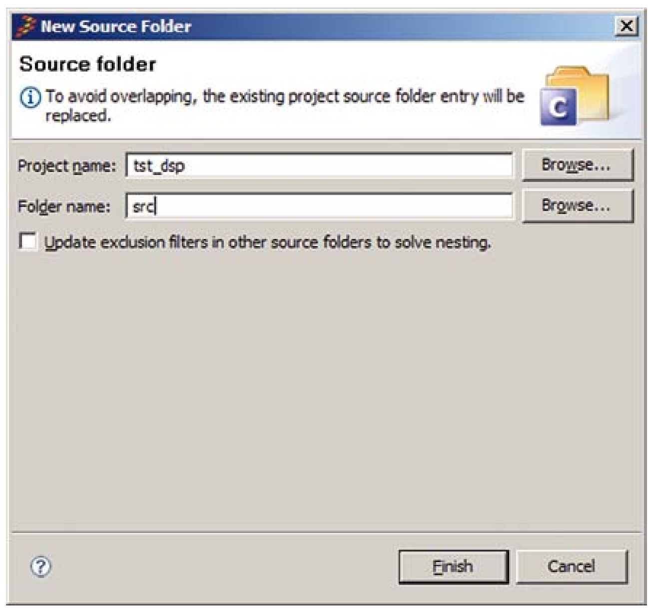


Figure 7. Adding a source directory to the project.

The

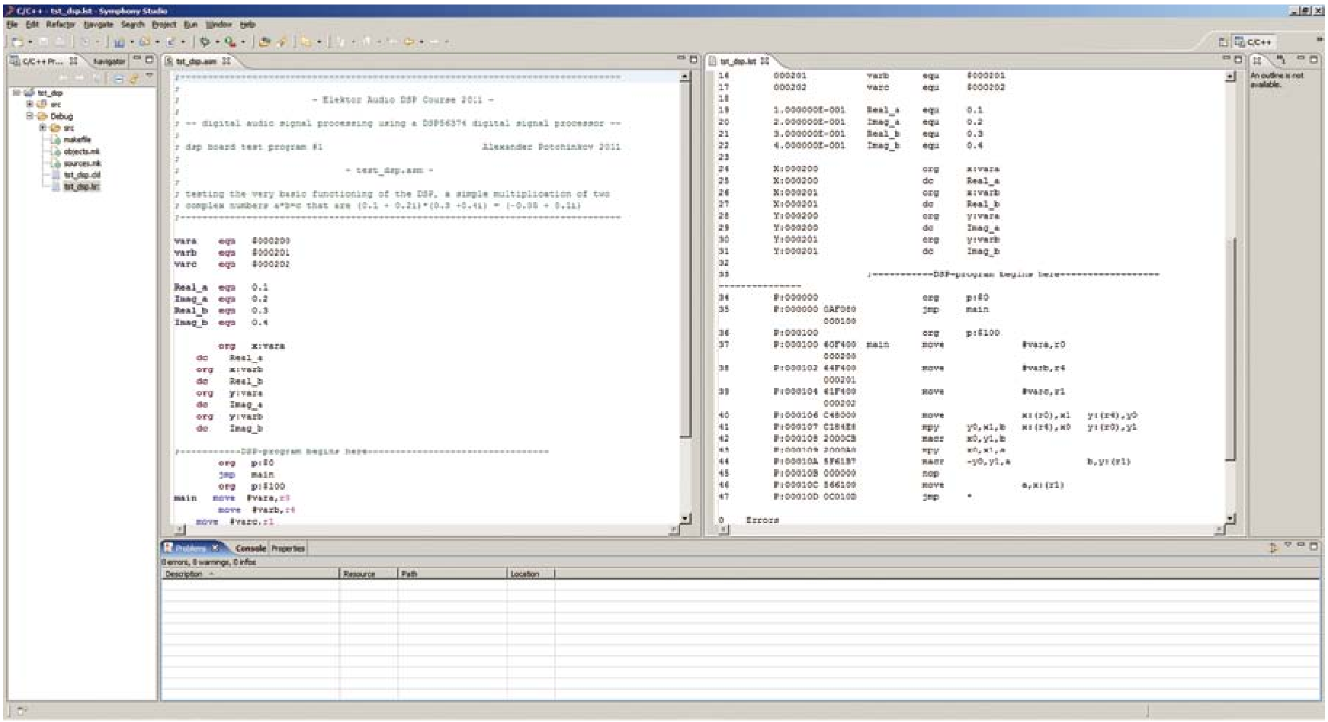


Figure 8. Project, source code and listing views in the C/C++ perspective.

with a yellow plus sign. Alternatively, the same effect can be achieved with a double click on 'OpenOCD GDB Server'.

- Select 'DSP56300' from the device list and 'soundbite' from the dongle selection list.
- Connect the hardware to the PC via the adaptor. Windows will take a few moments to find and load the correct driver.
- When the hardware has been recognized and is ready, press the 'Run' button to open the debugger. If this is successful the status line should give the message 'Info: openocd.c:82 main(): Open On-Chip Debugger' and there should be no error messages. If an error does occur, it is usually best to go back to step 1 and try to establish connection again from scratch.
- Before beginning the debugging session we have to select the project that we wish to debug. Go to the C/C++ perspective and click on the project directory `tst_dsp`. A blue background confirms the selection.
- Return to the Debug perspective.
- To start debugging click on the Run -> Debug menu item. As before select 'Freescale 563xx' for processor and create a new debug configuration using the 'New Launch Configuration' button (piece of paper with a yellow plus sign). Alternatively, the same effect can be achieved with a double click on 'Freescale 563xx'.
- A new debug configuration bearing the name of the current project will be created.
- As the error message 'Program not specified' under the heading 'Create, manage and run configurations' indicates, we have still not yet indicated what program we want to load into the DSP. Locate the object code file `tst_dsp.cld` on the machine using the 'Browse' button or more simply use 'Search Project'.
- Click on 'Apply' to store the configuration settings and then 'Debug' to run the debugger.
- In the Debug view the program can be started and stopped using Run -> Resume and Run -> Suspend. Breakpoints can be set and cleared by double-clicking in the left edge of the disassembly view. The view showing the processor's registers is the most important debugging tool. Clicking on the plus symbols allows particular groups of registers to be displayed.
- Using Run -> Step Into (or just pressing function key F5) single-steps the DSP program. This allows the effect of each instruction on the contents of all the registers to be examined.

Less than satisfactory is the way that the register group display closes after each instruction is executed. With multiple mouse clicks on the register view it is possible to move it so that it remains open.

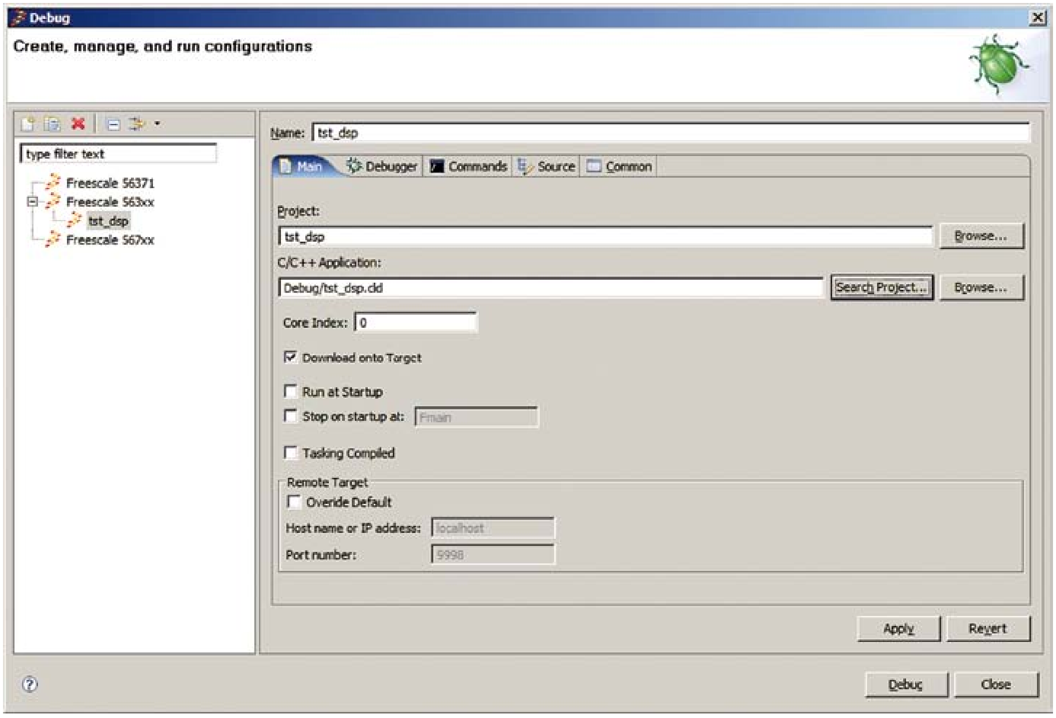


Figure 9. Configuring the debugger.

If debugging is to be repeated then the stored 'External Tools' and 'Debug' configurations can be recalled. These configurations are available from the 'External Tools' and 'Debug' menu items and icons.
When a debugging session is complete the OpenOCD connection must be shut down properly, or it will not be possible to establish the connection again when restarting the debugger: click on 'Terminate'.

To run the simulator take the following steps.

- Switch to the Debug perspective (upper right corner of the window) and select the drop-down menu item Run -> External Tools -> External Tools.
- Select the external tool 'Simapi GDB Server'.
- Press the 'New Launch Configuration' button (piece of paper with a yellow plus sign). Alternatively, the same effect can be achieved with a double click on 'Simapi GDB Server'.
- Click on 'Run'.
- In the Console view the title 'DSP56720 Simulator [SIMAPI GDB Server]' should appear, along with a path, and a red 'stop' button which is used to stop the simulator server.

To use the simulator follow the same steps (from step 7) as for the debugger given above.

Adaptor for Elektor readers

The term 'dongle' used in Symphony Studio corresponds to our use of 'adaptor'. The selection of 'soundbite' in the fourth step of the debugger instructions given above is also the correct choice when using the author's USB adaptor. Care will need to be taken if a different adaptor is used: suitable alternatives were discussed in the second article in this series. The author uses two USB adaptors that he designed himself, one for Suite56 with the Domaintec debugger and one for Symphony Studio, which appears as a 'soundbite dongle'.
The author's Suite56/Domaintec adaptor consists of an OTP (one-time programmable) 68HC05-family microcontroller and an FTDI device to convert the USB signals to a serial form compatible with the microcontroller. The unit converts between RS-232 format communications on the PC side and the five signals for the synchronous serial ONCE port on the DSP side. The FTDI FT232BL appears on the PC as a virtual COM port operating over USB. If the operating system does not already have a suitable driver available, the VCP (virtual COM port) driver must be downloaded from the manufacturer's website [5] and installed. Since the author cannot accurately estimate the demand from *Elektor* readers for the adaptor, he has arranged only to make a small number of printed circuit boards and programmed microcontrollers available. Should demand be sufficient, it will

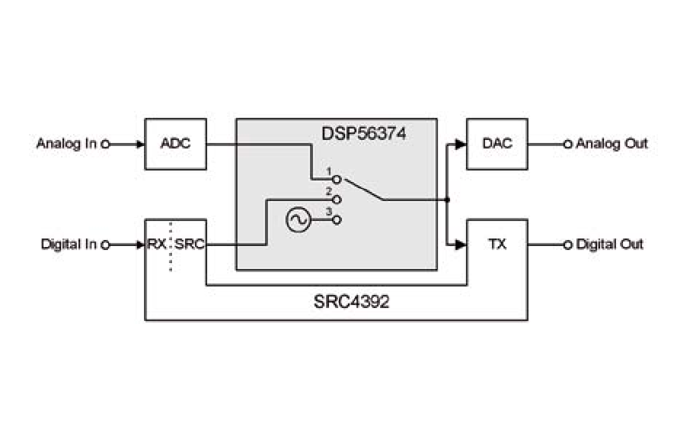


Figure 10. Audio signal paths.

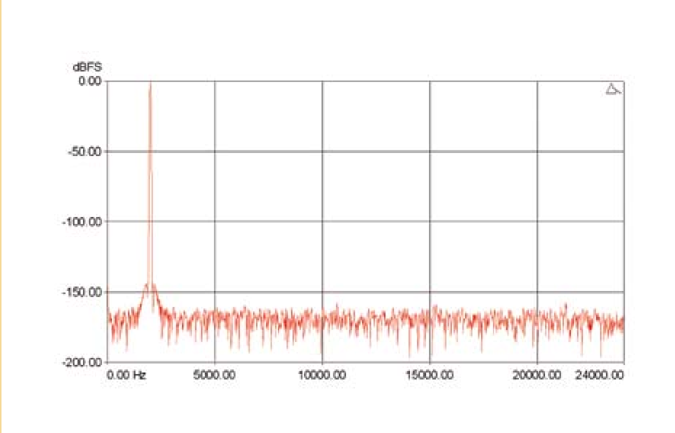


Figure 11. Spectrum of the digital output in test 5.

be possible to arrange for assembled units to be made available.

The Symphony Studio adaptor uses an FTDI USB-to-parallel converter without a microcontroller. This makes the unit simpler, since only a few additional components around the FTDI device are required. The author has had a number of these adaptors made and can supply them to *Elektor* readers.

Readers interested in one or both of the adaptors should contact the author at [6]. As mentioned in the second article in this series, adaptors are also available from several different manufacturers. Even the old-school parallel port adaptor, which is easy enough to make yourself, can be installed and used in conjunction with Symphony Studio. It is worth noting that although the USB-to-parallel port converters that are used as a substitute for the bidirectional parallel ports that used to be common on PCs are ideal for interfacing to older printers, they are not suitable for use as a programming and debugging adaptor.

Finally, please note that an OnCE/JTAG interface developed by Elektor will appear in a future edition. This interface can be used in conjunction with Symphony Studio for programming the DSP board. Like the DSP board, the interface will be supplied ready-assembled.

Testing the hardware

With the board assembled and the power supplies working properly (the current consumption is a little over 130 mA) we need to test the various parts of the circuit in the signal processing chain. These are the ADC and the DAC along with their support components on the analog side, and the SRC and the DSP on the digital side. The DSP is hard-wired as the master controller for all parts of the circuit: this simplifies the design and programming, but it does mean that nothing on the board can work without code running in the DSP. This goes for testing the hardware too, of course, and so we have written a suite of five test programs. The numbering of the programs indicates a sensible order in which they can be run, but sticking to this order is not compulsory.

The ideal instrument for testing the hardware is an audio analyzer with analog and digital interfaces. However, it is likely that very few Elektor readers will have such a unit lying idly around, and so we propose a simpler (although admittedly less accurate and reliable) approach employing the PC that we already have to hand. The following lists what is required.

A CD or DVD player to be used as an analog and digital signal source. We mainly need sine waves with various (but known) amplitudes: WAV files containing suitable test signals can be downloaded from the internet and burned onto a CD or DVD, or waveforms can be created using an audio editor. We can feed these signals into the ADC in analog form or into the SRC in digital form.

A waveform editor. Wavelab is professional commercial software for this task, or free software such as Audacity can be used. The editor will be used as an analog or digital oscilloscope to display signals in the time domain (as a waveform) or in the frequency domain (using FFT analysis). Wavelab can perform these functions 'online'; other editors may have to be operated in 'offline' mode, whereby a WAV file is captured and subsequently analyzed. Alternatively, an internet search will turn up free audio oscilloscope programs that use the sound card in a PC.

A conventional oscilloscope can also be used for testing the DAC, although (unless it is a digital instrument with an FFT feature) it is practically impossible to see small distortions in this way.

A simple USB sound card. These are available very cheaply and can also be used to generate test signals. For testing the SRC it is useful to be able to generate a test signal with a sample rate different from the 48 kHz used by the DSP test program. It is for this reason that we prefer to suggest using a CD or DVD player as an asynchronous signal source.

The test programs (see **Table 1**) are available for download along with their associated files from the Elektor website [7]. The extra files include program code such as the interrupt service routines that drive the audio interfaces, useful definitions, byte sequences for configuring the SRC and the sine wave signals for test programs 2 and 4.

Test program 1, tst_dsp.asm: test the DSP

This test program computes the product of two complex numbers a*b=c, where a=0.1+0.2i, b=0.3+0.4i and hence c=–0.05+0.1i. We will hold the values of a, b and c in consecutive memory locations $200, $201 and $202, with the real parts in X RAM and the imaginary parts in Y RAM. When the test completes and the DSP enters the debug state we can look at the DSP's registers and memory areas using the debugger and check that the values are as follows: x0=0.3; x1=0.1; y0=0.4; y1=0.2; a=-0.04999…; b=0.1000…; r0=$200; r1=$202; r4=$201; X:$200=$0CCCCD (representing 0.1); X:$201=$266666 (representing 0.3); X:$202=$F9999A (representing –0.05); Y:$200=$19999A (representing

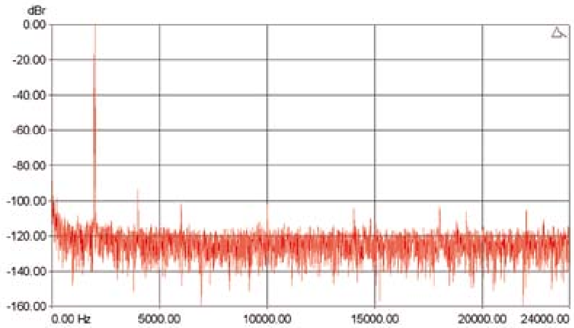


Figure 12. Spectrum of the analog output in test 5.

Table 1.
Additional files used by the test programs.

`src4392.tab`	Byte sequence for configuring the SRC
`sin1k192.tab`, `sin2k192.tab`	Sine wave signals, 1 kHz and 2 kHz, 192 kHz sample rate
`ivt.asm`	Entries in the interrupt vector table: audio interrupts
`esai4r2t.asm`	Audio interrupt service routine: 4 input channels, 2 output channels
`mioequ.asm`	More readable names for the DSP's I/O addresses

0.2); Y:$201=$333333 (representing 0.4); Y:$202=$0CCCCD (representing 0.1).

Test program 2, tst_dac.asm: test the DACs

This test program works with switch setting 3 in **Figure 10** and generates two sine waves: one at a frequency of 1 kHz on the left channel, and the other at a frequency of 2 kHz on the right channel. In each case the amplitude of the wave is 0.5 FS. At higher output levels the DAC introduces noticeable distortion. Both sine waves should be checked at the analog output using either an oscilloscope or headphones. If using headphones they should have as high an impedance as possible, and a series resistor should be used to limit the output volume.

To assemble this program some changes to the project settings must be made because of the include files it uses. A dedicated directory in the project for all the required include files makes things tidier, and naturally enough we call this directory `include`. This can be done in Windows Explorer, or it can be done in the same way as we did for the `src` directory above. We now copy the relevant files into this new directory (see Table 1). The new directory has to be added into the project, which can be done using the 'Refresh' command. Any error messages that appear in the console can be ignored. In the tab 'C/C++ Projects' (in the C/C++ perspective) find the subdirectory `src` and click with the right button on `test_dac.asm`. Then click the right button on 'Properties' and select 'C/C++ Build'. Then in the 'Tool Settings' tab select 'Options' and scroll down to 'Include File (-I)'. Click on the small green plus sign and then find the right directory using 'File System'. Now the three asm files must be excluded from the assembly process. Go to each of these files in turn in the `include` subdirectory (still under the 'C/C++ Projects' tab) and click on it with the right mouse button. Again select 'Properties' and then 'C/C++ Build'. Under 'Active Resource Configuration' tick the check box labeled 'Exclude from build'. When this has been done for all three asm files you should see in the console that the assembly process has been successful and that the file `tst_dac.cld` has been created.

Test program 3, tst_adc.asm: test the ADCs

Now that we have verified the operation of the DACs using test program 2, we can move on to testing the ADCs. This test program works with switch setting 1 in Figure 10, which loops the signal from the ADCs directly into the DACs. A signal fed into the analog input port, for example from a signal generator, should also be found at the analog output port.

Test program 4, tst_src1.asm: test the SRC, input side

Next we can test the SRC, which is in charge of both the digital audio interfaces. This test program works with switch setting 3 in Figure 10 and generates two sine waves: one at a frequency of 1 kHz on the left channel, and the other at a frequency of 2 kHz on the right channel. In each case the amplitude of the wave is 0.5 FS. The test program first resets the SRC and then configures it. The two sine waves generated by the DSP should be found on both the analog and the digital outputs. To test the digital output interface we recommend using a PC with a (USB) sound card that has a digital input.

Test program 5, tst_src2.asm: test the SRC, input and output sides

This test program works with switch setting 2 in Figure 10, which causes the digital input signal to be routed to the digital outputs and to the DAC. Any digital source signal, for example from a CD player, connected to the input should be found on both the analog and digital outputs. **Figure 11** and **Figure 12** were obtained using an audio analyzer (a Prism Sound dScope Series III) and show the spectra at the digital and audio outputs when a 2 kHz sine wave is applied to the digital input.

If you choose not to store the test program files and the other auxiliary files listed in the table in their own directory, the 'include' directives in the DSP program must be suitably amended.

Once all five tests have been successfully carried out, we can proceed to writing our own programs.

(110004)

Internet Links

[1] www.domaintec.com/ftp/domtech/e30x_331.zip

[2] www.freescale.com/files/dsp/doc/user_guide/DSPSTUDIOUG.pdf

[3] http://cache.freescale.com/files/dsp/doc/app_note/AN3754.pdf

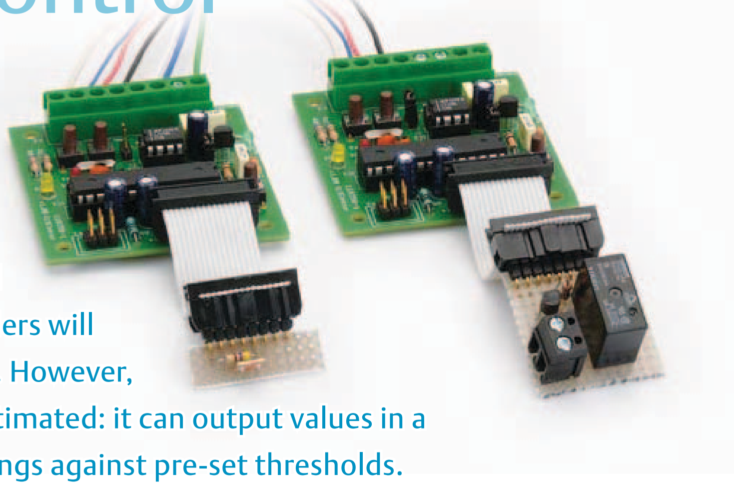
[4] www.oracle.com/technetwork/java/javase/downloads/index.html

[5] www.ftdichip.com/Drivers/VCP.htm

[6] signum.dsp@gmx.de

[7] www.elektor.com/110004

Here comes the Bus! (8)
Measurement and control



In the previous installment in this series we looked at a simple protocol for communicating the results of measurements. Now we look at how the protocol can be used in a control application. To this end we will add a couple of simple components to the experimental board: a light-dependent resistor and a relay. Many readers will probably already have suitable devices in their junk box. However, the flexibility of the sensor node should not be underestimated: it can output values in a variety of different units and autonomously check readings against pre-set thresholds.

By Jens Nickel (Elektor Germany Editorial)

Readers who have been following this series for a while will know that we start each installment with a quick round-up of what we discussed in the previous one. In the September issue we described a simple protocol specifying how the eight payload bytes within each sixteen-byte message are used. This ensures that the various nodes (sensors, actuators and controllers) can all understand what the others are saying.
A bus participant can use the eight bytes to communicate up to four values at a time. So, for example, a node could be equipped with four temperature sensors. Conversely, values could be sent to up to four actuators using a single message.
Which bytes within the message belong to which sub-module within the node is determined simply by their position: we call bytes 6 and 7 'channel 0', bytes 8 and 9 'channel 1', and so on: see **Figure 1**. Each of these channels can carry a ten-bit quantity, along with a sign bit: **Figure 2** shows how the data bits are laid out. Bit xH.5 indicates whether the quantity in question is a measured value or a setting (0 for a measured value, 1 for a setting), while bit xH.4 is used to distinguish between an acknowledge message (bit set) and the original message (bit clear).
We have already said that we would add an

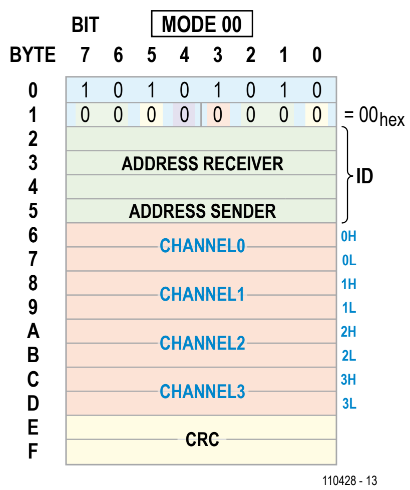
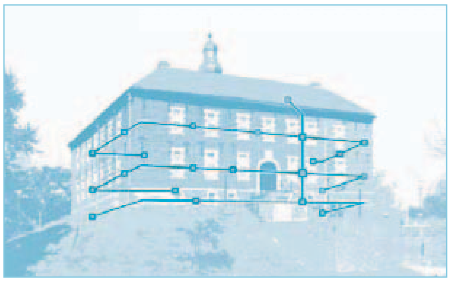


Figure 1. In 'two byte mode' the eight payload bytes are divided into four pairs. Values for four channels (individual sensors or actuators attached to a node) can be communicated in one go.

extra mode using four bytes per channel ('four byte mode'), allowing for the communication of more precise values or special commands. We distinguish between 'two byte mode' and 'four byte mode' using bit 6 of the first byte: set for two bytes per channel and clear for four bytes per channel. There will be a fair amount more bit-twiddling like this in what follows. We understand this is not everyone's cup of tea, so for easy reference we have gathered together the most important decimal equivalents of binary and hex values in **Table 1**.

The first sensor

In order to demonstrate measuring a real-world quantity we use the ultra-simple circuit shown in **Figure 3**. K1 connects directly to the expansion header K4 on the experimental node board [1]. We assembled the circuit on a small piece of prototyping board and rustled up a suitable ribbon cable: we only use one row of the 2-by-8 insulation displacement connector. This cable will come in handy frequently in the future.
If you have already programmed the firmware from the last installment into the nodes, you can start to test the system as soon as you have assembled the hardware.



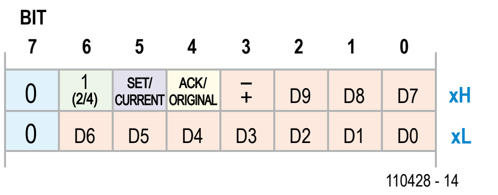


Figure 2. 'Two byte mode' in detail:
the resolution of ten bits (plus sign) is plenty for most applications.

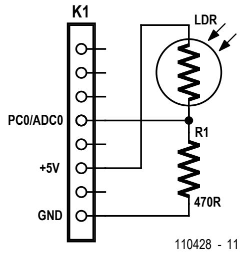


Figure 3. Our first sensor.
K1 is connected directly to header K4 on the experimental node.

The node with the light-dependent resistor attached should be configured with bus address 02 and device mode 01. This is done by programming EEPROM addresses 002 and 006 respectively with those values. The value 01 should be programmed at address 004 (corresponding to the variable 'Scheduled' in the code) so that the node knows that it will be regularly interrogated by the scheduler running on the PC. The PC software and the firmware from the previous installment can be found on the project web pages [2].
When the scheduler software is started on the PC the relevant ADC conversion results are transferred from node 2 to the PC at regular intervals using channel 0 (that is, using the first two payload bytes). The ADC value displayed in the text box is then a measure of the light level on the light-dependent resistor. From a technical point of view it is

Table 1: Bit-twiddling made easy

Representing values from –1023 to +1023 SIGN = 8 for negative values, 0 otherwise LOW = lower seven bits of magnitude (in BASCOM: Low = Value And 127) HIGH = upper three bits of magnitude (in BASCOM: Shift Value, Right, 7 : High = Value)				
	Byte 1	Byte 2		
Transmit reading	64 + SIGN + HIGH	LOW		
Set value	96 + SIGN + HIGH	LOW		
Switch on	96	1		
Switch off	96	0		
Acknowledgement from receiver: original byte 1 value plus 16				
Quantity, units and scaling CH = channel number POT = exponent ('power of ten') absolute value PSIGN = 16 for negative exponent, 0 otherwise				
	Byte 1	Byte 2	Byte 3	Byte 4
Set	40 + CH	193	see Table 2	PSIGN + POT
Voltage in V	40 + CH	193	16	0
Voltage in mV	40 + CH	193	16	19
Current in mA	40 + CH	193	17	19
Trigger transmission of preset quantity and units from sensor: byte 1 = 8 + CH				
Thresholds and alarm CH = channel number				
	Byte 1	Byte 2		
Set lower threshold	104 + CH	209		
Set upper threshold	104 + CH	210		
Alarm: value below threshold	72 + CH	209		
Alarm: value above threshold	72 + CH	210		
Value between thresholds	72 + CH	208		
Acknowledgement from receiver: original byte 1 value plus 16				

Table 2: Physical quantities

Byte (hex)	Byte (decimal)	Quantity
01	1	Raw ADC value
10	16	Voltage
11	17	Current
12	18	Resistance
14	20	Power
21	33	Temperature
22	34	Humidity
24	36	Pressure

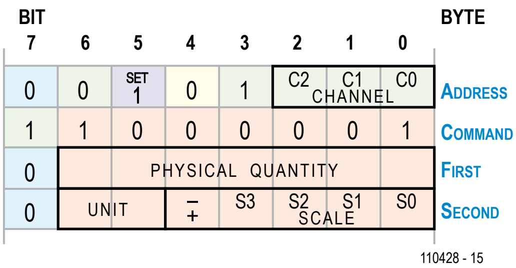


Figure 4. A total of four bytes is required to set the quantity, units and scaling factor for an intelligent sensor.

Figure 5. The user interface of our simple master controller.

interesting to know the actual resistance of the sensor: given the fixed resistor value in the sensor circuit, the resolution of the ADC and the reference voltage (5 V in this case), it is of course possible to calculate the sensor resistance on the PC from the ADC reading. But for the moment let us imagine that we are presented with the sensor as a black box (that we cannot get open!): it would be nice if the sensor node were more intelligent and could be instructed to transmit the resistance value rather than the raw ADC conversion result on the bus.

Other units

The application protocol can provide for exactly this possibility. We define a sequence of exactly four consecutive bytes, called 'address', 'command', 'first' and 'second', as shown in **Figure 4**. The protocol does not prescribe where these four bytes occur within a message: we could, for example, use the first four bytes of the payload, or we could equally well use the second half of the payload. The latter option would allow us also to communicate values to two actuators (using channel 0 and channel 1) at the same time.

All special functions are identified by a '1' in the most significant position in the second byte. This is exceptional in our protocol: the most significant bit is otherwise always zero in the payload bytes. Recall that we do this because we want to preclude the possibility of the byte value AA_{hex} (170 decimal) occurring in the payload: this value is reserved for use as the start byte of each message. We therefore choose to use the fixed value $C1_{hex}$ (193 decimal) as the command byte to indicate 'quantity, units and scaling' data.

Turning to the first byte of the four-byte sequence, the value of 'SetBit' should be 1 as we are writing rather than reading data.

The bits labeled C0 to C2 give the channel address (that is, the sensor number): we are no longer able to encode which sensor is meant by the position of the bytes within the payload. Since our light sensor is connected to channel 0 these three bits are all set to zero. Bit 3 of the first byte is always set to one in 'four byte mode': this simple trick ensures that any four-byte data packet will always start with a byte having a value greater than zero, and the receiver can then reliably use the presence of a zero byte to detect that no data packet is included in this part of the payload. Putting all the bits from this example together, we see that to set the quantity, units and scaling for a sensor on channel 0 we must send the byte 28_{hex} followed by $C1_{hex}$.

The third and fourth bytes are simpler to explain. The third byte specifies what physical quantity is being communicated: an outline proposal is given in **Table 2**. For some types of quantity (such as temperature) where various units are possible, which unit is used is encoded in the last byte. For SI units such as the volt, ohm or ampere, these bits are set to zero. The remaining five bits

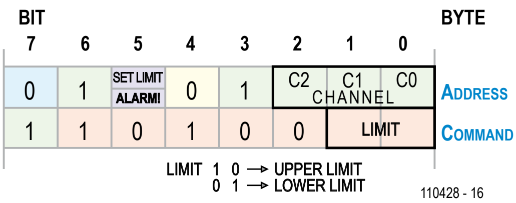


Figure 6. Setting bit 5 of the first byte instructs the sensor to store the current reading as the upper or lower threshold value.
The two bytes sent by the sensor to indicate a threshold alarm are almost identical: the difference is that bit 5 of the first byte is clear.

Floating-point numbers

Even measurements of electrical quantities often require precision spanning a range of several orders of magnitude. Our two byte mode, with just ten bits (plus sign) available, cannot cope with such a high dynamic range. For such cases we can use four bytes to represent a reading or setting. The figure shows how an individual sensor or actuator attached to a node is addressed using the channel bits C2--C0 in the first byte, as described in the text. The bytes labeled 'High', 'Middle' and 'Low' carry the actual value. High.6 is set to indicate that the bytes represent a floating-point value; High.5 gives the sign of the mantissa. MSIGN, M3, M2, M1 and M0 give the exponent (as a power of ten), and the remaining fourteen bits (D13 down to D0) give the magnitude of the mantissa. The largest number that can be represented (without using the scaling feature) is +16383 * 10^{+15}.

BIT 7	6	5	4	3	2	1	0	BYTE
0	0	SET CURRENT	ACK ORIG.	1	C2	C1 CHANNEL	C0	ADDRESS
0	FLOAT NO FLOAT	– +	MSIGN D18	M3 D17	M2 D16	M1 D15	M0 D14	HIGH
0	D13	D12	D11	D10	D9	D8	D7	MIDDLE
0	D6	D5	D4	D3	D2	D1	D0	LOW

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If High.6 is clear, 19 bits are available to represent a value directly.

of the last byte indicate the scaling factor. Bits S0 to S3 specify the exponent (power of 10) used: with the addition of the sign bit we cover the range from 10^{-15} to 10^{+15}. We suspect this might be enough for most applications our readers can dream up!

In our example, where we send a resistance value measured in ohms, the table tells us that the third and fourth bytes should be 12_{hex} and 00_{hex}. The whole command is thus 28-C1-12-00_{hex}.

Demonstration software

As usual, we have prepared some demonstration software which can be downloaded for free from the web pages accompanying this article [3]. In contrast to earlier versions of the software, the master controller node, at address 10, is responsible for a larger number of messages: previously it was only responsible for sending acknowledge messages. This node is therefore also now prompted to transmit data by the scheduler at regular intervals. In the interests of simplicity the command that triggers the master node to send its messages is simply placed inside the scheduler loop in the code running on the PC. This is clearly not the 'right' way to do it, since it treats the scheduler and master as bus nodes independent of one another. However, the trick saves us from some fiddly thread programming and timing adjustments.

When the appropriate check box in the user interface is ticked (see screenshot in **Figure 5**), the master controller node sends the byte sequence 28-C1-12-00_{hex} to the sensor node and then receives a readings from the sensor node expressed in ohms. The byte sequence 28-C1-12-00_{hex} resets the node to sending raw data. The BASCOM firmware calculates the resistance of the light-dependent resistor without using floating-point arithmetic, which helps keep the code size down. The value of the fixed resistor is specified in the line that starts 'Resistor ='. Unfortunately, resistance values of greater than 1023 ohms cannot be communicated. Two-byte mode cannot really offer the possibility of floating-point values (as on an autoranging multimeter, for example). However, it is in principle feasible in four-byte mode: the text box gives some ideas, but we will not pursue them further in this article.

Everything under control

At the beginning of this article I promised that we would be looking at a real control application. How about a simple security light that is automatically turned on when the ambient light level falls below a specified value? The comparison against the threshold value could in principle be done in the master controller, but here we choose a better approach, making the sensor into a slightly more intelligent device. At some point as evening draws in we take the current reading and program it back in to the sensor as a threshold value. From then on the sensor will emit a special 'alarm' message when the ambient light level falls below this lower threshold, and a further special message in the morning when the ambient light level rises above an upper threshold.

Figure 6 shows the format of these messages. Two bytes are needed, and as with all special functions these two bytes can appear at any position within the payload. The sensor that is reporting the threshold alarm must include the relevant channel number in the first of the bytes (in bits C1 and C2). The values that can occur in the second byte are $D1_{hex}$ to indicate that the reading is below the lower threshold, $D2_{hex}$ to indicate that the reading is above the upper threshold, and $D0_{hex}$ to indicate that the reading is in the 'comfort zone' between the two thresholds.

The same message format is used by the master controller to instruct a sensor to store the current reading as a lower or upper threshold value for future use: in this case 'SetBit' equal to 1 to indicates that this is a control value rather than a reading. In our example, setting a lower threshold on channel 0, the alarm message comprises the bytes 48-$D1_{hex}$ and the command to set the threshold value is 68-$D1_{hex}$. In the interests of reliability the master controller acknowledges the alarm with the sequence 58-$D1_{hex}$, and the sensor acknowledges the setting of its threshold with 78-$D1_{hex}$ (the acknowledge bit being set in both cases). As one of the first reader applications has shown, this feature can come in very handy: see the text box.

In the next part of this series we will look at how thresholds can be defined freely, rather than by simply storing the current reading.

The first actuator

The demonstration PC software reports the crossing of the lower threshold by displaying the work 'Alarm!' in a text box. The threshold itself can be set by clicking on the 'Set Limit' button, and the current threshold value is shown in another text box. However, this does not yet amount to a control system.

The next step is to connect the simple circuit shown in **Figure 7** to node 1. Pin ADC0/PC0 on the header is used to drive a small 5 V relay via a transistor. **Figure 8** shows an overview of the system configuration. The same firmware is used in nodes 1 and 2, the variable 'Devicemode' (programmed into the EEPROM at address 006) determining

The bus in use

Elektor reader André Goldberg writes to tell me of the first practical application for the bus: a level monitor for a water storage tank. In such an application we would of course not want to keep a PC running all the time, and so the scheduler has to run on a microcontroller. He therefore implemented a simple version of the scheduler using a timer in BASCOM. After I had given him an advance preview of the protocol and demonstration software developed for this installment in the series, André immediately developed a controller to refill the tank automatically. Unfortunately he discovered that if an alarm message is only sent once it does not always reliably arrive at the receiver: shortage of time prevented us from getting to the bottom of this problem. For critical applications the protocol therefore includes the possibility for such messages to be acknowledged by the receiver. The transmitter must then keep repeating the alarm message until it receives the 'acknowledge message' (a copy of the transmitted bytes, but with the 'acknowledge bit' set). This feature is included in the demonstration software accompanying this article. The variable 'Sendalarmflag' is set in the microcontroller firmware when the threshold is passed and reset when confirmation of reception of the alarm message is received from the master controller. The sensor node is interrogated periodically and it will thus repeat the alarm message for as long as the flag remains set. If, meanwhile, the value goes below the lower threshold, the alarm is cancelled: 'Sendalarmflag' is cleared, and 'Sendresetalarmflag' is set. The same happens, mutatis mutandis, when the situation is reversed. On the PC side there are two integer state variables, 'intSetAlarmstatus' and 'intResetAlarmstatus'. In these variables the value '2' means that the alarm message has been received and the relay is to be driven; the value '1' means that the alarm message from the sensor needs to be acknowledged; and the value '0' means that no more messages need to be sent. The sequence of states is '0', '2', '1', '0', and so on. The message to the relay is sent first to minimize delay. Note that an alarm message that sets intSetAlarmstatus to 2 must simultaneously clear intResetAlarmstatus to 0 (and vice versa): otherwise an undefined state could be reached after a rapid sequence of events.

André is now experimenting with a web server module designed by Ulrich Radig, with the idea of using it to allow readings to be displayed in a browser. More on this interesting development in the next installment of this series.

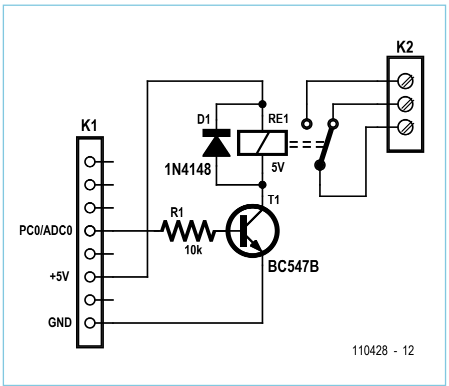

Figure 7. The relay driver circuit can be built on a small piece of prototyping board.

whether the node is behaving as an actuator (with the relay connected) or a sensor (with the light-dependent resistor connected). Pin ADC0/PC0 is correspondingly configured either as an analog input or as a digital output.
When the master controller receives a threshold alarm from node 2 it sends the byte sequence 60-01$_{hex}$ to node 1, which prompts it to set PC0 high, pulling in the relay. If node 2 should now report that the alarm is no longer set, the master controller sends the sequence 60-00$_{hex}$ to node 1: this takes PC0 low again and the relay drops out. As on-the-ball readers will have realised, the value 60$_{hex}$ arises from bit 6 ('two byte mode') and 'SetBit' both being set.

Once a threshold value has been set (and assuming everything has been properly soldered together, programmed and wired up!) you should find that a security light connected to the relay will be switched on whenever the ambient light level at the sensor goes low enough. *Voilà!*

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**What do you think?
Feel free to write to us
with your opinions and ideas.**

Internet Links

[1] www.elektor.com/110258

[2] www.elektor.com/110382

[3] www.elektor.com/110428

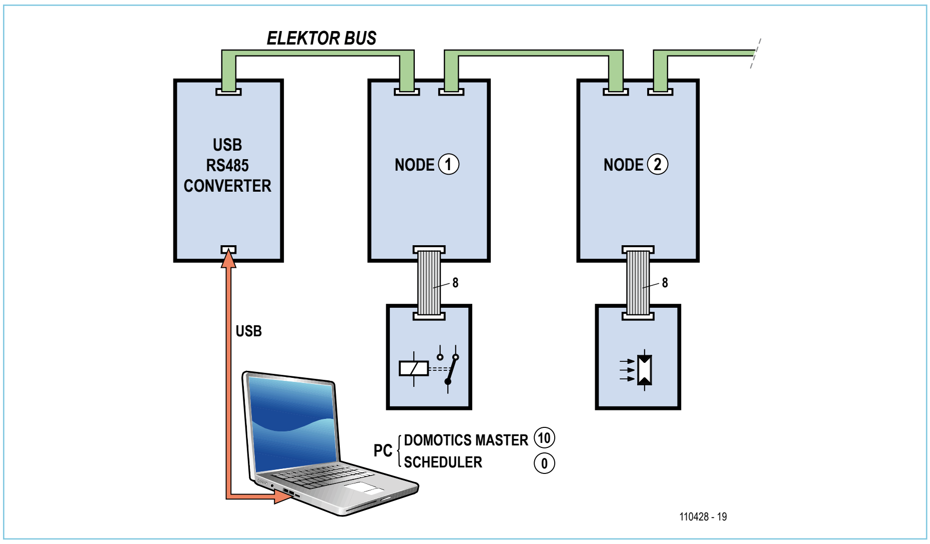


Figure 8. An overview of the simple application. The PC simultaneously takes on the roles of bus scheduler (address 0) and master controller (address 10).

Fan-Flash Alternative

Stroboscope effects with Old-School digital logic

This project is based on the 'Fan-Flash' published in the December issue of 2010 [1], a circuit that gives the illusion of stopping the blades of a running fan in a PC by using a flashing light. Prompted by a number of remarks that the educational value of this project would be much higher if the circuit was implemented without a microcontroller, we hereby present a circuit with almost the same functionality, but built using digital logic only.

By Raymond Vermeulen (Elektor Labs)

The principle of the circuit has remained the same: we give (a number of) LED(s) a number of pulses for each revolution of the fan, which corresponds to the number of fan blades. The schematic describes our circuit, which was designed for a fan with a rotation speed of 750 revolutions per minute (rpm) and nine blades. If you want to use a fan with a different number of blades then a few things will have to be changed.

LEDs

Take into account the amount of current you are going to run through the LED(s). Choose a suitable value for R1 (see **Figure 1**) based on the desired current. A good rule-of-thumb for 'ordinary LEDs' is 20 mA continuously or a maximum of 500 mA per pulse. For the forward voltage drop we assume a value of 3.5 V. This calculation is done for the fan that we used and using four white, 5-mm LEDs, which are connected in parallel as follows:

The total current through the LEDs amounts to

(12 V–3.5 V) / 12 Ω = 0.708 A.

During a pulse there is therefore 0.177 A through each LED. The fan rotates at 750 rpm = 12.5 Hz, and with nine (number of blades) pulses per revolution. From this follows that there are 12.5 ×9 = 112.5 pulses per second. One single pulse is 0.11 ms wide (see section 'The NE555'), so that the total pulse-width per second amounts to 112.5 × 0.11 ms = 12.38 ms. This establishes the duty-cycle as 1.238 %. The average current that each LED has to handle comes to 177 mA × 0.01238 = 2.19 mA. Both current values therefore fall well within the maximum current ratings.

The type of LED that you can use is, just as in the original article, entirely up to you. The circuit is easily adapted for either power LEDs or for a pair of 5-mm diameter LEDs connected in parallel. Note that in the latter case these LEDs must all of the same type and preferably all from the same batch, otherwise there is the risk that the current does not divide nicely (equally) across all the LEDs and that some LEDs will be brighter and others dimmer.

MOSFET

From the schematic you can see clearly that the part that carries the high currents is mostly the same. The differences are that a different MOSFET was selected and that the 3-pin fan connector is not connected to the motherboard but connected directly to the circuit. For this purpose there is a pull-up resistor between the tacho signal and the 12-V line.

The MOSFET does not necessarily need to be an IRF3704 either. If you choose something else, note that it has to be an N-channel type and which can be properly turned with a signal of 4 V. A V_{th} of, for example, less than 2.5 V will work well. A tip: Look in the datasheet for the graph with V_{ds} on the horizontal axis and I_d on the vertical axis. Choose the 4-V line (or the line closest to it), follow

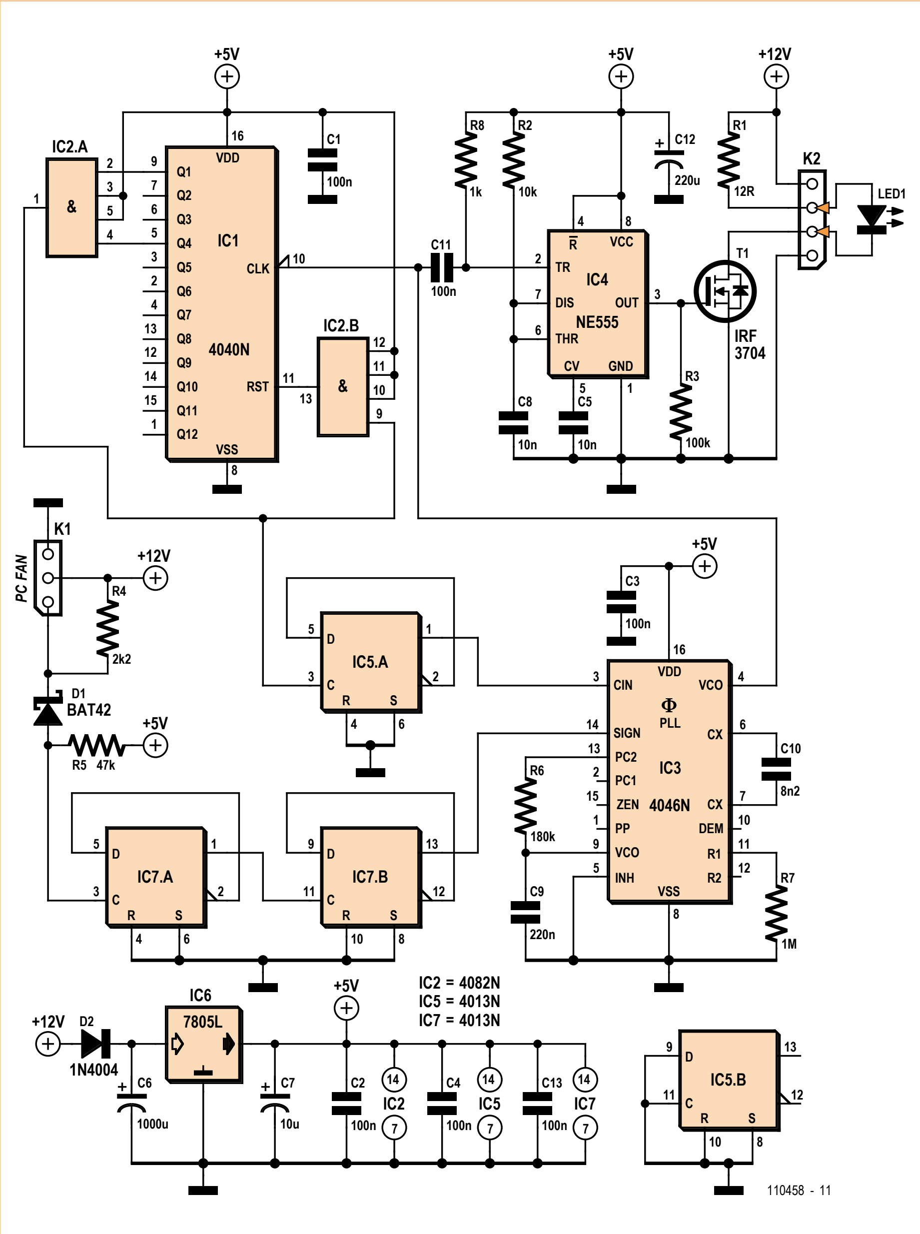


Figure 1. In this schematic we hail the ‘old-fashioned’ design of a digital circuit.

this to V_{ds} = 12 V and read the corresponding value of I_d. The curve has to be flat and I_d has to be greater than the peak current which we intend the run through the LED(s). Allow plenty of margin just to be sure.
Also note whether the rise and fall times are adequate. Typically accept a value of less than 10% of the pulse time, so that the pulse shape is preserved nicely. Most MOSFETS will have absolutely no problem with this.

Digital logic

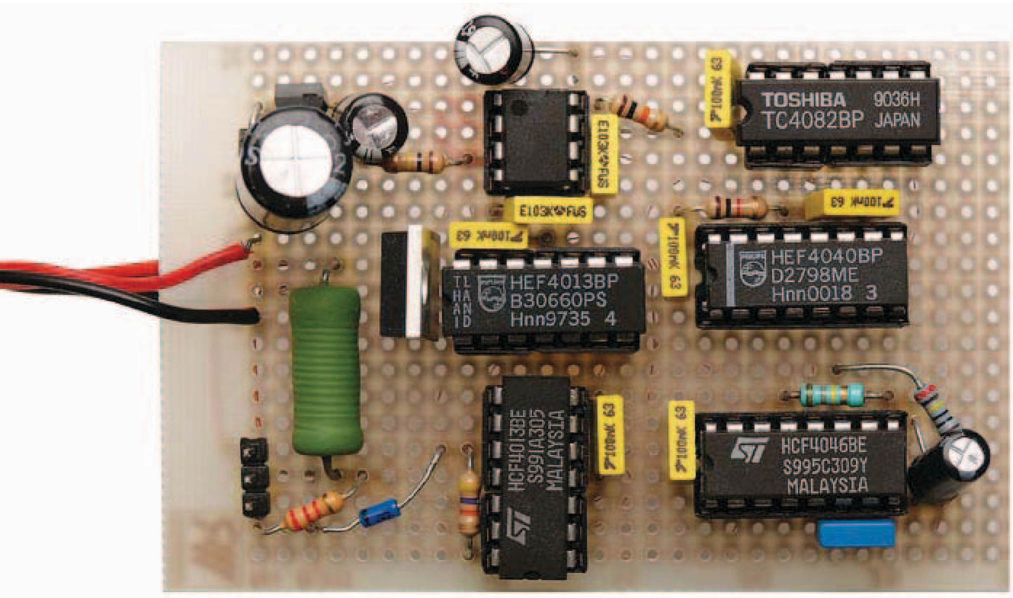
Now continuing with ‘the brains’ of this circuit. To tune the frequency of the flashing LED(s) to the rotational speed of the fan, as measured with the tacho signal, we use the services of a PLL (Phase Locked Loop), the 4046 (IC3). This IC compares the frequencies of the signals at pin 3 (CIN) and pin 14 (SIGN) and subsequently adjusts the frequency of its output signal on pin 4 (VCO) until there is no difference between both these input signals. By using a frequency divider (IC1 together with IC5) in a feedback loop, we actually make a frequency multiplier. This works as follows:
Assume that a signal of 1 Hz arrives at pin 14. At this time there is not yet a signal at pin 3 (frequency is 0 Hz). The output (pin 4) attempts to correct this difference and begins, for example, to generate a signal of 1 Hz. This frequency is then divided by a certain number (in our case that is 18) by the counter and flip-flop. The difference with the frequency at the input signal on pin 14 has become smaller, but it is still not 0. So the frequency at the output increases some more. This continues until the frequency on both inputs is the same. Since the counter and flip-flop divide the output signal by 18, at the output of the PLL is a signal that is 18 times the frequency of the input signal at pin 14. So we now have adjusted the pulse frequency to the fan that we used.

Incidentally, the flip-flop (IC5A) is necessary because there are short pulses at the output of IC2B (because of the way the feedback works to the reset of the counter with IC2B). The flip-flop turns this back into a signal with a duty-cycle of 50 % (and divides the pulse frequency by two). IC2B adds an additional delay to ensure that IC1 is not reset too quickly.

At the tacho input D-flip-flop IC7 halves the pulse frequency of the tacho signal. This is necessary because IC1 can only divide the frequency by a whole number. Because IC5A halves the ‘reference frequency’, this is therefore also done at the input (with IC7B). At 750 revolutions per minute the tacho signal from the PC fan gives 1500 pulses per minute. The tacho signal therefore has a frequency of 25 Hz. This is divided by 4 and then multiplied by 18, so that at pin 4 of IC3 we have a frequency of 112.5 Hz.

The NE555

This frequency we then convert into a pulsewidth modulated signal for driving the LED(s). We use the celebrated 555 (IC4) for this, which has been configured as a monostable for this purpose. The pulse at the trigger input is not allowed to be wider than the pulse that the 555 is to generate. As a consequence of the low frequency and the 50 % duty cycle the 112.5 Hz signal has to be capacitively coupled (C11). The result is a spike at every falling edge, which is small enough for the trigger input of the



555. The pulse width of the signal generated by the 555 is determined according to the following formula:

$$T = 1.1 \times R2 \times C8\ [s].$$

Using the values indicated results in pulses with a duration of 0.11 ms at the output (pin 3). The purpose of C12 is to prevent the collapse of the 5-V rail, when the 555 generates a pulse.
C10 and R7 determine the 'capture range' i.e. the range within which the PLL can 'lock'. This is approximated by the formula:

$$2 \times f_c = f_{max} = 1 / (0.5 \times R7 \times C10).$$

With the prescribed component values this results in a range of 0 to 244 Hz. The frequency used — 112.5 Hz — falls nicely in this range. If higher frequencies are required then C10 can be replaced with a capacitor with a lower value.
The low-pass filter formed by R6 and C9 determines the frequency range over which the input remains locked. This is expressed by the following formula:

$$f_{lockrange} = (1 / \pi) \times \sqrt{(2\pi f_c)} / (R6 \times C9),$$

which with the components used creates a range of 44.3 Hz. Because of this it can appear that the fan is rocking back and forth while in use. By changing the value of these components different effects can be created.
The circuit is powered from the 12-V power supply which is normally readily available in a PC. A 7805 turns this into a regulated 5 Volts required by the ICs.

Additional tips

If you are using a fan with a different number of blades, then you can adapt the circuit by correspondingly changing the connections from the outputs of counters IC1 to IC2A (we are now dividing by nine because the fan we used has nine blades).
The BAT42 in the schematic may be replaced with, for example, a BAT48 or a BAT43.
The 1N4004 may be replaced with, for example, a 1N4007.
IC5B is not used. It is recommended practice to connect the inputs of unused components to ground.
If the 3-pin fan connector proves hard to find you can also use a simple header instead. The pitch of these is equal to 2.54 mm just as the special Molex connector.

(110458)

Internet Link

[1] www.elektor.com/100127

The Chaos Machine

Analog Computing Rediscovered (2)

By Maarten H. P. Ambaum and R. Giles Harrison (Department of Meteorology, University of Reading, UK), Jan Buiting and Thijs Beckers (Elektor Labs)

The analog computer we set out to describe in the previous installment was constructed from separate computation modules for multiplication, integration, summation and scaling, combined to represent the Lorenz 1963 equation system (ref. part 1). The circuits for the modules are largely based on suggestions in Peyton and Walsh, *Analog Electronics with Op Amps: A Source Book of Practical Circuits*, where more details on their functionality can be found. We found the use of breadboards very suitable for this project but have also made a soldered version that travels better.

Modular approach to Chaos

Figure 1 provides an overview of how the computational modules are combined, in terms of the signal paths and **Figures 2a through 2g** provide individual circuit schematics for each of the computational modules required. A summary of their function is given below, but first the

Block diagram (Figure 1). This figure shows the combination of computation modules required for the complete analog computer. Triangles represent function modules, each with a set of inputs and a single output.

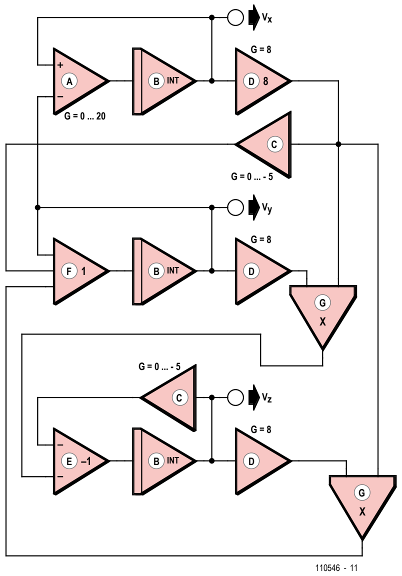


Figure 1. Block diagram of the Chaos Machine. Each function shown corresponds to one of seven basic circuits from Figures 2a through 2g, solving the Lorenz equations.

Symbols (+) and (–) are used to denote non-inverting and inverting inputs, and (×) multiplication. A thin rectangle on the input side of the triangle denotes an integrator. The gain-8 scaling amplifiers (ident: 'D') are included to ensure that the voltages in each wire do not exceed the stated maximum amplitude of ±10 V in any of the op amp input stages and the multiplier chip.

Output voltages are available at the three nodes marked V_x, V_y, V_z, for use with an oscilloscope having an 'xy'-display mode and 'z' axis (intensity) modulation.

This model has a control (in module 'A') to vary the Prandtl number (parameter σ in the Lorenz equations) between 0 and 20, to display the different regimes of the Lorenz equations.

A: Differential Amplifier (Figure 2a). Input voltages V_1 and V_2 are buffered by dual op amp stage A1, subtracted in op amp stage A2.A, and then amplified by an inverting amplifier stage A2.B with gain G (up to × –20). Function: $V_{out} = G\,(V_1 - V_2)$.

B: Inverting Integrator (Figure 2b). Input voltage V_1, referred to the signal ground, is buffered by op amp stage A2.A, and then integrated by stage A2.B. A dual op amp package provides both amplifiers. Function: $V_{out} = \int V_1\,dt \,/\, (3.3 \times 10^{-4}\ \mathrm{s})$

C: Inverting Scaling Amplifier (Figure 2c). Input voltage V_1, referred to the signal ground, is buffered, and applied to an inverting amplifier stage with variable gain G (up to × –5) set by the 100 kΩ potentiometer. Function: $V_{out} = -GV_1$. Top C: $G = -3.5$; bottom C: $G = -2.7$.

D: Non-inverting Scaling Amplifier (Figure 2d). Input voltage V_1, referred to the signal ground, is buffered, and amplified by a non-inverting stage with a fixed gain of 8. Function: $V_{out} = 8V_1$.

E: Inverting Summer Amplifier (Figure 2e). Input voltages V_1 and V_2 are buffered, and added in the third, inverting, stage. A dual op amp package provides both input amplifiers, and a further package, the summation stage. Function: $V_{out} = -(V_1 + V_2)$.

F: Non-inverting Summer Amplifier (Figure 2f). Each of the three input voltages V_1, V_2, and V_3 are buffered, and then added in a summation stage. Two dual op amp packages can be used. Function: $V_{out} = V_1 + V_2 + V_3$.

G: Multiplier (Figure 2g). A function chip (type AD633) is used to determine the product of two input voltages, with a further non-inverting stage contributing a gain of ×10 to establish a scaling voltage V_0 of 1 V. Function: $V_{out} = V_1 \times V_2 \,/\, V_0$.

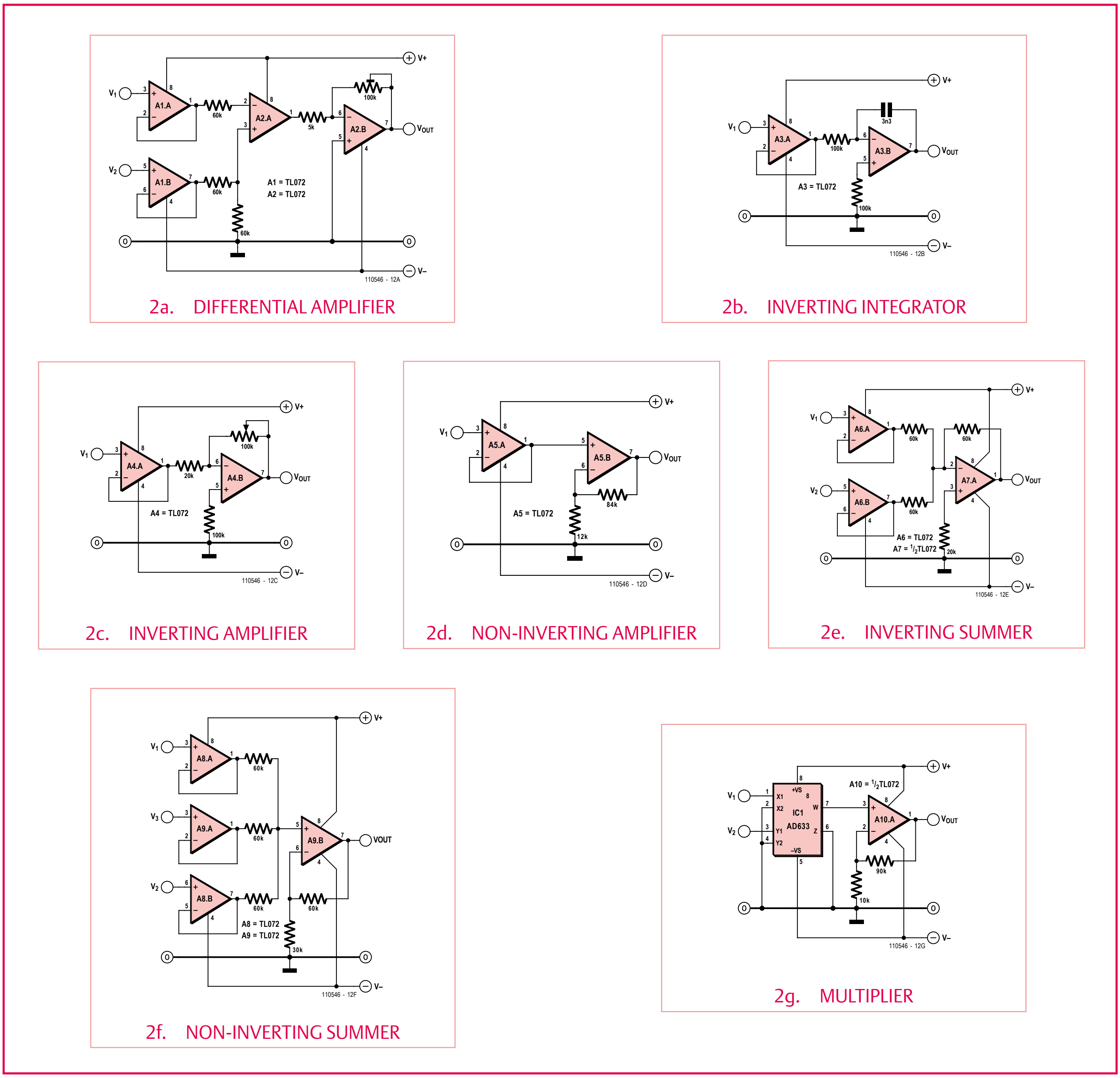


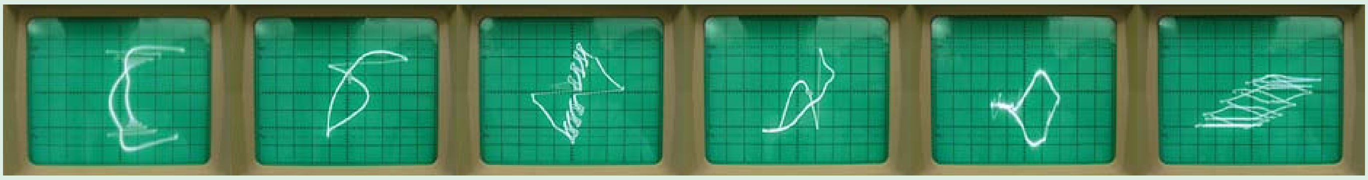
Figure 2. Overview of all required mathematical functions required for the Chaos Machine, realised using op amps for the most part.

Chaos in theory

The basic conclusion of Lorenz's work is that even if you know the initial conditions quite precisely the error in specifying the initial condition rapidly grows, so that after even a short time we cannot predict the *details* of the motion — the sensitive dependence on initial conditions is one of the defining properties of chaos.

Chaos for real

By Jan Buiting, Editor.



Retronics installments normally meet with silent understanding and approval from Elektor's technically inclined people, and mild surprise or the odd chuckle from all other staff seeing and hearing vintage equipment hauled into and out of the damp cellars of medieval Elektor House. However when the word was out that "*Chaos has descended upon Jan's pages in the September 2011 edition*" many staff were disenchanted to see a neatly formatted Retronics installment with solid content, and no chaos or other disordered mess to revel at.

Keen to experience chaos for real, a few enthusiasts murmured and then suggested to actually build the Chaos Generator and so we did, where 'we' ≈ [Thijs Beckers ± Jan Buiting] of *Chaosfree Desks*, a small, quiet faction within the Elektor editorial and lab bunch.

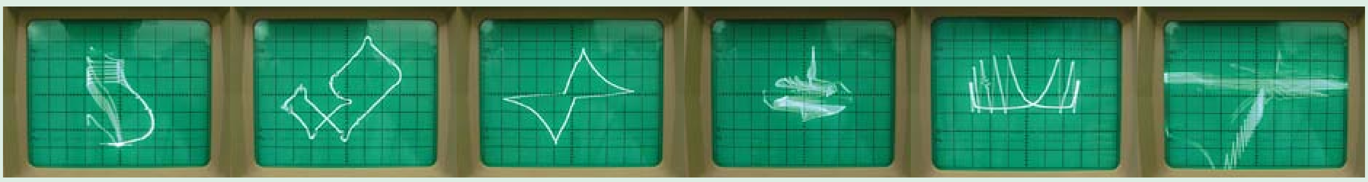
The math functions that hopefully enable the generator to behave chaotically were linked to circuits, components and eventually, modules for interconnecting with wires (signals as well as power supply). The thing worked spot on, producing bizarre images on our Hameg oscilloscope in x-y mode (sadly, all models with z modulation were on the blink). Turning the two pots and occasionally introducing stray capacitance with our fingers under some boards, we were able to produce extremely complex shapes ranging from sea horses to Möbius' bands, DNA strings, styled epsilons and even business models not unfit for graduating Hons. at the *London School of Economics* (LSE) we told our MD, accounts and marketing staff. Dilbert and Professor Bill Phillips would have loved it. For example, advancing the pot on module 'A' (LSE: "upping XYZ Corp.'s sales resources") beyond a certain critical level caused the entire riotous scope image (LSE: "this highly creative organization") to change shape (LSE: "come to terms with its budgets"), then DC–shift off the scope screen (LSE: "go in pursuit of other challenges") and finally bounce back on to the screen looking like a violent vortex not unlike that in an aircraft toilet (LSE: "sudden depreciation of assets"). As fickle as modern financial markets!

Some of the better chaotic images are shown in this inset, as well as filmed for a video clip you can view on Elektor's very own YouTube Chanel (details to be announced online). All of the images shown here are likely due to opamp saturation at some point in the system.

The sound signals taken from the outputs were as impressive and uncanny as Maarten and Giles mentioned in part 1 of this article. You have to hear it believe it and everyone's invited to check it out at the Elektor Live! event this November.

To some the generator is a gizmo you just can't resist tweaking and adjusting by means of the two controls for yet more wacky shapes on the 'scope screen. To others, it is a serious implementation of complex mathematical functions a powerful DSP of PIC micro would be challenged to produce equal results, i.e. visually and at speed. Admittedly the practical use of the machine is limited at best, with some consolation that the weather is the largest recognized chaotic system we know — with some workplaces at Elektor House happily contending for second place.

At this point, we challenge our readers to investigate if their powerful 32- and 64-bit electronics simulation programs and PCs are up to the disarmingly simple Chaos Generator circuitry shown here. Failing that, or tired of error reports popping up (*Division by Zero!*), send us the best application of the Chaos Generator you can think of! Or a Chaos applet for the iPhone or Android allowing top ranking business people to use it on the train — there's money to be made.



live! chaos

Experience the Chaos Generator at Elektor Live! 2011
Elektor Audio & Retro Division
Eindhoven, The Netherlands, November 26

Suggestions for construction

At Reading University, the components for the prototype were assembled on solderless breadboard, using a separate breadboard for each functional module. All the circuit stages were powered from a common ±15 V power supply, with a conventional ground voltage of 0 V throughout. The operational amplifiers used were type OP97. This op amp is available in single (OP97) and dual versions (OP297), which can be combined to reduce the number of integrated circuit packages required, whilst preserving the independence of the modules. Pin numbers refer to the standard dual in-line integrated circuit packages for the OP97 and OP297. The multiplication stages use a mathematical function chip, the AD633, which uses the same bipolar power supplies.

The replica of the Chaos Machine built at Elektor Labs uses TL072 op amps throughout for the simple reason that they happened to be available. Also, some of the theoretical resistance values like 60 kΩ were replaced by their nearest real-life equivalents lurking in component drawers. To add some aesthetics to the project, the modules were secured to a central post made from stacked PCB pillars, and turned to resemble the steps of a virtually round staircase, see **Figure 3**. 'Elektor Universal Prototyping Board size-1' (UPB-1 a.k.a. Elex-1) was used to construct all modules and give them a uniform look. The boards were labeled and some duplicated to enable other mathematical functions and configurations to be set up.

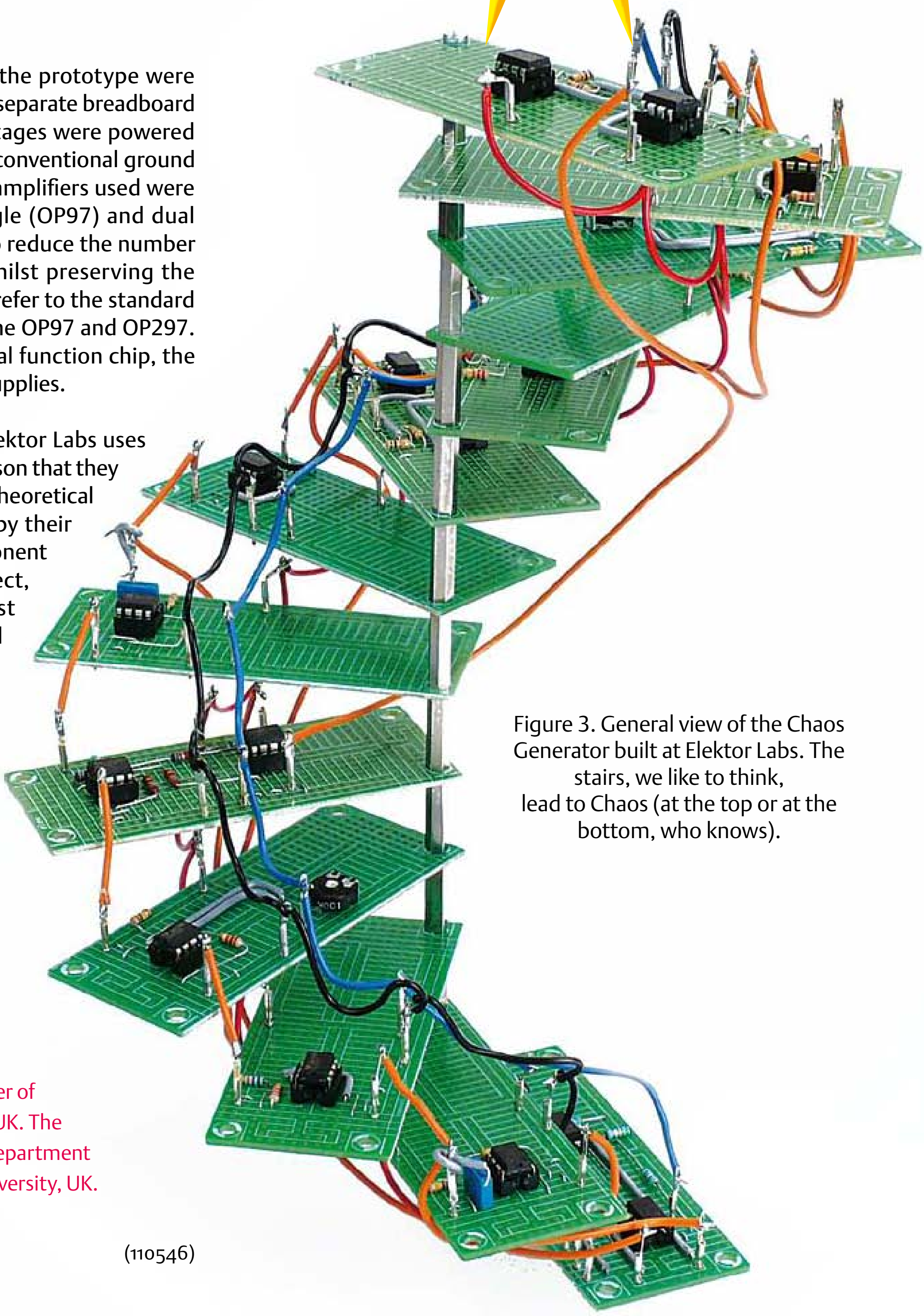


Figure 3. General view of the Chaos Generator built at Elektor Labs. The stairs, we like to think, lead to Chaos (at the top or at the bottom, who knows).

Acknowledgements: This project was stimulated through interdisciplinary workshops of artists and scientists led by artist Charlie Hooker of the University of Brighton Fine Art Department, UK. The analog computer was built in the Meteorology Department laboratories by Stephen R. Tames, at Reading University, UK.

(110546)

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

Puzzle with an electronics touch

Confident as you might feel juggling hexadecimal numbers in your compilers or 32-bit microcontroller registers, this here Hexadoku is a different kettle of fish if you rely on sharp thinking and your pencil only. Enter the right numbers in the puzzle. Next, send the ones in the grey boxes to us and you automatically enter the prize draw for one of four Elektor Shop vouchers. Have fun!

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

Solve Hexadoku and win!

Correct solutions received from the entire Elektor readership automatically enter a prize draw for one Elektor Shop voucher worth $ 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, 2011, send your solution (the numbers in the grey 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 2011 Hexamurai is: **ABC879**.

The Elektor $140.00 voucher has been awarded to Marianne Meyers (Luxembourg).

The Elektor $70.00 vouchers have been awarded to Brian Unitt (UK), Jean-Claude Carré (France) and Erik Petrich (USA).

Congratulations everyone!

2	A		7		C			9	D	6	4	8			
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	1					0		8					4	A	B
					7		2			B	C		0		3
C	2		8		D	3				4	E				
		F	A	7		2		B		3		1	C	0	4
				4			F			1					E
9			B	1								2	3		
		8	C								0	3			D
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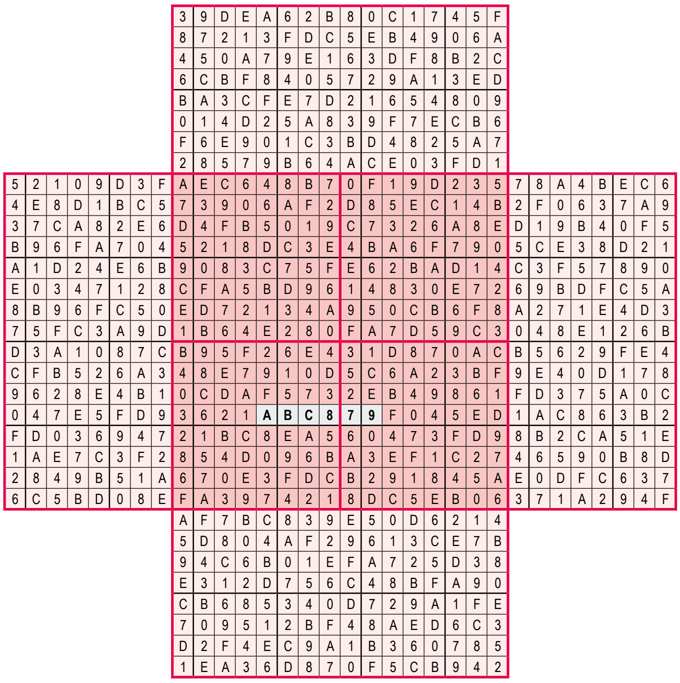
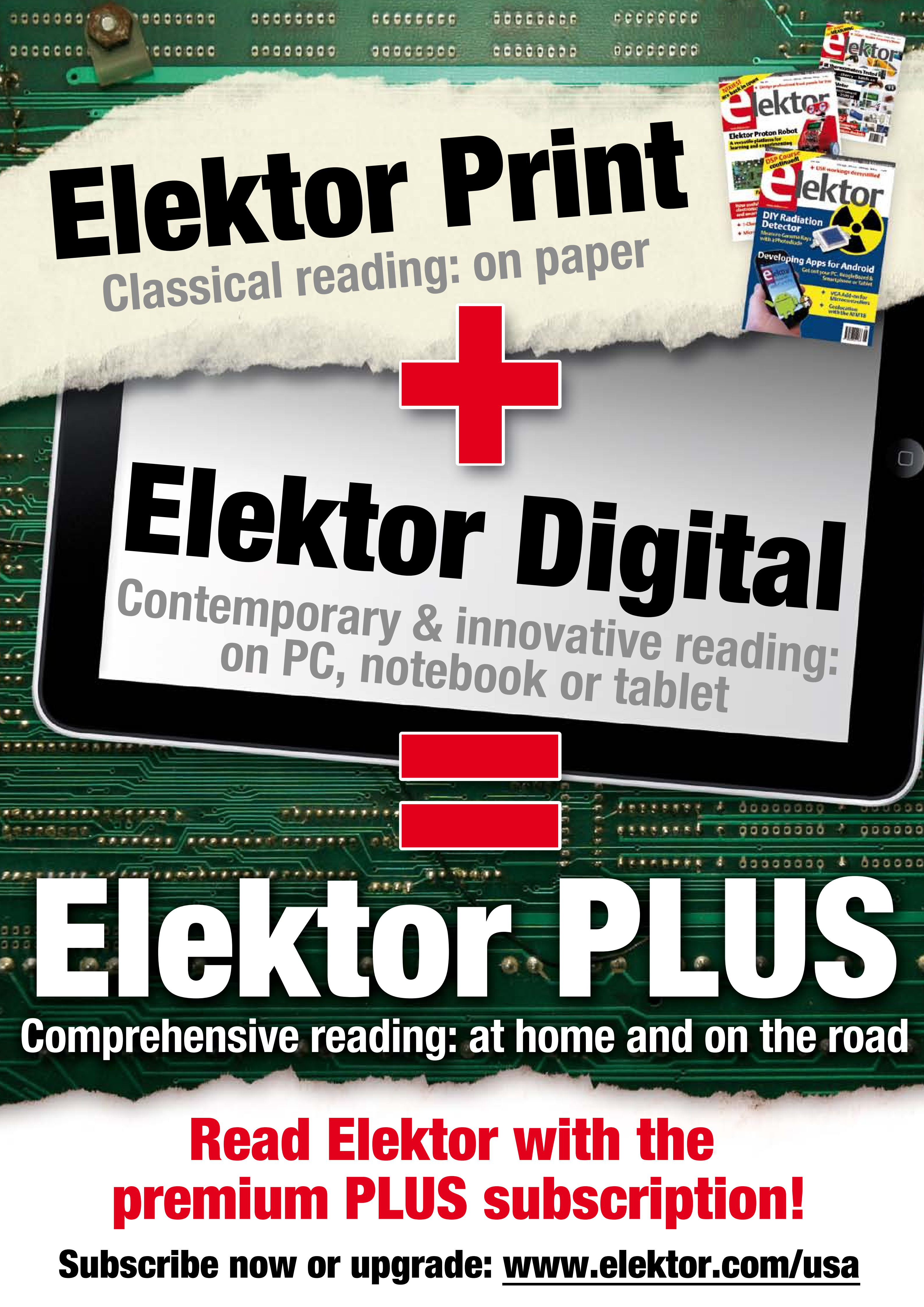
(Grey boxes: row 13, columns 12–16.)

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Teaching Yourself

Gerard Fonte (USA)

The half-life of technical engineering information is generally considered to be 5 years. That is, after 5 years, half of what you learned is obsolete. Engineering, by far, is the fastest paced profession that there is. As Alice said, "You have to keep running as fast as you can, just to stay in the same place!" You can certainly take formal coursework to maintain your level of technical expertise. But often this is a difficult and expensive option. On the other hand, it's really fairly easy, and usually fun, to teach yourself.

Read, Read, Read

You can subscribe to dozens of free technical journals — both in print and on-line. These provide all sorts of information on the latest advances, products, news and ideas. They can keep you up-to-date on new developments while you're eating, watching TV, or at the beach. (You do multi-task, don't you?)

Just do an internet search for "Engineering Trade Magazines" and you'll find more than you bargained for. I glanced at "www.tech-expo.com/tech_mag.html" and they have hundreds of magazines listed. Although, not all of them are free. However, everything at "www.freetrademagazines.com/engineering-industrial-magazines" is free. There are many, many areas besides engineering, as well. There's a good chance that you'll find something completely different, but interesting. Nor are these two sites all that there is. It seems that everyone wants you to read about their technical subject.

Note: free trade journals rely entirely on advertisers for income. This means that they often accept articles from companies which are thinly veiled promotions for their products. This is not necessarily bad, but it is something to be aware of. Generally, the author's affiliation is also listed, to eliminate confusion.

There is one "gotcha" about technical magazines. They usually require you to enter a Company name and address. If you're a student or a hobbyist, this can be a problem. However, most magazines have an option for "home delivery" if the place of business doesn't allow magazines at work. So a parent's or friend's company could be named. If you are a student, they will sometimes accept "student" as occupation title and your school as the business.

Alternatively, you can "start" your own business by going down to the county hall and registering as a DBA (Doing Business As). There's usually a small one-time fee and that's all there is. Then you can truthfully say that you're the president of Dyno-Dyne. (Refer to Elektor, January 2010 column "DBA").

Playing at Work

Another way of learning is by doing (This is where hobbyists have the edge). There is nothing better than hands-on experience. Getting that new chip or software package and figuring out how it works, is fun. And in the process you learn a lot.

You can save considerable money by getting samples of products instead of buying them. Obviously you can't get common resistors or things like that. And if you have a shopping list, you're likely to get a cold shoulder. But it's not at all unreasonable to obtain the two or three main chips you need for your new project for free. Just ask.

Most of the major manufacturers have websites that allow you to get free samples of parts. Although you generally have to pay for the shipping (Analog Devices pays for shipping, but they sample from overseas and it may take up to two or three weeks to get your parts). Not every variation of every part may be available. You may be somewhat limited in things such as package type and some performance specifications. But this is still a great deal. Like the free magazines, they will want you to list your company and job title (And there is a free magazine you can subscribe to that describes/lists free electronic parts. It's called the "Sample Source". It's associated with EDN magazine).

Many businesses will provide small "grants" for research if you can show them that it will improve the bottom line. They are interested in new products, cheaper methods of manufacturing, faster design to market and things like that (And while they want you to maintain your state-of-the-art experience, they want to do it as cheaply as possible). Incidentally, these "research projects" look nice on your resume. Generally, the best compromise is that you provide your own time and they will provide the money for the hardware/software.

Everything Old is New Again

Way back when, in BC times (Before Computers), manufacturers would provide hard copy data books. These made it easy to browse through their products and compare this with that. It was also easy to compare between manufacturers. But the best thing was their "Application Databooks" or "Applications Handbooks". These were collections of scores or even hundreds of circuits and ideas all in one place.

These are jewels beyond price. If you ever have an opportunity to get one, don't pass it up. While the devices that are mentioned are obsolete, the concepts and circuits are still extremely useful and valuable. Good ideas do not follow the 5-year half-life rule. Specifically, the National Semiconductor Linear Applications Databook, 1986 is a gem. The 2002 edition is excellent, but not as good for fundamental ideas (App notes AN-20 and AN-31 should be in everyone's library). The 1997 "Microchip Embedded Control Handbook (Volume 1)" is another gem. The 2000 "Embedded Control Handbook Update" is excellent.

The great thing about the analog circuits is that many of the problems of 25 years ago no longer apply. Back then, it was very difficult to address temperature drift or component variation, etc. It was impractical to require the user to verify proper circuit operation every time the unit was turned on. But with the advent of microcomputers, that problem is addressed with a start-up self-test/calibration routine. The marriage of old analog circuit ideas with new embedded computers opens up a new world in analog design.

In closing, I would like to remember two giants of the analog world who died recently: Bob Pease of National Semiconductor and Jim Williams of Linear Technology. They broke the ground and built the foundation of analog IC's.

(110626)

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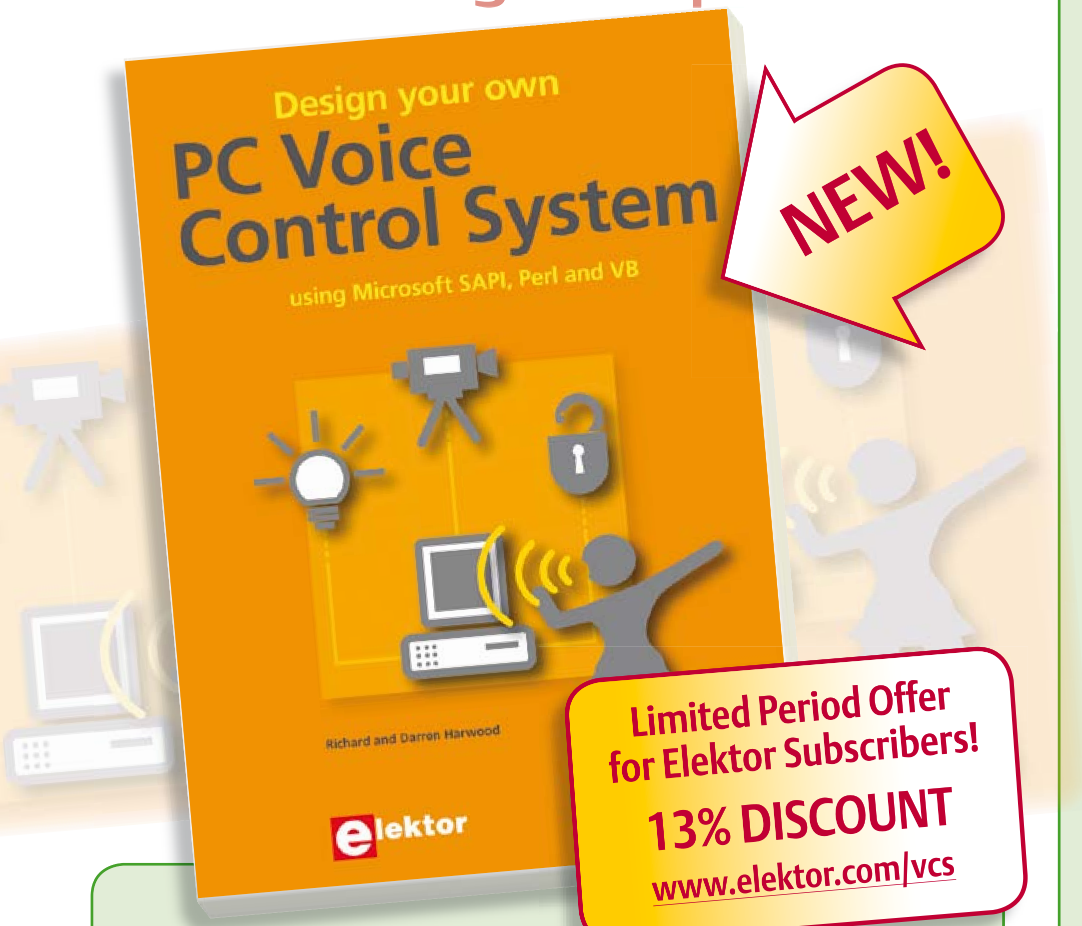

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User: "Computer, turn on hall lights" – Computer: "Hall lights on"

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Don't you feel it's just about time we could simply talk with computers and get them to handle some of the everyday house automation tasks - lights, doors, gates, curtains, televisions, music and other domestic appliances? Or even make the information super-highway slicker by talking with you and telling you about the information you requested to be retrieved from the web? Think of all the time and inconvenience you could save - no more need to install yourself at a desk and fumble about with keyboard and mouse. Well now you can! This book guides you through practical speech recognition, speech annunciation and control of really useful peripherals. It details a project which will enable you to instruct your computer using your voice and get it to control electrical devices, tell you the time, check your share values, get the weather forecast, etc. and speak it all back to you in a natural human voice. If you are interested in the practical technology of interfacing with machines using voice, such as talking with your own PC, then this book is your guide!

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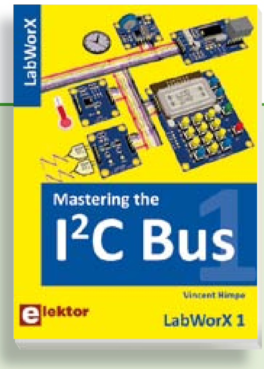

LabWorX: Straight from the Lab to your Brain

Mastering the I²C Bus

Mastering the I²C Bus is the first book in the LabWorX collection. It takes you on an exploratory journey of the I²C Bus and its applications. Besides the Bus protocol plenty of attention is given to the practical applications and designing a solid system. The most common I²C compatible chip classes are covered in detail. Two experimentation boards are available that allow for rapid prototype development. These are completed by a USB to I²C probe and a software framework to control I²C devices from your computer.

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Solutions for control system applications

Introduction to Control Engineering

This book is intended as a source of reference for hardware and software associated with instrumentation and control engineering. Examples are presented from a range of industries and applications. Throughout the book, circuit diagrams and software listings are described, typical of many measurement and control applications. The hardware and software designs may be used as a basis for application by the reader. The book contains examples of PIC, PLC, PAC and PC programming.

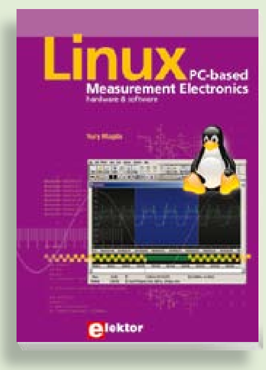
164 pages • ISBN 978-0-905705-99-6 • $44.40

Free mikroC compiler CD-ROM included

Controller Area Network Projects

The aim of the book is to teach you the basic principles of CAN networks and in addition the development of microcontroller based projects using the CAN bus. You will learn how to design microcontroller based CAN bus nodes, build a CAN bus, develop high-level programs, and then exchange data in real-time over the bus. You will also learn how to build microcontroller hardware and interface it to LEDs, LCDs, and A/D converters.

260 pages • ISBN 978-1-907920-04-2 • $47.60



A highly-practical guide

Linux – PC -based Measurement Electronics

If you want to learn how to quickly build Linux-based applications able to collect, process and display data on a PC from various analog and digital sensors, how to control circuitry attached to a computer, then even how to pass data via a network or control your embedded system wirelessly and more – then this is the book for you! The book covers both hardware and software aspects of designing typical embedded systems using schematics, code listings and full descriptions.

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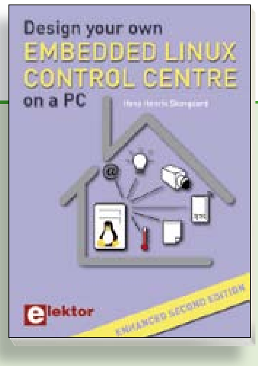

Enhanced second edition

Design your own Embedded Linux Control Centre on a PC

The main system described in this book reuses an old PC, a wireless mains outlet with three switches and one controller, and a USB webcam. All this is linked together by Linux. This book will serve up the basics of setting up a Linux environment – including a software development environment – so it can be used as a control centre. The book will also guide you through the necessary setup and configuration of a webserver, which will be the interface to your very own home control centre. New edition enhancements include details of extending the capabilities of your control center with ports for a mobile phone (for SMS messaging) and the Elektor "thermo snake" for low-cost networked real-time thermal monitoring of your house and outbuildings. Now you can additionally also send all kinds of useful temperature and sensor warnings to a mobile phone. All software needed will be available at the Elektor website.

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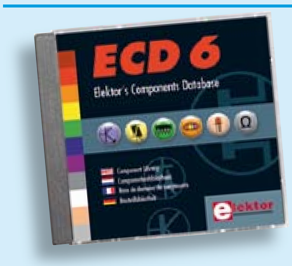
CD 1001 Circuits

This CD-ROM contains more than 1000 circuits, ideas, tips and tricks from the Summer Curcuits issues 2001-2010 of Elektor, supplemented with various other small projects, including all circuit diagrams, descriptions, component lists and full-sized layouts. The articles are grouped alphabetically in nine different sections: audio & video, computer & microcontroller, hobby & modelling, home & garden, high frequency, power supply, robotics, test & measurement and of course a section miscellaneous for everything that didn't fit in one of the other sections. Texts and component lists may be searched with the search function of Adobe Reader.

ISBN 978-1-907920-06-6 • $55.70



More than 70,000 components

CD Elektor's Components Database 6

This CD-ROM gives you easy access to design data for over 7,800 ICs, more than 35,600 transistors, FETs, thyristors and triacs, just under 25,000 diodes and 1,800 optocouplers. The program package consists of eight databanks covering ICs, transistors, diodes and optocouplers. A further eleven applications cover the calculation of, for example, zener diode series resistors, voltage regulators, voltage dividers and AMV's. A colour band decoder is included for determining resistor and inductor values. All data-bank applications are fully interactive, allowing the user to add, edit and complete component data. This CD-ROM is a must-have for all electronics enthusiasts!

ISBN 978-90-5381-258-7 • $40.20

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More than 25 projects based on the Elektor ATM18 board

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This CD-ROM contains all articles from the popular ATM18-CC2 series published in Elektor magazine. From RFID Reader and Bluetooth linking right up to a chess computer! Project software and PCB layouts in PDF format are included. What's more, this CD also contains a Bascom AVR programming course and helpful supplementary documentation.

ISBN 978-0-905705-92-7 • $39.60

All articles in Elektor Volume 2010

DVD Elektor 2010

This DVD-ROM contains all editorial articles published in Volume 2010 of the English, American, Spanish, Dutch, French and German editions of Elektor. Using the supplied Adobe Reader program, articles are presented in the same layout as originally found in the magazine. An extensive search machine is available to locate keywords in any article. With this DVD you can also produce hard copy of PCB layouts at printer resolution, adapt PCB layouts using your favourite graphics program, zoom in / out on selected PCB areas and export circuit diagrams and illustrations to other programs.

ISBN 978-90-5381-267-9 • $37.90

USB Long-Term Weather Logger

(September 2011)

This stand-alone data logger displays pressure, temperature and humidity readings generated by I²C bus sensors on an LCD panel, and can run for six to eight weeks on three AA batteries. The stored readings can be read out over USB and plotted on a PC using gnuplot. Digital sensor modules keep the hardware simple and no calibration is required.

Kit of parts incl. PCB, controller, humidity sensor and air pressure sensor modules

Art.# 100888-73 • $50.20

Pico C Meter

(April 2011)

RF and radio repair fans probably do need to be told, but when it comes to measurements below 200 pF or so, modern DMMs will produce coarse if not ridiculous results. Elektor's purpose-designed Pico C does a far better job. Beating many DMMs hands down, this little instrument easily and accurately measures capacitances down to fractions of a picofarad!

Kit of parts incl. Elektor Project Case, programmed microcontroller, LCD and PCB

Art.# 100823-71 • $118.40

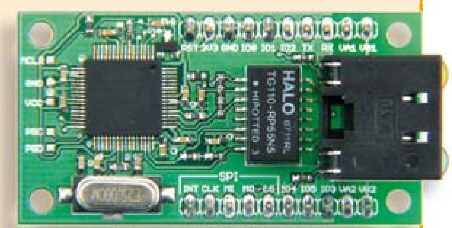
Wireless OBD-II

(April 2011)

The cheapest way to diagnose faults on a modern car is to connect its OBD-II interface to a (notebook) PC running suitable diagnostics software. However, a wired connection is not always the most suitable, and selfcontained OBD testers are a rather expensive and less flexible alternative to using a PC. An interesting option is a wireless OBD interface with a radio interface to a PC: this homebrew solution allows the choice of using either Bluetooth or ZigBee.

OBD-II-Zigbee or Bluetooth interface kit with all parts and enclosure

Art.# 100872-71 • $179.10 (Zigbee)
Art.# 100872-72 • $179.10 (Bluetooth)



NetWorker

(December 2010)

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

Module, ready assembled and tested

Art.# 100552-91 • $85.50

Kits & Modules

Product Shortlist

October 2011 (No. 34) $

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

September 2011 (No. 33)

eC-Reflow-Mate

100447-91 .... Professional SMT reflow oven 3495.00

USB Long-Term Weather Logger

100888-1 ...... Printed circuit board....25.90
100888-41 .... Programmed controller ATMEGA88-20PU 14.30
100888-71 .... HH10D humidity sensor module 11.50
100888-72 .... HP03SA air pressure sensor module 9.30
100888-73 .... Kit of parts incl. PCB, controller, humidity sensor and air pressure sensor modules 50.20

I²C Sensors

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EB069 .... E-blocks Wireless LAN board....212.90
TEDSSI4 .... Flowcode 4 for dsPIC/PIC24 ....288.40

FT232R USB/Serial Bridge/BOB

110553-91 .... PCB, assembled and tested....20.90

Here Comes the Bus! (7)

110258-1 ...... Experimental Node board, bare 8.60
110258-1C3 .. 3 x Experimental Node board, bare 18.60
110258-91 .... USB/RS485 Converter, ready made module 35.90

J2B: Universal MMI Module using ARM Cortex-M3

050176-74 .... Enclosure Bopla Unimas 160....14.30
110274-71 .... Tested PCB with LPC1343 microcontroller, crystal, 3V3 voltage regulator, LCD interface & USB interface mounted. LED and headers....www.elektor.com
110274-72 .... LC-display 4 x 20 characters (HD44780 compatible) ....www.elektor.com

July/August 2011 (No. 31/32)

2/4/6-hour Timer

110219-41 .... Programmed controller PIC12F675 DIL8....14.30

Morse Clock

110170-41 .... Programmed controller ATTiny4520-PU dip 8....14.30

Return of the Elex Prototyping Board

ELEX-1 .... Printed circuit board Universal exp. board....7.90
ELEX-2 .... Printed circuit board Double version universal exp. board....14.25
ELEX-4 .... Printed circuit board Quadruple version universal exp. board 25.80

Arc Welding Effect for Model Railway Layouts

110085-41 .... Programmed controller PIC10F200-I/P (DIP8) 14.30

Slave Flash for Underwater Camera

100584-41 .... Programmed controller PIC12F675i/p DIL8 ....14.30

WAV Doorbell

110080-41 .... Programmed controller ATmega328p DIL28 ....18.60

RGB Solar Lamp

100581-41 .... Programmed controller ATTiny13 DIL8....14.30

Jogging Timer

110160-41 .... Programmed controller ATtiny44-20PU dip 14 ....14.30

Battery Charge Monitor

110154-41 .... Programmed controller PIC16F873A....20.10

Roadwork Traffic Signals for Modellers

110203-41 .... Programmed controller ATTiny13 (8-pen DIP) 14.30

Make Your R8C/13 Speak CAN

050179-91 .... 16-bit R8C microcontroller board 17.60

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CD/DVD-ROMs	3	CD Elektor's Components Database 6	ISBN 978-90-5381-258-7	$40.20
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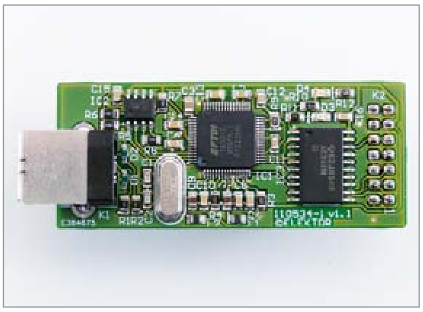
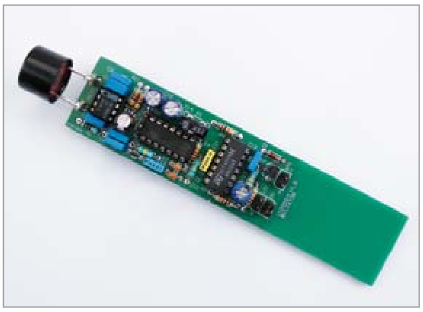


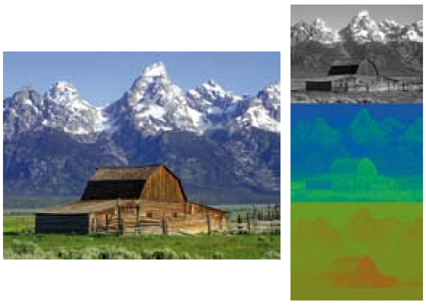
OnCE / JTAG Interface

For the DSP Programming Course, Elektor Labs developed a DSP board built around a Freescale DSP56374 chip. A JTAG interface is available on the PCB to allow DSP programming and debugging. For this, Freescale provides its own 14-pin connector, called OnCE (On-Chip Emulation). For easy connection to PC a small USB-to-OnCE/JTAG-interface was created, designed around a Hi-Speed Dual USB UART / FIFO IC from FTDI. The interface is also useful for other DSPs from Freescale and acts as a Symphony Soundbite adapter.



Low-cost Bat Detector

Unfortunately we did not have a PCB ready in time in support of the annual European Bat Night on Friday August 26, 2011, but that should not affect the general appeal of the circuit. We're talking about a simple frequency changer employing division to shift the ultrasonic sounds emitted by bats into the audible range for us humans to hear. The circuit is all built from standard components and can easily be mounted inside a piece of PVC pipe.



RGB – YPbPr Converter

Many satellite or Internet television receivers and/or decoders still don't have HDMI outputs, but do offer a good old SCART socket. Besides, the majority of high-definition flat-screen TVs, as well as high-quality video projectors, are fitted with inputs referred to as 'component' or more appropriately YPbPr (sometimes incorrectly called YUV). But although the SCART socket is often able to supply the video signals for the three primary colors red, green, and blue these can't unfortunately be fed directly to the Y/Pb/Pr inputs of TVs and video projectors. We decided to solve this problem with a DIY circuit.

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Elektor UK/European November 2011 edition: on sale October 20, 2011. Elektor USA November 2011 edition: published October 17, 2011.

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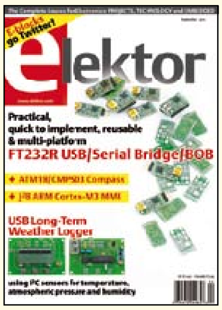

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