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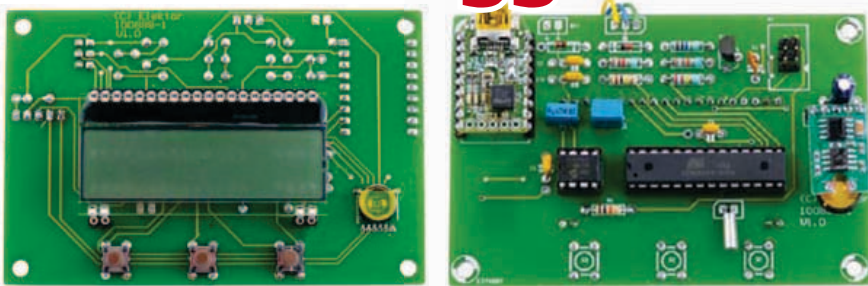
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+ ATM18/CMPS03 Compass

+ J²B ARM Cortex-M3 MMI

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Development Platforms for Smartphone and Tablet Accessories

Reduce Time to Market with Microchip Solutions

Develop Smartphone & Tablet Accessories



Want to design and develop an accessory for smartphones or tablets? The mobile device marketplace is exploding with ideas and opportunity. While much of the high-tech world has settled down into evolutionary improvements, the mobile world offers the promise of entirely new uses for ever smarter devices.

Microchip's new PIC24F Accessory Development Starter Kit for Android™ consists of a 16-bit PIC24 development board, a PICKIT™ 3 In-Circuit Debugger and a royalty-free, no fee licensed software library (available via download), which enables the fast and easy development of Android smartphone and tablet accessories based on Microchip's large portfolio of 16-bit and 32-bit PIC® microcontrollers (MCUs).

Development Board Key Features:

- PIC24F 16-bit PIC MCU with USB OTG
- Type A USB connector
- User interface buttons
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Let Microchip's PIC microcontroller-based development platforms help jump start your development of the next great accessory for remote control, home automation, financial transactions or portable medical devices.

Development resources are also available for iPod®, iPhone® and iPad®. For more information, visit: www.microchip.com/MFI

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PIC24F Accessory Development Starter Kit for Android (DM240415)

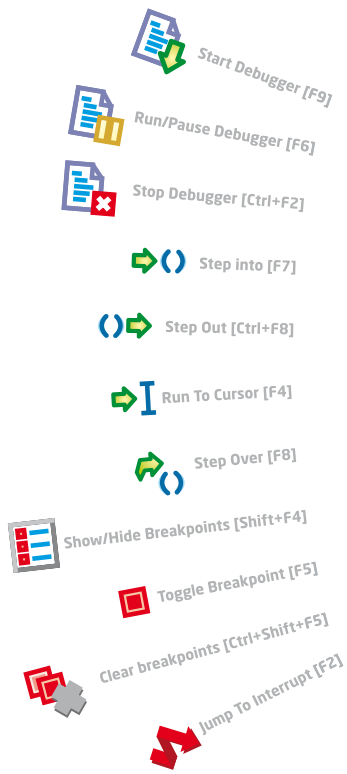
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Sensitive to sensors

In all honesty there's often a gross discrepancy between the number of pages devoted to technology and projects of the "look-what-this-microcontroller-can-do-on-a-green-circuit-board" type and the slight coverage of sensors, those analog components only a handful of people seem to be able to understand and work with these days. This month, we try to redress the balance.

At tech conferences, lots of raised hands in response to "hey guys, a workaround please to ARM7 TC/IP stack overflow error 5T26-i.822g but no prioritized interrupts and keep it all in Flash" but dead silence when the same crowd is prompted for wiring up a Kelvin junction or a word or two on resistor selection in a low-noise input amplifier.

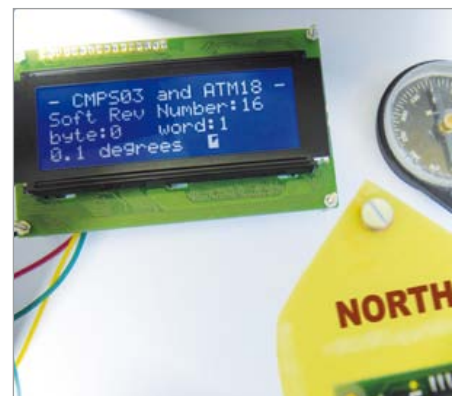
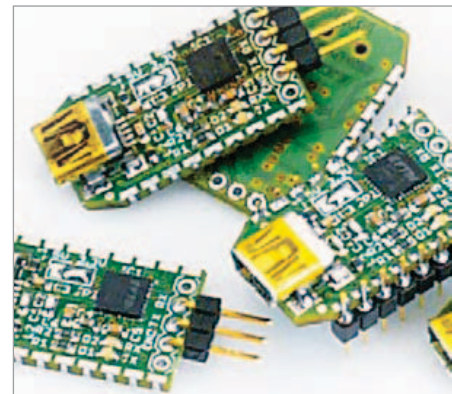
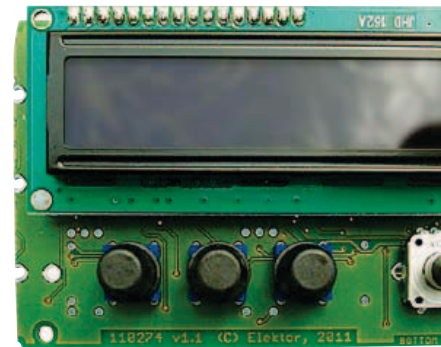
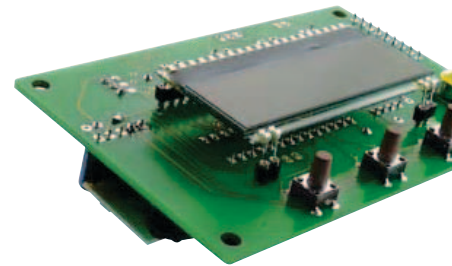
That is not to say the microcontroller and analog fields are incompatible in any way, or mutually exclusive, it's just that that one needs the other to culminate in a working product. Fortunately sensor manufacturers are working hard to make their products as microcontroller-savvy as possible, while pizza-powered youngsters are providing code for their micros to get all the processing done as fast and user friendly as possible. With good results, as you can see from the USB Long Term Data Logger on page 16 and the ATM18 Compass on page 32. The Data Logger is accompanied by a separate article on I²C sensors on page 22 explaining some of the design backgrounds. Sensors want to be promoted, too. When I mentioned the use of a CMPS03 magnetic field sensor in our ATM18 Compass, Gerry at Devantech (Robot-Electronics) UK not only set up an exclusive reader offer but also sent me a sample of their latest compass sensor module.

There are other gems in this edition and they are in unexpected sections. Like the hardware for our DSP programming course that's attracting quite some attention worldwide, our new FT232/USB BOB (break out board) or, returning to the all-analog level, the Chaos Generator introduced on this month's Retronics pages. But your sensors may tell you differently.

Enjoy reading this edition,
Jan Buiting, Editor

elektor

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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.



24 J²B: Universal MMI Module using ARM Cortex-M3

This ultra-versatile microcontroller board allows the use of several types of LCD and a variable number of buttons. And thanks to its up-to-the-minute LPC1343 ARM Cortex-M3 processor, this board is extra powerful and amazingly easy to use.



32 FT232R USB Serial Bridge / BOB

You'll be surprised first and foremost by the size of this USB/serial converter – no larger than the moulded plug on a USB cable! And you're also bound to appreciate that fact that it's practical, quick to implement, reusable, and multi-platform (Windows, Linux, etc.) – and yet for all that, not too expensive.



56 ATM18 Compass

Now you can forget all about magnetized needles on their pivots for finding magnetic North. And it doesn't matter if you live in the Southern or Northern hemisphere – all that counts here is that you have both feet firmly on the ground and this little device in your hand.

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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.



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Elektor Proton Robot

New



A versatile platform for learning and experimenting

The Proton Robot from Elektor is a versatile platform that's suitable for students, enthusiasts and professionals alike. The robot can operate with a variety of microcontroller families and it supports a broad spectrum of sensors and actuators. What's more, this robot can easily be extended in all sorts of ways!

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- LCD
- Red and black buttons
- Audio module
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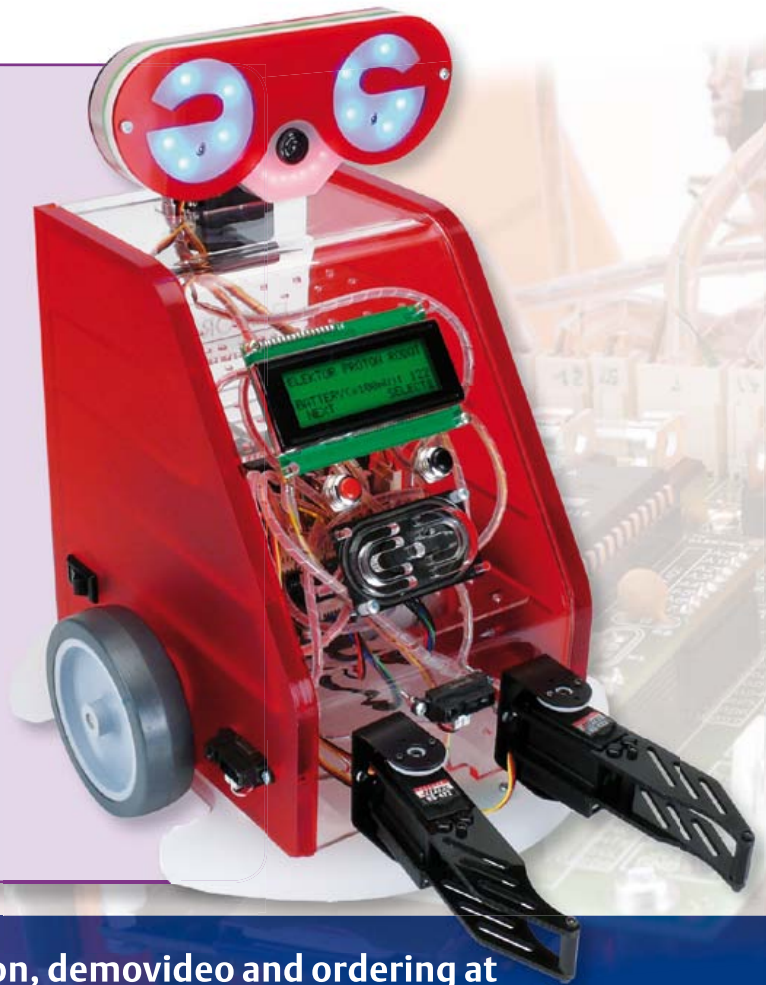
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Wireless sensor networks to measure radiation levels

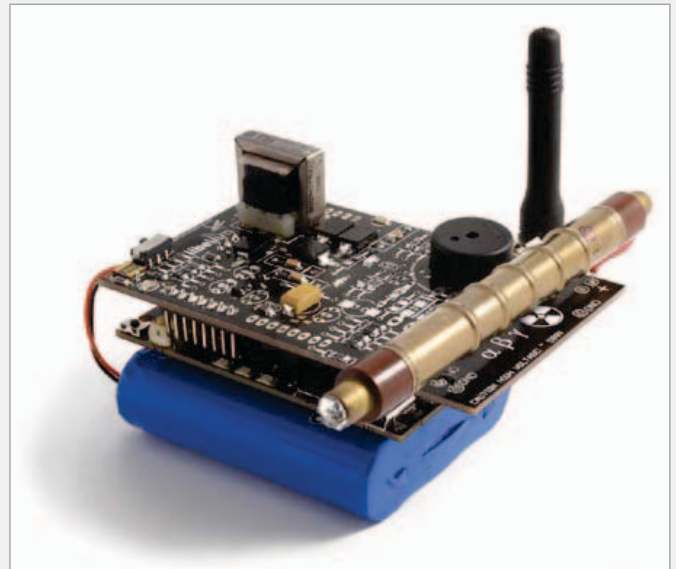
The creation of Libelium's Radiation Sensor Board has been motivated by the nuclear disaster in Fukushima after the unfortunate earthquake and tsunami struck Japan. The company wants to help authorities and security forces to measure the levels of radiation of affected zones without compromising the life of the workers. For this reason Libelium have created an autonomous battery powered Geiger Counter capable of reading radiation levels automatically and sending the information in real time using wireless technologies like ZigBee and GPRS.

The design of the sensor board is open hardware and the source code is released under GPL.

The idea is simple, each node acts as an autonomous and wireless Geiger Counter, measuring the number of counts per minute detected by the Geiger tube and send this value using ZigBee and GPRS protocols to the control point. The system is powered with high-load internal batteries what ensures a lifetime of years.

Using this technology radiation measurements can be taken in real time without compromising the life of the security corps members as they do not have to be inside the security perimeter in order to activate the Geiger counters. The information is extracted automatically and sent wirelessly to the Gateway of the network.

The Geiger tube integrated in the Radiation Sensor Board is sensible to Beta and Gamma particles as they can be detected omnidirectionally. Consequently the orientation of the Geiger



sensor with respect to the source of radioactivity is uncritical — only the distance matters. For this reason fitting the nodes in the right places is essential to detecting a possible leakage from a nuclear source.

www.libelium.com (110582-III)

Micro-inverter reference design board

Future Energy Solutions recently released and demonstrated a micro-inverter reference design board, providing a model for the rapid development of highly efficient and reliable micro-inverter end products. The reference design is suitable for micro-inverters serving Photovoltaic (PV) solar panel arrays rated up to 200 watts and comprising up to 72 cells.

Developed in collaboration with Future Electronics' franchised suppliers Freescale Semiconductor and Fairchild Semiconductor, the design is a two-stage grid-connected micro-inverter providing high efficiency of up to 95% through the implementation of innovative design features including a sophisticated maximum power point tracking (MPPT) technique.

The system is comprised of two boards: a controller board which features the 16-bit MC56F8257 digital signal controller from Freescale, and an inverter board which includes the DC-DC boost and DC-AC inverter stages and an auxiliary power supply. Customers can use the boards as a development platform to which they can

easily add peripheral features such as a display screen, user interface and communications. They can also source the original design files from Future Electronics and modify them freely.



Danny Miller, vice-president of Future Electronics' Future Energy Solutions division, which serves OEMs in the renewable and alternative energy markets, said: "Micro-

inverters are a hot segment of the fast-growing market for solar inverters, which is expected to grow to \$8.5 bn in sales in 2014. This reference board is a useful tool for our customers as they work to optimise their micro-inverter designs and adopt relevant new technology."

The design has adopted a non-isolating topology consisting of a DC-DC boost stage followed by a DC-AC inverter. Its omission of an isolating transformer, normally found in existing micro-inverter designs, helps to reduce losses markedly during power conversion.

The topology allows only a small 50 Hz ripple current to be reflected back from the 230 V AC load to the PV solar panel. The ripple current and ripple voltage are used to implement a fast MPPT technique called ripple correlation control, which is an effective means for capturing the maximum possible power from the PV solar panel throughout the hours of daylight.

Improvements over conventional micro-inverter designs have addressed durability issues as well as efficacy. The micro-inverter was designed from the outset to achieve long-term reliability both through significant derating of components, and through avoiding the use of life-limited aluminium

electrolytic capacitors.

Future Electronics provides the developer with two alternative implementations. The demonstration at InterSolar is of an all-analogue implementation, which uses active components from Fairchild, including FCB20N60 ultra-fast switch-off MOSFETs and FAN7393 gate drivers.

On its general release, the reference design will also provide a parallel topology in which the boost stage and inverter stage control and MPPT are implemented in software on the MC56F8257 DSC.

This software-based version allows the designer to take advantage of the many peripheral features integrated into the MC56F8257, which include multiple high-resolution PWM channels, two 8-channel 12-bit ADCs, and support for an OLED display. It also provides the ability to implement quickly new and improved MPPT algorithms – an important consideration given the rapid evolution that the PV inverter market is experiencing.

A standard 160-way Future-Blox interface connects the control board to the inverter stage.

www.futureelectronics.com (110582-1)

New evaluation kit for Sensirion's differential pressure sensor

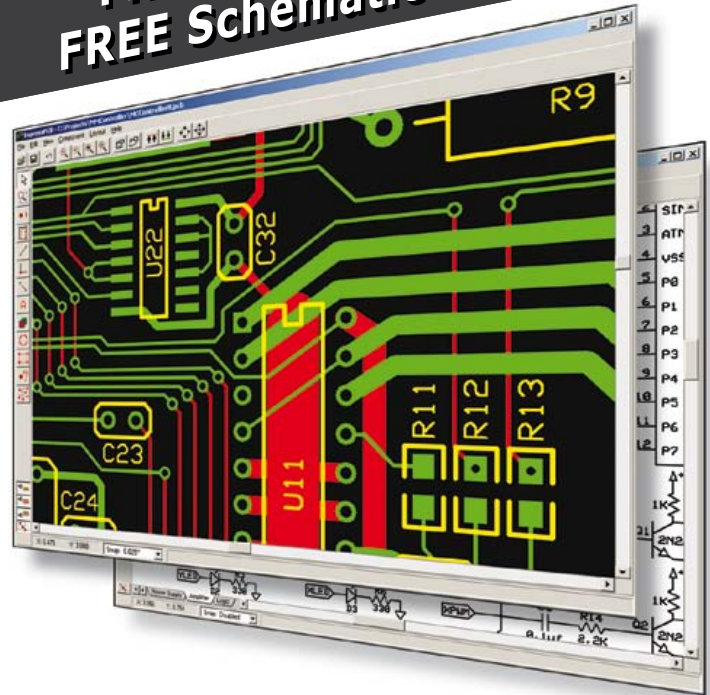
EK-P3, the new evaluation kit from Sensirion, represents a straightforward and cost effective option for testing the digital differential pressure sensors of the SDP600 series.

The set consists of a USB stick that is connected to the SDP610 sensor by an adapter cable. With the help of the software, which is available online for download, the differ-



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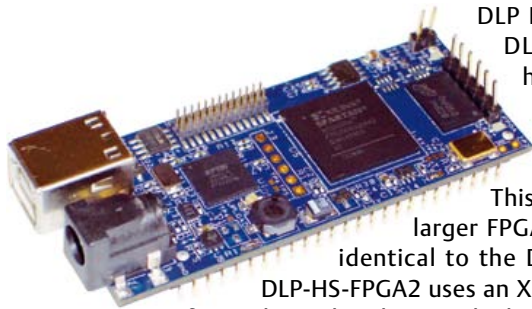
ential pressure sensor can be tested under realistic conditions by following five simple installation steps. Consequently, there is no need to program a microprocessor as the evaluation kit maybe connected directly to a PC. The included software allows displaying measured values on the screen and additionally provides the option of exporting the data to an Excel spreadsheet. This enables the data to be saved and processed in a simple manner.

The differential pressure sensors of the SDP600 family, which has recorded millions

of sales, have a digital (I²C) output signal, are extremely long term stable and impress with their excellent accuracy and sensitivity, even at very low differential pressure values. The high performance is reached due to the thermal flow through principle. Thanks to the new EK-P3, the customer can learn more about the differential pressure sensor, become convinced of the benefits it provides and experience these clear advantages in a highly time efficient and economical manner.

www.sensirion.com/datasheet_ekp3 (110582-IV)

New Xilinx FPGA and FTDI USB high-speed 2.0 module



DLP Design, Inc.'s new DLP-HS-FPGA2 is a high-speed FPGA module based on silicon from Xilinx and FTDI.

This new version has a larger FPGA but is otherwise identical to the DLP-HS-FPGA. The DLP-HS-FPGA2 uses an XC3S400A-4FT256C from Xilinx. It has the same high-speed USB 2.0 interface based on the FTDI FT2232H, and 32 M x 8 DDR2 SDRAM from Micron, as the previous version. The module also comes with a working reference design, and is available from both Digi-Key and Mouser.

The DLP-HS-FPGA2 module is a low-cost, compact prototyping tool that can be used for rapid proof of concept or within educational environments. A 10,000-line reference design is provided for the Spartan™ 3A FPGA on the DLP-HS-FPGA2 to those who purchase the module. The design was written in VHDL and built using the free Xilinx ISE™ WebPACK™ tools.

As a bonus feature, the second channel of the dual-channel USB interface is used to load user bit files directly to the SPI Flash. No external programmer is required. This represents a savings of more than \$200. All that is needed to load bit files to the FPGA on the DLP-HS-FPGA2 is a Windows software utility (free with purchase), a Windows PC, and a USB cable. The new product is priced at \$179.95.

www.dlpdesign.com (110582-VII)

Industrial versions of Elnec programmers

Elnec, Europe's leading provider of solutions for programming NAND Flash memory, microcontrollers and other programmable devices, have released programmers type BeeHive204AP and BeeProg2AP, which are industrial versions of the BeeHive204 and BeeProg2 programmers respectively. The new programmers now available on market were specifically developed for implementation into 3rd party automated programmers and automatic test equipments (ATE).



The new programmers have several enhancements which will be appreciated by electronics manufacturers and programming centres. In particular, the dimensions of the programmers were reduced, the cases are more

robust. Also, the programming modules now have a different construction to ensure greater mechanical stability. For easy and convenient connection of the programmers to 3rd party automated machines, a simple Elnec remote control application was enhanced. Elnec continues its tradition of manufacturing high quality products and provides a worldwide unique 3-year warranty with this new series of programmers dedicated for industrial use. Updates to the programmer's software, including new device support, are available from the Elnec website free of charge. Elnec provides very flexible support and releases new software on average every two working days! Willing to consider requirements of manufacturers, Elnec is providing considerable quantity discounts on programming modules.



www.elnec.com (110582-V)

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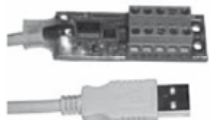
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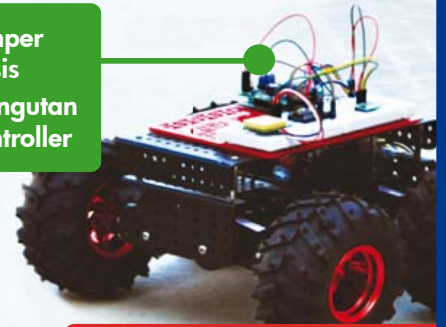
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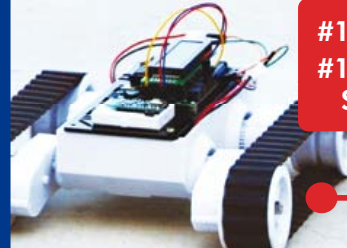


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#1327: Orangutan
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#2151: m3pi Robot
#2150: ARM mbed Dev. Board
#1336: Wixel USB Programmable
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**Take your robot
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eC-Reflow-Mate

A new, professional SMT reflow oven with unique features

In the wake of the popular SMT reflow oven introduced by Elektor in late 2008, we now present a new SMT oven, developed in cooperation with EuroCircuits Belgium, that is even more precise, has more room for PCBs, and can even be operated from a PC. In short, it is a truly professional machine that deserves a place in every electronics lab or shop where SMD boards are assembled on a regular basis.

eC-reflow-mate specifications

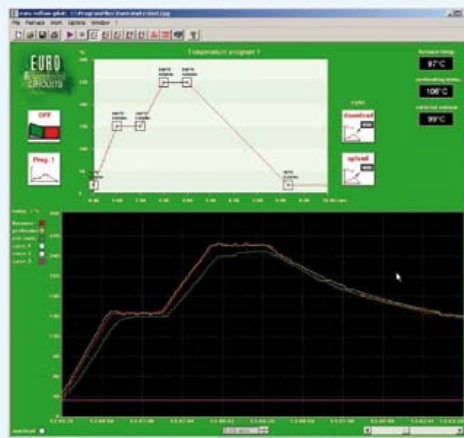
Supply voltage:	230 V / 50 Hz only	Menu languages:	English, French, German, Dutch, Italian, Hungarian
Power:	3500 W	Temperature range:	25 to 300 °C
Weight:	approx. 29 kg	Maximum PCB size:	400 × 285 mm
Dimensions:	620 × 245 × 520 mm (W × H × D)	Temperature sensors:	2 internal and 1 external (included)
Heating method:	Combined IR radiation and hot air	Special features:	<ul style="list-style-type: none"> • Optimal temperature distribution thanks to special IR lamps • Drawer opens automatically at end of soldering process • Glass front for easy viewing
Operation:	Directly using menu buttons and LCD on oven Remotely using PC software and USB connection		

The **eC-reflow-mate** is ideal for assembling prototypes and small production batches of PCBs with SMD components. This SMT oven has a very large heating compartment, which provides plenty of space for several PCBs. Two built-in sensors and IR lamps with non-linear profiles, specially developed for this machine, help keep the temperature inside the entire oven compartment very uniform and constant. An additional sensor can be connected separately to

measure the surface temperature of a component or the PCB. The oven is supplied as standard with five preconfigured heating profiles, which can easily be adapted to your own wishes. The accompanying PC software allows you to monitor the temperature curves of all sensors precisely during the soldering process, and it enables you to modify existing temperature/time profiles or create new ones. This can be done very easily by using the mouse to move

PC interface

The eC-reflow-pilot software for the eC-reflow-mate, which is compatible with Windows XP, Windows Vista and Windows 7, enables full remote control of the oven over a USB link. The screen provides a simultaneous display of the selected (configured) temperature/time profile and the actual temperature/time profile inside the oven. The individual temperatures of all sensors in the oven (2 or 3) are displayed constantly. Temperature/time profiles can be



adjusted by using the mouse to drag one or more corner points of the curve in the horizontal or vertical direction to change the time or temperature, respectively. The screen also has buttons for saving new or modified temperature/time profiles or opening existing profiles. The oven can even be switched on or off from the PC. Switching to a different user interface language is easy. Five languages are presently available; more languages will be added in the future.

corner points on the screen in order to adjust times and temperatures. A glass front panel lets you keep an eye on what's happening inside the oven at all times.

The eC-reflow-mate features especially robust construction. The large drawer is mounted on multiple support rails, and it can be opened either mechanically or electronically. The drawer opens automatically at the end of the soldering process. A clever air circulation system in the oven maintains a uniform air temperature inside the entire compartment. The oven is well insulated to maintain the case temperature at a safe low level, even with prolonged use.

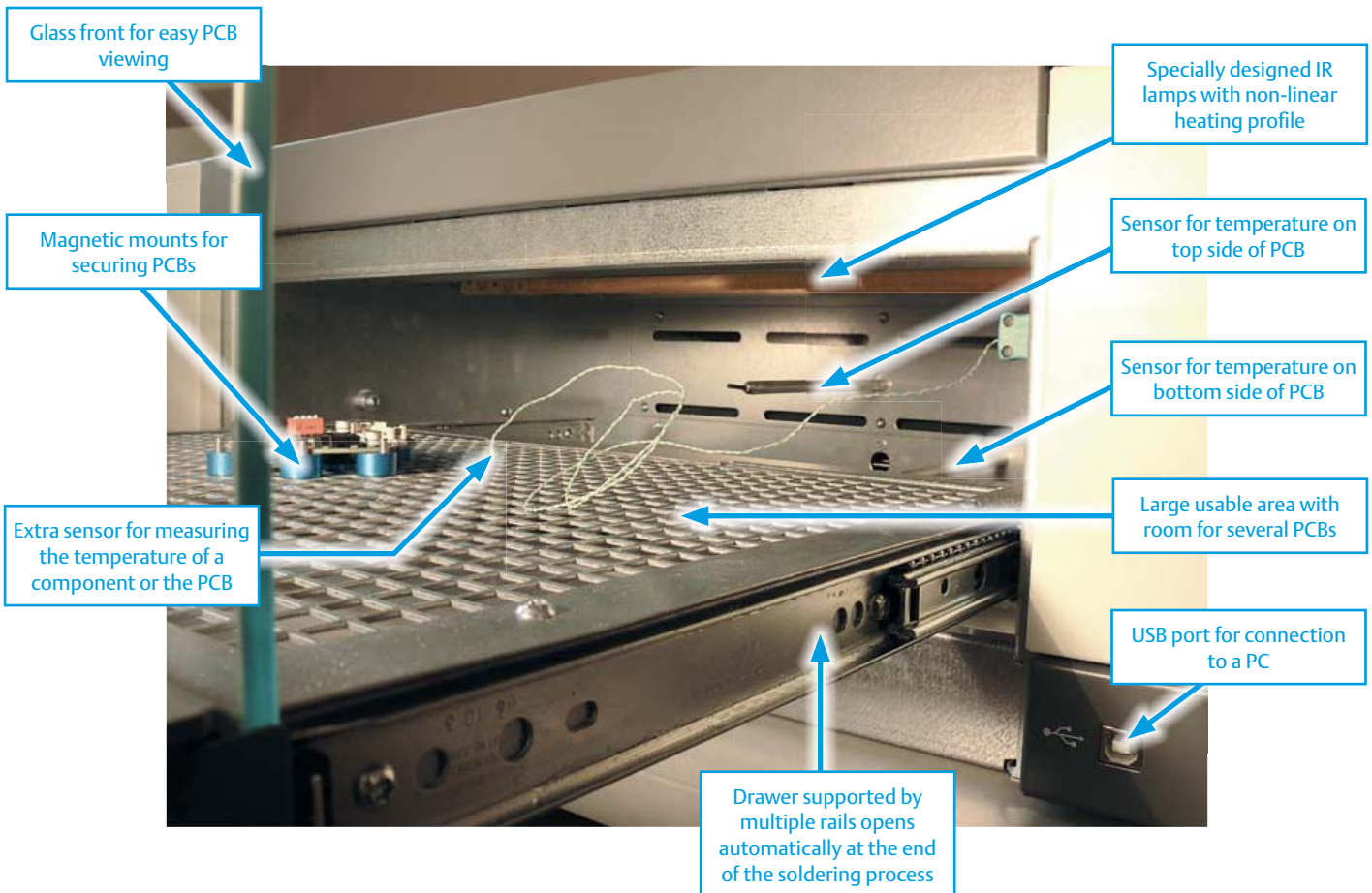
The eC-reflow-mate is an uncompromising SMT oven with extensive features, and it is a valuable asset for everyone who regularly needs to assemble PCBs with SMD components.



The eC-reflow-mate is priced at € 2495 (plus VAT and shipping charges) and supplied directly by EuroCircuits in Belgium.

(100447)

For ordering information, visit www.elektor.com/reflow-mate



Glass front for easy PCB viewing

Magnetic mounts for securing PCBs

Extra sensor for measuring the temperature of a component or the PCB

Specially designed IR lamps with non-linear heating profile

Sensor for temperature on top side of PCB

Sensor for temperature on bottom side of PCB

Large usable area with room for several PCBs

USB port for connection to a PC

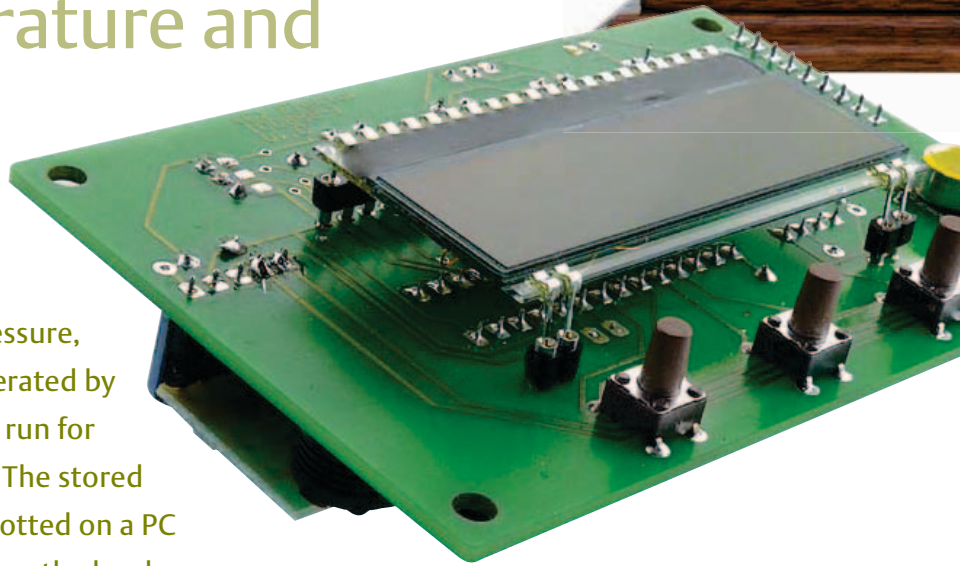
Drawer supported by multiple rails opens automatically at the end of the soldering process

USB Long-Term Weather Logger

Using I²C sensors for atmospheric pressure, temperature and humidity

By Wilfried Wätzig (Germany)
wr-waetzig@t-online.de

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.



The author designed this data logger as a long-term recording system for pressure, temperature and humidity data. Samples are taken at regular intervals and stored in a serial EEPROM, which means that they are preserved even when power is lost. A serial-to-USB module allows the data to be read out by a connected PC for processing. The sensor modules (one for pressure and temperature, one for humidity) with I²C interfaces are described more thoroughly elsewhere in this issue and are supplied ready-calibrated [1], which simplifies construction and processing considerably. Thanks to its LCD panel and (rechargeable) battery power supply the logger can be installed anywhere for stand-alone operation. The use of a

power-efficient ATmega88 microcontroller keeps the average current draw of the circuit below 2 mA.

The firmware is written in C and compiled using AVR-GCC. The source code is available as a free download, so that it can be modified to work with other types of I²C sensor if necessary.

Hardware

Since modules are used for some of the functional blocks, the circuit in **Figure 1** is simple and clear. At the heart of the circuit is the ATmega88 controller (IC2) [2], which is connected to the various modules. Two of these are connected in the usual fashion to port pins.

The DOGM162 display (LCD1) [3] is a two-line by sixteen-character unit without backlight. The display is driven in four-bit mode over PORTB. It was chosen because it can operate from a 3.3 V supply.

Mod1 is a new serial-to-USB converter module (BOB-FT232R) [4], which is also described elsewhere in this issue.

The other three modules (actually two modules and one IC) are connected to the microcontroller over an I²C bus: the Atmel incarnation of this is called a 'two wire interface' (TWI). This very widely-used bus allows up to 128 bus participants ('slaves') to be connected using just two signal wires. In this circuit the integrated TWI controller [5] in

Elektor Products & Services

- Printed circuit board: order code 100888-1
- Ready-programmed microcontroller: order code 100888-41
- BOB-FT232R V2.20 serial-to-USB module: order code 110533-91

- HH10D humidity sensor: order code 100888-71
- HP03S atmospheric pressure sensor: order code 100888-72
- Project software: file # 100888-11 (free download)

Items available via www.elektor.com/100888



Features

- Accurate measurement of atmospheric pressure, temperature and humidity without calibration
- Store up to six records (each containing pressure, temperature and humidity readings) per hour
- Non-volatile storage for 8191 data records
- Up to eight weeks' stand-alone operation from three AA cells
- Calibrated sensor modules with digital outputs for pressure, temperature and humidity
- Data can be read out over a USB interface

the ATmega88 is configured as the 'master' of the following slaves.

The HP03S pressure sensor from Hope Microelectronics (a company

perhaps already known to *Elektor* readers through its radio modules [6]) contains a piezoresistive transducer and integrated 15-bit A/D converter (ADC), along with control logic and an I²C interface. The transducer outputs one voltage that depends on pressure and one that depends on temperature. These analog values are alternately converted by the ADC and the results made available on the I²C interface. During the manufacturing process

eleven sensor-specific calibration values with a length of two bytes are stored in the device's EEPROM, and these can also be retrieved by the microcontroller. A 32 kHz clock with an amplitude of 3 V is required to drive the ADC: since the 32 kHz oscillator on the ATmega88 has an output amplitude of only about 0.5 V, a BS170 (T1) is used for amplification.

The HH10D humidity sensor is made by the same manufacturer (Hope Microelectron-

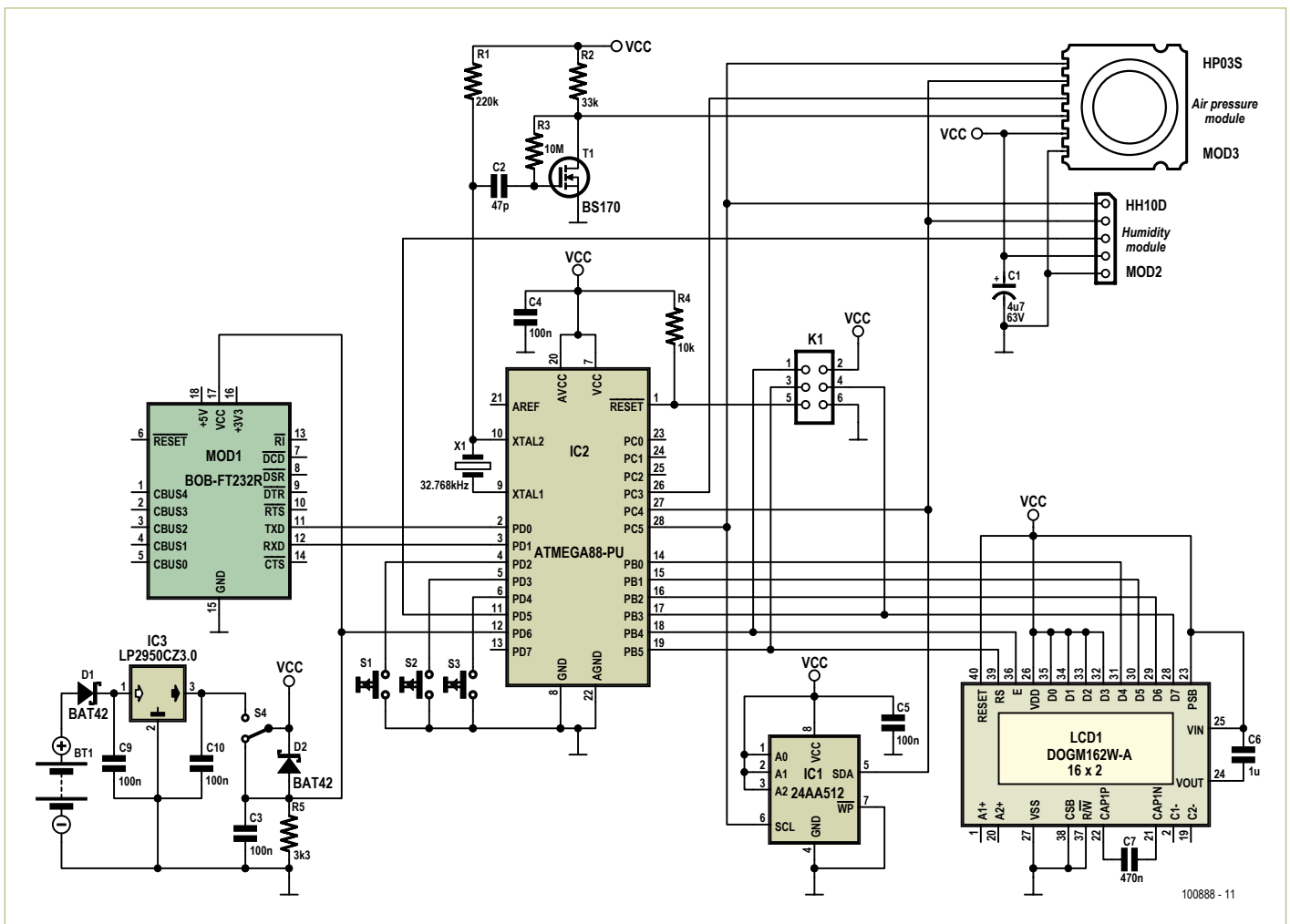


Figure 1. Circuit diagram of the logger: an ATmega88 and an I²C EEPROM are accompanied by four modules (USB interface, LCD, and sensors for humidity and for pressure and temperature).

COMPONENT LIST

Resistors

R1 = 220k Ω
 R2 = 33k Ω
 R3 = 10M Ω
 R4 = 10k Ω
 R5 = 1.3k Ω

Capacitors

C1 = 4.7 μ F 63V radial
 C2 = 47pF
 C3, C4, C5, C9, C10 = 100nF
 C6 = 1 μ F MKT 5mm lead pitch
 C7 = 470nF

Semiconductors

D1, D2 = BAT42
 T1 = BS170
 IC1 = 24AA512
 IC2 = ATMEGA88-20PU, programmed, Elektor # 100888-41
 IC3 = LP2950-3.3 or -3.0

Miscellaneous

S1, S2, S3 = 6mm switch, PCB mount
 S4 = single-pole switch
 X1 = 32.768-kHz quartz crystal
 LCD1 = DOGM162W-A (Electronic Assembly)
 Mod1 = BOB-FT232R-V2.20 (Elektor # 110533-91)
 Mod2 = humidity sensor HH10D (Hope RF, Elektor # 100888-71)
 Mod3 = pressure sensor HP03S (Hope RF, Elektor # 100888-72)
 K1 = 6-pin (2x3) pinheader (optional for ISP interface)
 20-way socket strip SIL for LCD1
 18-way (2x9) socket strip for MOD1
 5-way socket strip for MOD2
 IC socket for IC1 (8-way) and IC2 (28-way)
 PCB, Elektor # 100888-1

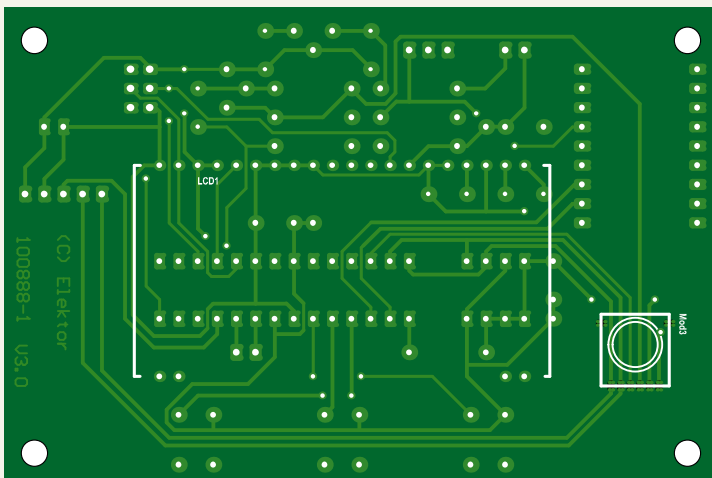
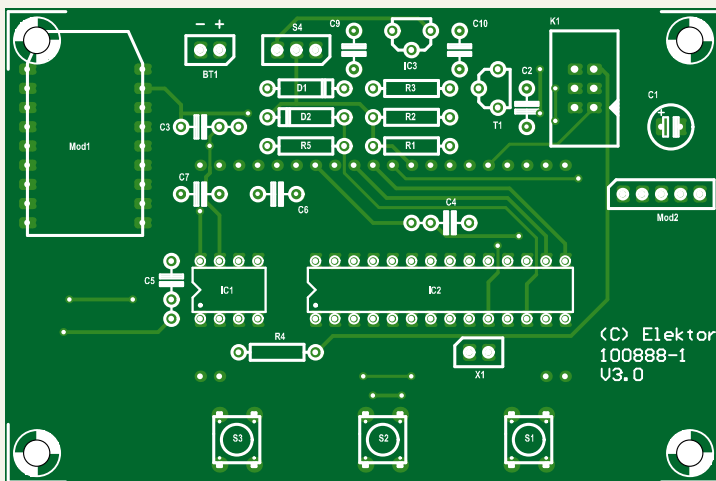


Figure 2. It is easy to populate the double-sided printed circuit board.

ics). A humidity-sensitive capacitor is used as the transducer element, determining the frequency of an ICM7555 timer IC. The frequency, in the range 6 kHz to 7 kHz, is measured by the ATmega88 and then converted into a relative humidity value with the help of two calibration parameters again stored in a serial EEPROM in the module. The ATmega88 measures the frequency by counting the output pulses of the module over a one second period using the 16-bit counter TIMER1.

The I²C serial EEPROM type 24AA512P (IC1) [7] has a capacity of 64 Kbyte and stores the measured quantities (elapsed hours, time, humidity, temperature and pressure). Up to 8191 data records can be stored.

Three pushbuttons are provided for the user interface to the device. S4 is used to select between (rechargeable) battery and USB power for the unit, and K1 allows an AVRISP or compatible programmer to be connected.

Software

The firmware for the microcontroller is written in C and compiled using AVR-GCC 4.3.0 (WinAVR 20080610). Separate source files are used for the functions corresponding to each module.

The main program in `weather_station.c` calls as required routines in `lcd_driver.c` (to control the display), `usart_driver.c` (to control the serial interfaces via the USART) and `twi_driver.c` (for I²C bus control). There are device-specific functions within each of these files.

TIMER2 is driven by the 32.768 kHz crystal and is configured to generate an interrupt once per second. The interrupt service routine `TIMER2_COMPA_vect` increments the current time (expressed in hours, minutes and seconds) and sets the event variable `flag1sec`. At the beginning of each minute a test is made to see whether a new set of readings is to be stored: this is done a pre-set number of times per hour. If new readings are required the event variable `flagmstor` is set.

These variables are checked in the infinite loop in the main program. If `flag1sec` is

set then the microcontroller is switched at the fifty-ninth second of the minute from SLEEP_MODE_POWER_SAVE to SLEEP_MODE_IDLE (which re-enables IO_CLK), so that TIMER1 can measure the frequency of the signal from the humidity sensor. If the variable `flagmstor` is set then a reading is collected from the pressure sensor module, the calibration correction calculations are carried out, and the final results are written to the I²C EEPROM. The CPU then returns to SLEEP_MODE_POWER_SAVE and waits for the next interrupt from TIMER2.

Construction

The double-sided printed circuit board shown in **Figure 2** is, like the circuit diagram, very straightforwardly laid out. Apart from the pressure sensor all the components are leaded and are mounted normally. It is best to start with the SMD pressure sensor, which is not too tricky to solder by hand to the underside of the board. Also mounted on the underside of the board are the three buttons S1 to S3 and the sockets for mounting the LCD module. Sockets are soldered on the component side of the board for mounting the humidity module and the serial-to-USB module. It is a good idea to use sockets for the two ICs. The first version of the board made at the Elektor labs is shown in **Figure 3** and **Figure 4** (Figure 2 shows the final version).

The fuse settings which are to be programmed into the microcontroller using the ISP connector K1 are given in the text box. The programming job (and connector K1 itself) can be avoided if a ready-programmed microcontroller is used: this, along with the sensor modules and the serial-to-USB module, is available from the Elektor shop.

After carefully checking your soldering you can switch the logger on for the first time. Make sure S4 is in the correct position to select between external power (3.3 V at BT1) and power over USB. The unit requires no calibration.

Operation

The three buttons (S1, S2 and S3) allow the time and other parameters to be set.

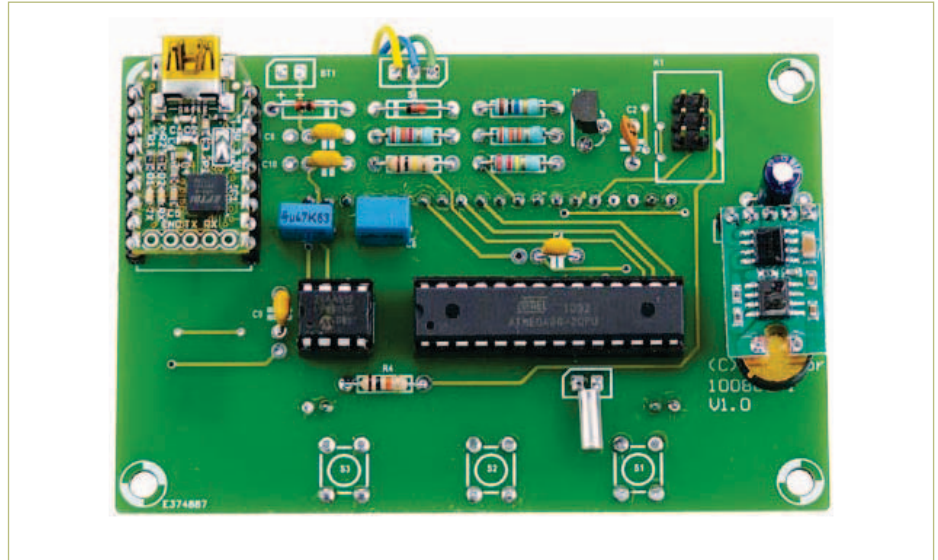


Figure 3. Component side of the Elektor labs prototype board.

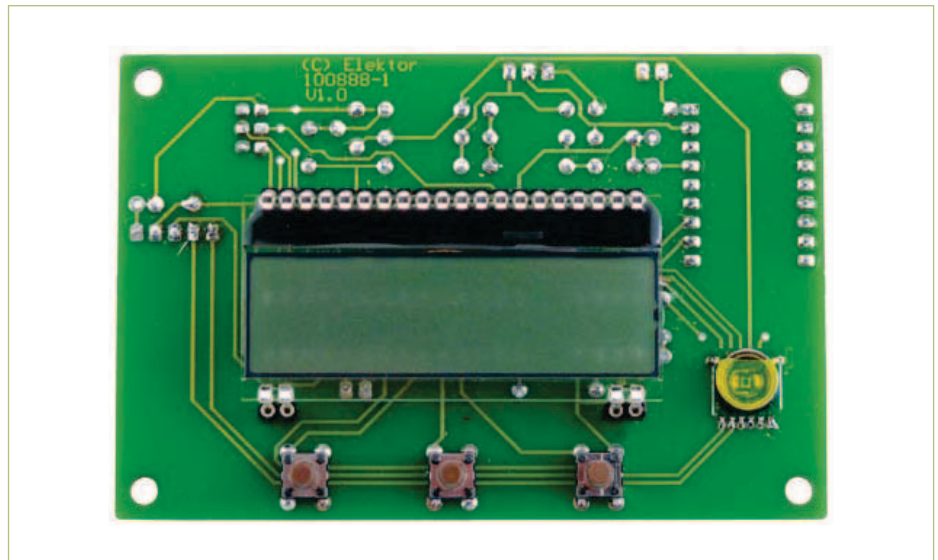


Figure 4. The LCD module and the pressure sensor are mounted on the underside of the board.

Table 1 gives an overview of the functions of each button.

Button S1 cycles between various function modes (numbered 0 to 4 and corresponding

to the rows of the table) for S2 and S3. Each press of S1 advances to the next mode. Each row of the table indicates what S2 and S3 do in that mode. **Figure 5** shows the appear-

Table 1. Settings and functions using buttons S1 to S3		
Function mode selected by S1	Function of S2	Function of S3
0: normal display	display pressure reading	display humidity reading
1: adjust time	increment hours	increment minutes
2: adjust M and N	increment M from 0 to 6	reset N
3: UART control	continue	exit
4: display readings	continue	exit

M = readings per hour; N = count of readings

Table 2. Interactive commands for data transfer	
Command	Action
h =help	print available commands as: # h=help/a=show-p/p#=print#/m#=set-fm#/c=clear/x=exit
a =show-p	print count of readings taken
p# =print#	p0 prints the readings with labels: 123 12:30:00 T= 25.6 degC H=43% P= 987.6 hPa p1 prints just the raw numbers: 123 12:30:00 256 43 9876 p2 prints the time value in hours and the other values without labels, making the output suitable for loading into gnuplot: 68.50 256 43 9876
m# =set-fm#	set number of readings per hour, from 0 to 6 m0 no readings taken m6 six readings per hour (i.e., one every ten minutes)n
c =clear	reset reading count N
x =exit	close serial connection

Table 3. Current drawn by entire system at 3.3 V		
CPU frequency	Sleep mode	Current drawn
8 MHz	none	5.8 mA
1 MHz	none	2.4 mA
1 MHz	IDLE	2.0 mA
1 MHz	POWER_SAVE	1.5 mA

Fuse settings for ATmega88			
Fuses:	EXT.	0xF9	8 MHz internal oscillator (divided by 8, hence CPU clock is 1 MHz)
	HIGH	0xDF	CKDIV8 enabled, Brown-Out disabled
	LOW	0x62	65 ms startup

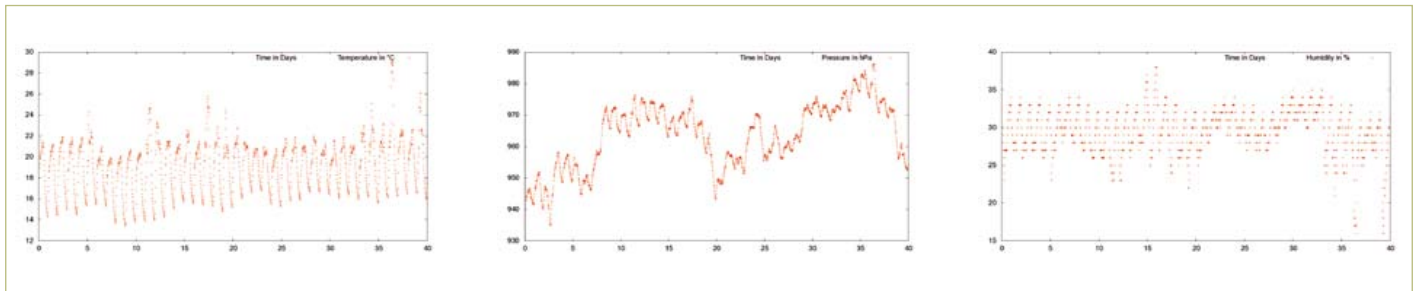


Figure 5. Changes in temperature, humidity and atmospheric pressure can be shown graphically using a program such as gnuplot.

ance of the display in 'normal display' mode (mode 0).

To transfer stored readings to a host PC or laptop first connect it to the module using a USB cable. Driver installation is covered in the article on the BOB-FT232R serial-to-USB module elsewhere in this issue.

The microcontroller can detect whether the 3.3 V supply is available from the BOB-FT232R module using port pin PD6.

The PC can retrieve data from the unit over a virtual serial port using the interactive commands described in Table 2, for example with the help of HyperTerminal or HTerm.

Power supply

The weather logger operates from a supply voltage of nominally 3.3 V, which, when it is powered over USB, is available at pin 17 (VCC) of the BOB-FT232R serial-to-USB converter module. For stand-alone operation the unit can be powered via BT1 using a supply voltage between 3.5 V and 30 V and an LDO regulator (IC3). Diode D1 protects against accidental reverse polarity connection.

It is important to employ various current-reduction measures to maximise battery life in stand-alone operation. The ATmega88 microcontroller is responsible for the majority of the power consumption, and so we concentrate our efforts there. The measured current draw of the entire circuit at 3.3 V under various conditions is shown in Table 3. When using a battery pack consisting of three alkaline or NiMH AA cells (i.e. 4.5 V or 3.6 V; nominal capacity of between 2 Ah and 3 Ah) the weather log-

ger can record data for at least 1000 hours. Instead of three AA cells, feel free to employ a single Li-Ion or LiPo cell supplying 3.6 V or 3.7 V respectively.

One power-saving measure is to carry out only one measurement per minute rather than one every second. At one-minute intervals we update only the time, the record count and the elapsed hours timer on the display. The device goes into this mode when no button is pressed for a period of 100 seconds.

Measurements show that the system draws an extra current of about 2.5 mA for about 120 ms when taking a reading; in between these peaks are peaks lasting just 10 ms corresponding to the 1 Hz interrupt.

The device is switched from POWER_SAVE mode into IDLE mode for the fifty-ninth second of the minute. This enables the I/O clock in the microcontroller, which is needed in order to be able to count the pulses from the humidity sensor: the final reading is then available in the sixtieth second. This power-saving trick is only effective if the ATmega88 is operated with a 1MHz CPU clock: the necessary fuse settings are given in the text box.

Displaying the results

The free software package gnuplot can be used to help display the results on a PC in graphical form. **Figure 6** shows examples of image files that can be created using this software, including temperature, humidity and pressure graphs.

The steps required to produce such graphs, including the transfer of data to the PC using HyperTerminal or HTerm, are given below. The filenames used correspond to the example.

1. Set up HTerm on the PC to read data over USB as follows:

COM3 9600 baud 8N1

newline at: CR

send on enter: CR

storage format: RAW

2. Put the weather logger into USB mode: connect the weather logger to the computer with a USB cable; press the 'function' button S1 until the message 'UART-control>USB' appears;

Pressure readings

The weather logger measures and stores instantaneous values of atmospheric pressure. The values depend not only on the weather but also on altitude and other factors such as temperature and humidity. The pressure values published by weather services are corrected to give the effective atmospheric pressure at sea level (0 m altitude), based on the 'International Standard Atmosphere' values for temperature, humidity and so on. For example, the 'base atmospheric pressure' at sea level is defined as 1013.25 hPa and the 'base temperature' as +15 °C. The pressure values reported by the logger can be converted approximately to sea-level values using the barometric formula

$$p(0) = p(h) / (1 - 22.558 \times 10^{-6} h)^{5.255}$$

where h is the altitude in meters, $p(h)$ is the measured pressure at altitude h measured in hectopascals, and $p(0)$ is the corrected pressure at sea level.

There is a simpler approach: to a good approximation at low altitudes (up to say 2000 m) pressure falls off linearly at about 1 hPa for every 8 m of altitude. So, for example, a pressure of 970 hPa recorded at an altitude of 400 m corresponds to an equivalent sea-level pressure of about 1020 hPa.

press S2 for 'continue': the message 'USB-UART active' should appear.

3. In HTerm give the command 'p2'. Data transfer will start with the format: Hours Temperature * 10 Humidity Pressure * 10 Stop data transfer by typing 'x'. Save the received data as 'pltdata0.txt'.

4. Plot the data using the Windows version of gnuplot ('wgnuplot'). Open the file 'plotfile0.plt', which contains the plotting commands for wgnuplot that will result in the creation of the following three image files:
ptemp0.png (temperature graph)
ppres0.png (pressure graph)
phumid0.png (humidity graph)

These three image files can be opened in a graphics editor or included in a word processor document using Word or OpenOffice. An illustrated manual is contained in the archive file for this project [8]

(100888)

Internet Links

- [1] www.elektor.com/110376
- [2] www.atmel.com/dyn/resources/prod_documents/doc2545.pdf
- [3] www.lcd-module.com/eng/pdf/doma-dog-me.pdf
- [4] www.elektor.com/110533
- [5] www.atmel.com/dyn/resources/prod_documents/doc1981.pdf
- [6] www.elektor.com/071125
- [7] ww1.microchip.com/downloads/en/devicedoc/21754h.pdf
- [8] www.elektor.com/100888

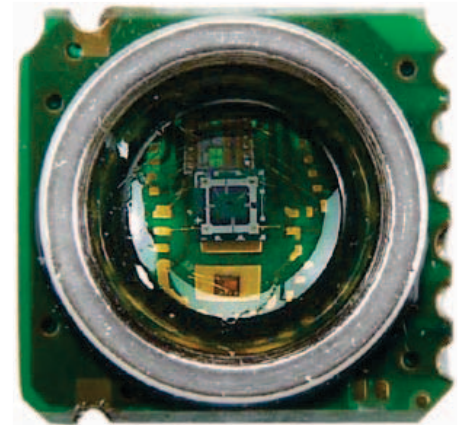
About the author

Wilfried Wätzig's first encounter with programming was using ALGOL on the (then current) Zuse Z22 and Electrologica X1 machines during his physics studies. Later he developed interface hardware and data processing software for process control computers in a university environment. Finally he worked as a system administrator at the computing service of a technical college and now, in retirement, maintains a keen interest in recent developments in hardware, software and information technology.

I²C Sensors For temperature, atmospheric pressure and humidity

By Ernst Krempelsauer (Elektor Germany Editorial)

Most sensors are inherently analog and in general it is necessary to amplify, compensate and calibrate their outputs before digitizing them. The sensor modules described here have everything built in: a microcontroller connected to the module can fetch the calibration data needed to correct the digitized results over the I²C bus, meaning that no calibration is necessary.



The signal conditioning circuitry built into sensors with a digital output saves development effort, board space and cost. Also, because the sensor element and the conditioning circuitry are closely linked both electrically and thermally, performance of the sensor improves too. The two sensor devices from Hope Microelectronics [1] described here are a frugal choice from the point of view of both cost and power consumption, and both are available from the Elektor shop [2].

The HP03S pressure and temperature module

The HP03S module contains a piezoresistive pressure sensor which can be viewed electrically as four resistive elements in a bridge configuration. As the block diagram in Figure 1 shows, this conventional pressure sensor is connected directly to a signal conditioning circuit comprising an input multiplexer, an A/D converter and an I²C interface. Also provided on the module a 24C02-compatible EEPROM, which contains calibration data for the sensor pre-loaded by the manufacturer.

Pressure is determined by measuring the voltage across the bridge, which is digitized by the ADC; for temperature measurement the (temperature-dependent) total top-to-bottom resistance of the sensor bridge is

measured by making it appear as one arm of a new bridge circuit that includes resistors R1 to R4.

The A/D converter is a 16-bit sigma-delta type with an overall effective resolution of 14 bits. Further technical details can be

found in the 'Features' text box.

The datasheet claims the following absolute atmospheric pressure measurement accuracy over the normally-encountered range from 750 hPa to 1100 hPa:

HP03S pressure and temperature module features

- Pressure measurement range: 300 hPa to 1100 hPa
- Temperature measurement range: -40 °C to +85 °C (-40 °F to +185 °F)
- Supply voltage: 2.2 V to 3.6 V (3 V typical)
- Current consumption: 1 µA (standby), 500 µA (during measurement)
- Operating temperature: -40 °C to +85 °C (-40 °F to +185 °F)
- I²C interface SCL maximum frequency: 500 kHz
- MCLK frequency: 30 kHz to 35 kHz (32.768 kHz typical)

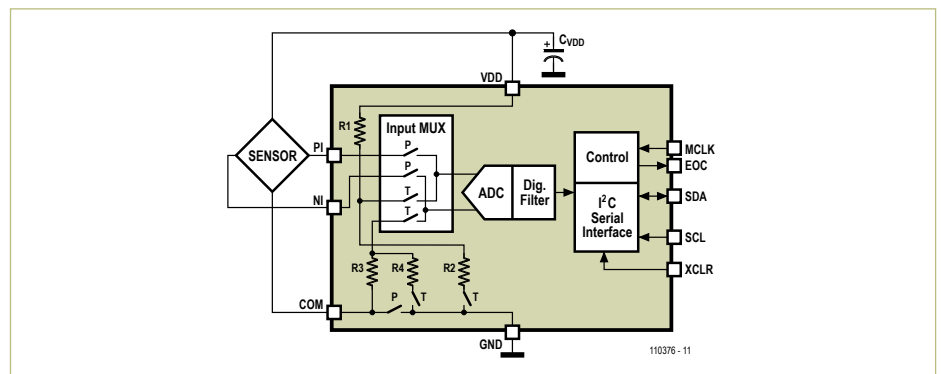


Figure 1. Block diagram of the HP03S pressure and temperature module.

Elektor Products & Services

- Humidity sensor HH10D: #100888-71
- Pressure sensor HP03SA: #100888-72

- Software example: #100888-11 (free download)
- Available at www.elektor.com/100888 and [2]

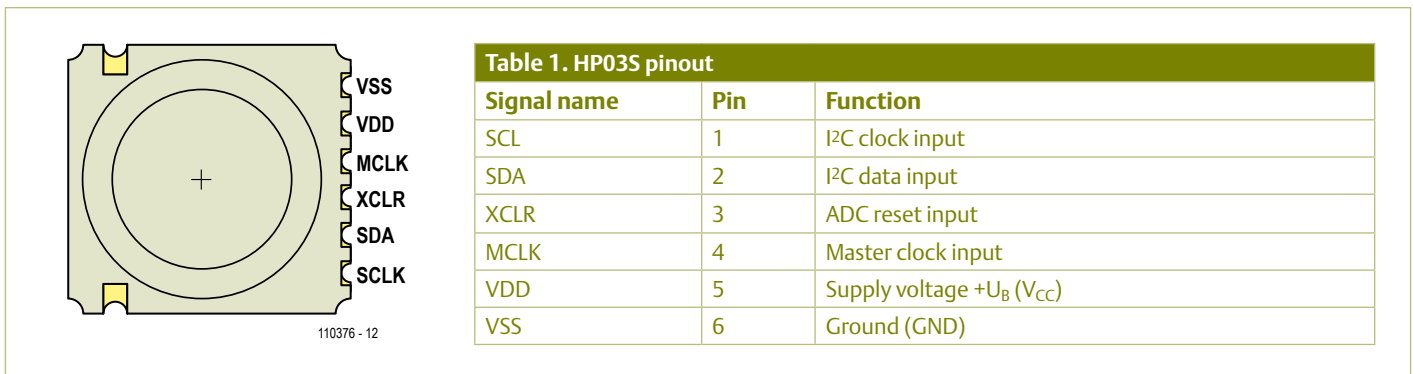


Figure 2. Pinout of the HP03S in its SMD package.

- ±1.5 hPa (HP03SA for temperatures from 0 °C to +50 °C)
- ±3.0 hPa (HP03SA for temperatures from –20 °C to +60 °C)
- ±3.0 hPa (HP03SB for temperatures from 0 °C to +50 °C)
- ±5.0 hPa (HP03SB for temperatures from –20 °C to +60 °C)

Both sensor variants (A and B) offer:
Long-term stability (12 months): 2 hPa typical

Voltage dependence (2.4 V to 3.6 V): ±1.5 hPa

Temperature measurement accuracy (0 °C to +50 °C): ±1.0 °C

Temperature measurement accuracy (–20 °C to +60 °C): ±2.0 °C

The pinout of the device is shown in **Figure 2** and the signals are explained in **Table 1**.

A little care is required with the XCLR connection, which resets the ADC. XCLR should only be taken high to carry out an A/D conversion and when reading out pressure and temperature data; otherwise it should be held low, both in the quiescent state and when reading from the module's EEPROM. The quality of the 32 kHz clock signal MCLK affects the current consumption of the module. The recommendations regarding signal level (2.2 V minimum), edge slew rate and duty cycle (40 % to 60 %) should be adhered to.

The ADC delivers uncorrected readings over the I²C bus: these readings are called 'D1' (nominally pressure) and 'D2' (nominally temperature). Since the pressure readings are highly sensitive to temperature, compensation is required. Seven coefficients and four sensor parameters are stored in the module's serial EEPROM by the manufacturer during calibration. These are labeled as follows.

C1	sensitivity coefficient
C2	offset coefficient
C3	temperature coefficient of sensitivity
C4	temperature coefficient of offset
C5	reference temperature
C6	temperature coefficient of temperature
C7	offset fine tuning
A, B, C and D	sensor parameters

The following computations have to be performed on the raw D1 and D2 values to obtain values for temperature (T), offset (OFF), sensitivity (SENS) and pressure (P). The arithmetic can easily be done in a microprocessor and no floating-point operations are needed.

$$dUT = D2 - C5$$

$$T = 250 + dUT \times C6 / 2^{16}$$

temperature in Celsius × 10

$$OFF = (C2 + (C4 - 2048) \times dUT / 2^{14}) \times 4$$

$$SENS = C1 + C3 \times dUT / 2^{10}$$

$$X = SENS \times (D1 - 7168) / 2^{14} - OFF$$

$$P = X \times 10 / 2^5 + C7$$

pressure in hPa × 10

A practical example application for this sensor, connected to the I²C interface of a microcontroller, is the long-term weather logger circuit presented elsewhere in this issue of *Elektor* [3]. The source code for that unit's firmware, written in C, is available at [3] for free download. From the comments in the code it is easy to see where the coefficients and parameters are read out from the module's EEPROM, where the ADC is read, and where the compensation

calculations are carried out. Alternatively, the manufacturer has a programming guide with an application example [4] written in C for an 8051 microcontroller.

The EEPROM and the ADC have different addresses on the I²C bus: 0xA1 to read the EEPROM and 0xEE to read the ADC. The datasheet of the 24C02 [5] gives a good introduction to bus timing. Remember that it is essential to take XCLR high when reading the ADC.

The module outputs all data in binary format. The first word read after power-up should be discarded: words from the second onwards can be used safely.

In the HP03S datasheet [6] there is a detailed example showing how to calculate pressure and temperature using the sensor's coefficient values and parameters. When using the sensor as part of an altimeter it is desirable to have a higher pressure resolution, calculating the pressure as

$$P = X \times 100 / 2^5 + C7 \times 10.$$

It is also clearly explained in the datasheet that the sensor is not designed for use in safety-critical applications, especially those where a failure of the sensor could put human health or life at risk.

HH10D humidity sensor

The Hope Microelectronics HH10D humidity sensor module uses a capacitive transducer, shown in the circuit diagram (**Figure 3**) as a variable capacitor, which determines the frequency of an oscillator built around an ICM7555 CMOS timer. The output signal from this 'capacitance-to-frequency converter' appears on the FOUT pin of the module (see pinout in **Figure 4**). The I²C interface of the HH10D is used only to read its 24C02 EEPROM, which again is used to store calibration values for the sensor. Each sensor is individually calibrated by

HH10D humidity sensor module features

- Relative humidity measurement range: 1 % to 99 %
- Accuracy: ± 3 %
- Resolution: 0.3 % to 0.05 % (0.08 % typical)
- Reproducibility: ± 0.3 %
- Reaction time: 8 seconds
- Hysteresis: 1 %
- Long-term stability: ± 0.5 %
- Supply voltage: 2.7 V to 3.3 V (3 V typical)
- Current consumption: 120 μ A to 180 μ A (150 μ A typical)
- Operating temperature: -10 °C to $+60$ °C (14 °F to 140 °F)
- Output frequency (FOUT): 5 kHz to 10 kHz (6.5 kHz typical)
- I²C interface: M24C02BN compatible

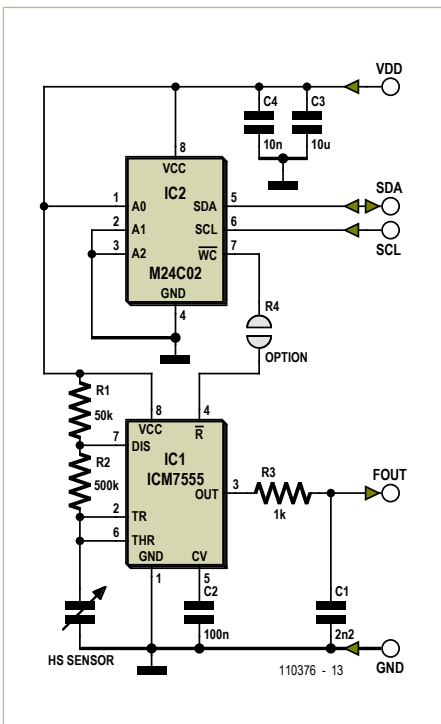


Figure 3. Circuit diagram of the HH10D humidity sensor module.

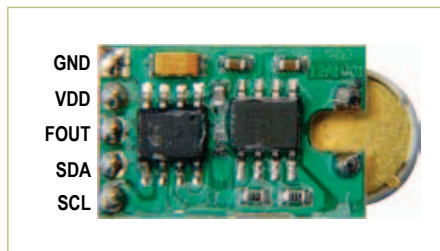


Figure 4. Pinout of the HH10D, available as a plug-in daughter module with a pin header.

the manufacturer in two different humidity-controlled environments. Using a capacitive sensor has the advantage that it reacts quickly to changes in ambient humidity. The sensor module also offers a particularly high resolution and, thanks to the stored calibration values, very high precision despite its low power consumption. The main features and technical specifications are given in the text box on the HH10D.

To compute a humidity value, a microcontroller connected to the SCL, SDA and FOUT

pins must first read out the two calibration coefficients stored in the serial EEPROM (two bytes each). These are as follows.

SENS sensitivity coefficient (EEPROM address 10)

OFF frequency offset (EEPROM address 12)

The address of the EEPROM itself is fixed at 01.

The frequency FREQ of the oscillator can be measured using a timer/counter in the microcontroller. This value can be converted into a relative humidity (RH), expressed as a percentage, as follows:

$$RH = (OFF - FREQ) \times SENS / 2^{12}$$

Again, a practical example showing how to use this sensor can be found in the source code accompanying the weather logger article [3]. The datasheet for the humidity sensor can be downloaded at [7].

Other I²C sensors

A wide range of other sensors with I²C interfaces is available. As the examples described above show, the implementations vary considerably from one sensor type to another and there is no alternative to studying the datasheet in each case.

Hope Microelectronics also produces the HDPM01 sensor module, an interesting device that combines an HM03 pressure sensor with a two-axis compass [8], again with an I²C interface. A different I²C compass sensor is used in the Elektor ATM18 project [9] elsewhere in this edition. Sensirion [10] is also worth mentioning for their I²C temperature and humidity sensors. For temperature sensors in particular there is a wide choice of I²C bus devices, for example from NXP [11] and Maxim [12].

Other well-known temperature sensors are the National Semiconductor LM76, the Maxim (formerly Dallas) DS1621 and DS1631, and the Texas Instruments TMP100.

(110376)

Internet Links

- [1] www.hoperf.com
- [2] www.elektor.com/110376
- [3] www.elektor.com/100888
- [4] www.hoperf.com/upload/sensor/HP03_code.pdf
- [5] <http://ww1.microchip.com/downloads/en/DeviceDoc/21202.pdf>
- [6] www.hoperf.com/upload/sensor/HP03S.pdf
- [7] www.hoperf.com/upload/sensor/HH10D.pdf
- [8] www.hoperf.com/sensor/app/HDPM01.htm
- [9] www.elektor.com/110389
- [10] www.sensirion.com/en/01_humidity_sensors/00_humidity_sensors.htm
- [11] <http://ics.nxp.com/products/i2cthermal>
- [12] www.maxim-ic.com/products/thermal-management

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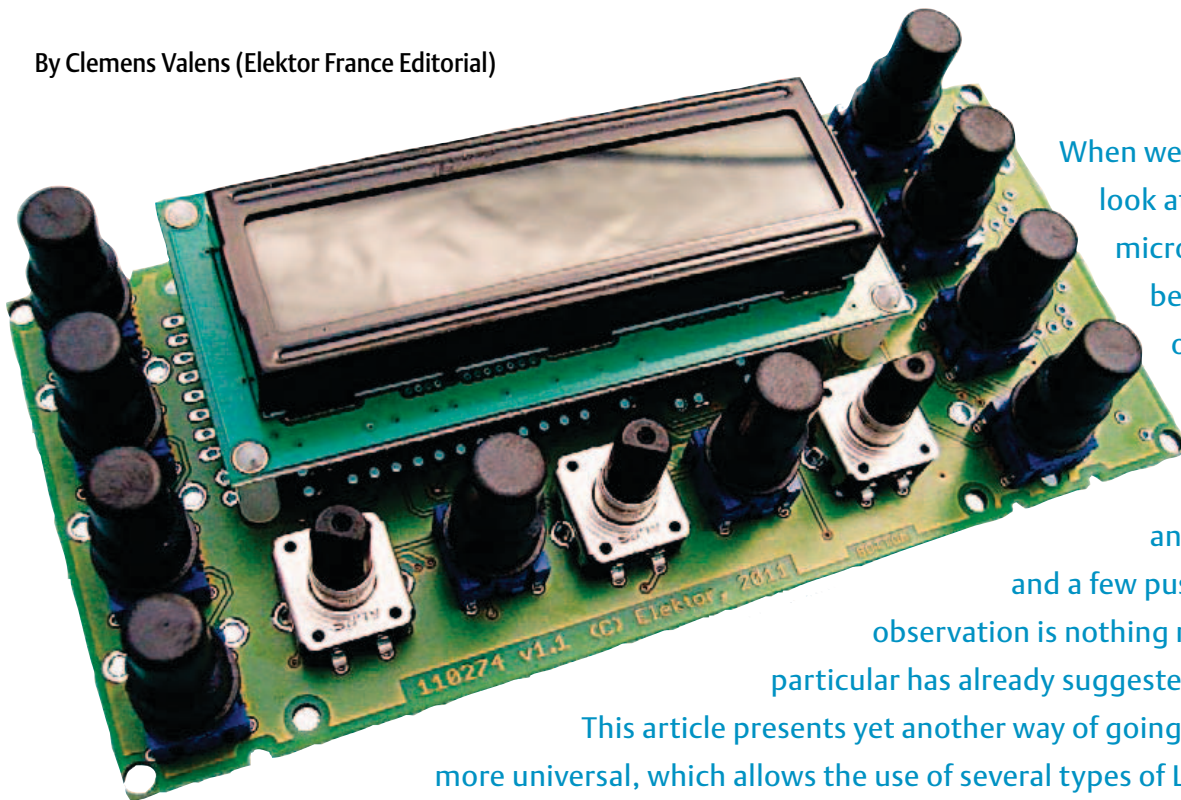
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J²B: Universal MMI Module using ARM Cortex-M3

Let's stop reinventing the wheel!

By Clemens Valens (Elektor France Editorial)



When we take a closer look at circuits using a microcontroller, it can be seen that in 75 % of cases the basic circuit is virtually identical: a microcontroller, an LCD display, and a few push-buttons. This observation is nothing new, and Elektor in particular has already suggested several solutions. This article presents yet another way of going about it, a little bit more universal, which allows the use of several types of LCD and a variable number of buttons. And thanks to its up-to-the-minute LPC1343 ARM Cortex-M3 processor, this board is extra powerful and amazingly easy to use.

The type of displays usually used in amateur projects generally have either 2 lines of 16 characters (2×16), or 4 lines of 20 characters (4×20). There are rarely more than four buttons, but rotary encoders are increasingly being seen. For circuits using a 2×16 LCD, the buttons are often below the display; for the 4×20 displays, they are more likely to be mounted to the side. The position of the buttons depends on the application and the user; a right-handed person tends to position them differently from a left-handed person. A universal solution must take all this into account and allow a free choice of the LCD and the position of the buttons.

Even though I'd originally had the idea for this circuit several years ago, I started actually building it quite recently, when for the umpteenth time I needed to add an MMI to a circuit that didn't have enough I/Os free; so I needed an additional port extender. Since NXP brought out their 32-bit ARM Cortex-M3 and M0 microcontrollers, cheaper than port extension devices, an ingenious and inexpensive solution is now possible. Particularly interesting for amateurs, this is the LPC1343, currently the easiest microcontroller to program. No need for a programmer or an RS-232/USB adaptor — this microcontroller is presented quite simply as a USB stick onto which all

you have to do is copy the software (only works under Windows; using Linux or MAC OS, you have to use a serial link or a special programmer).

Using a microcontroller like this as a port extender, we get USB, I²C, and SPI ports or a UART for communicating with the application. If we note that in most applications managing the display and the keyboard takes up easily 80 % of the software, we can likewise envisage having the whole application run by the microcontroller — especially when we have the computational power of a 32-bit processor available. So, instead of adding a port extender to an applica-

tion, we can add an application to a port extender.

Since the microcontroller is only available in an SMD package, I decided to use only SMD parts throughout (with the exception of the connectors and keyswitches). In the relatively confined space, cluttered with connectors, this allowed other functions to be added, like powering by rechargeable batteries or primary cells, and a charger for Lipo batteries. This means that the board is also suitable for mobile applications.

And to round everything off nicely, the board dimensions are suitable for a standard, cheap case, for a neat, robust finish for your project.

Specifications

- Suitable for 2×16, 4×16, and 4×20 LCD displays using a standard 14- or 16-pin connector (the latter if backlight is included), software-controlled backlight;
- 5×6 matrix keypad for a maximum of 12 keyswitches or nine rotary encoders with built-in push-button (equivalent to 27 pushbuttons!) or a mixed configuration;
- Buzzer;
- One LED;
- Power via USB, external 5 V supply, primary cells (0.9–4.5 V) or Lipo rechargeable battery;
- 5 V and 3.3 V regulators, software on/off control possible;
- Lipo battery charger, plus software measurement of battery level;
- 32-bit, 48-pin LPC1343 microcontroller with 32 KB Flash memory, 8 KB RAM and numerous peripherals like USB, I²C, SPI, MLI, UART, and counters;
- Compatible with the free LPCxpresso [2, 3, 4] and CooCox [7] IDEs;
- Compatible with the LPC-Link and CooCox programmers/debuggers;
- Extension connectors: almost all the microcontroller pins are available on a connector or a pad;
- Splittable! Certain unused parts can be cut off; detachable mini 4-key pad or a maximum of 3 rotary encoders;
- Dimensions adapted to Type 26160000 case from Bopla;
- Open source software and hardware.

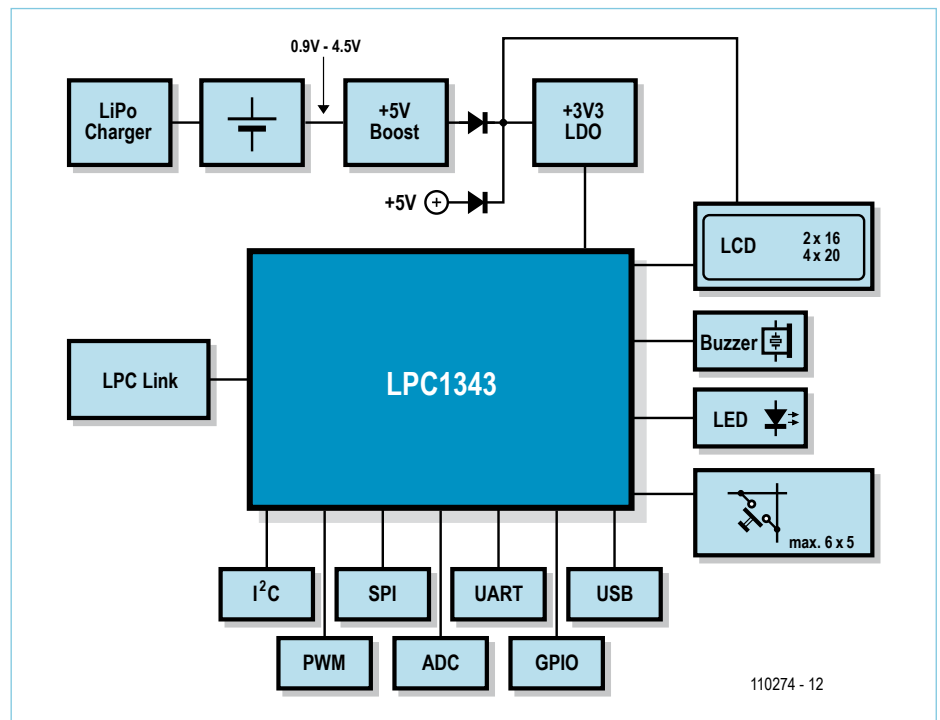


Figure 1. Block diagram of the J2B board.

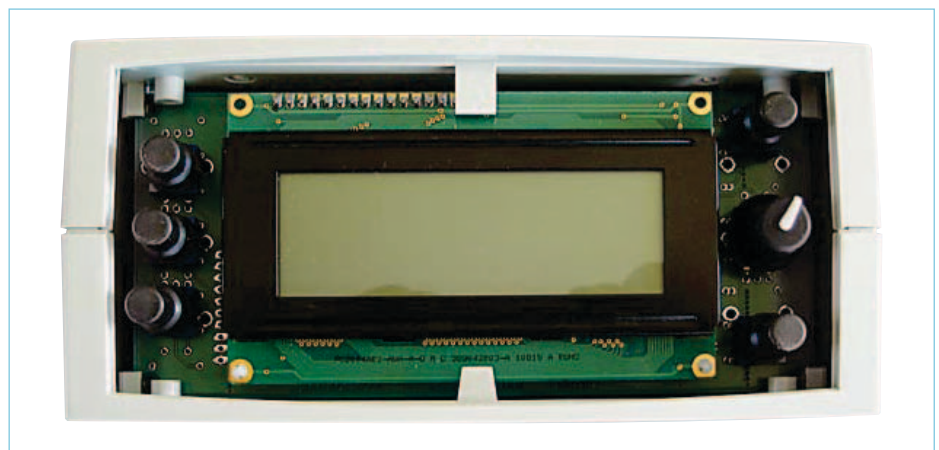
Operation

Microcontroller

Let's start with the board's brain, the microcontroller. An oscillator is necessary to make it work, and so three options present themselves: the internal RC oscillator (IRC), an external oscillator, or an external clock (which we are not using here). The microcontroller starts up on its internal oscillator. For applications requiring a more accurate clock, provision has been made to allow a crystal oscillator to be fitted. The microcontroller's data sheet advises values of 18 pF or 39 pF for C14 and C15, depending on the crystal used. However, most crystals ought to be able to

operate with either of these values.

The logic levels on PIO0.1 and PIO0.3 select the microcontroller's start-up mode after a reset. If PIO0.1 is low, the microcontroller will first run its bootloader (ISP mode), otherwise the user program will be run. The LPC1343 offers two ISP modes: by USB stick (PIO0.3 high) and by serial port (PIO0.3 low). Resistors R3 and R13 let us select the ISP mode. In theory, the function of R3 is also fulfilled by the USB voltage detection circuit, but fit it all the same in order to avoid any possible indeterminate situations, if ever the USB cable should not be connected (correctly). Fit R13 instead of R3 if you prefer to program the chip via a serial link.



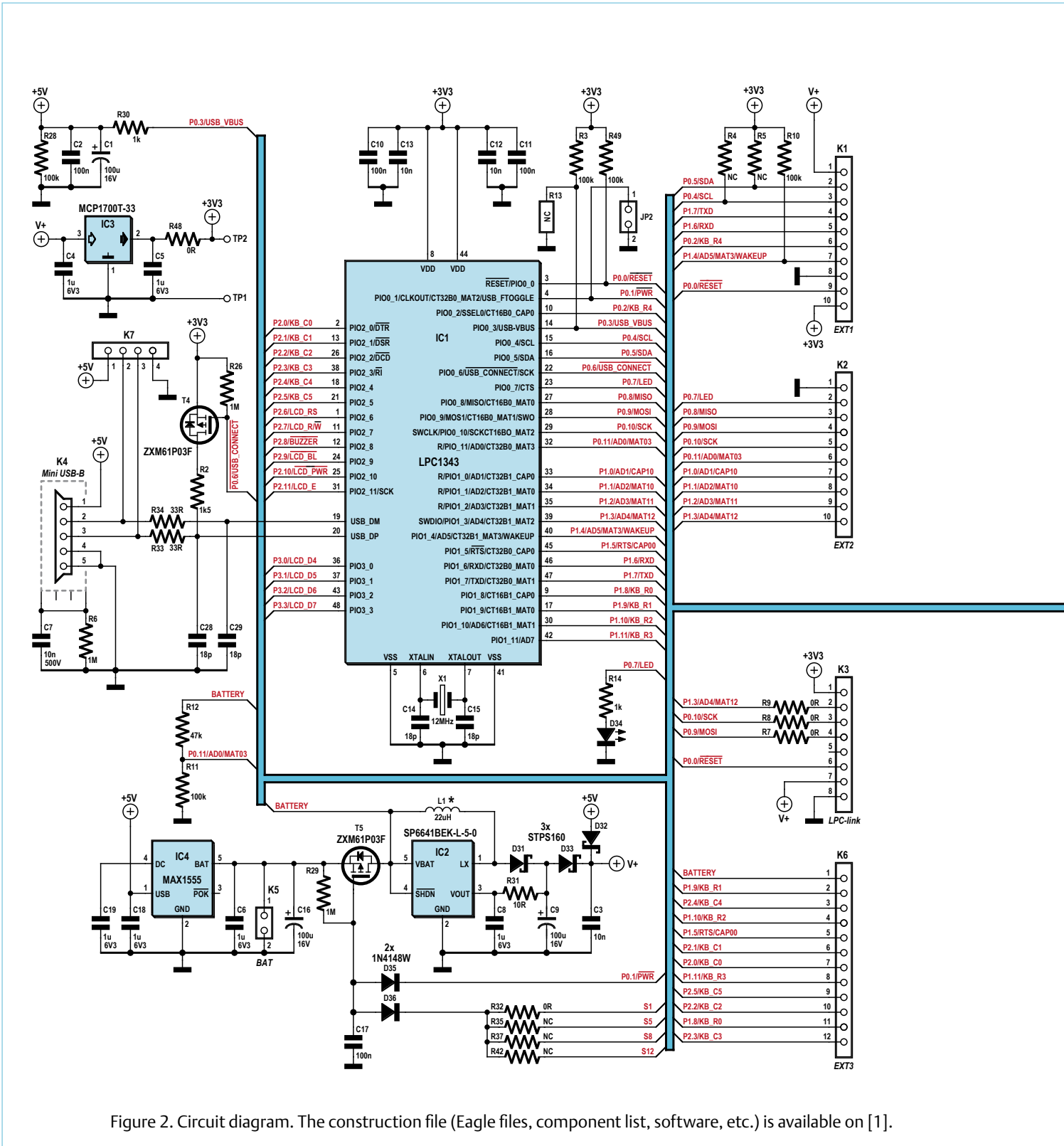
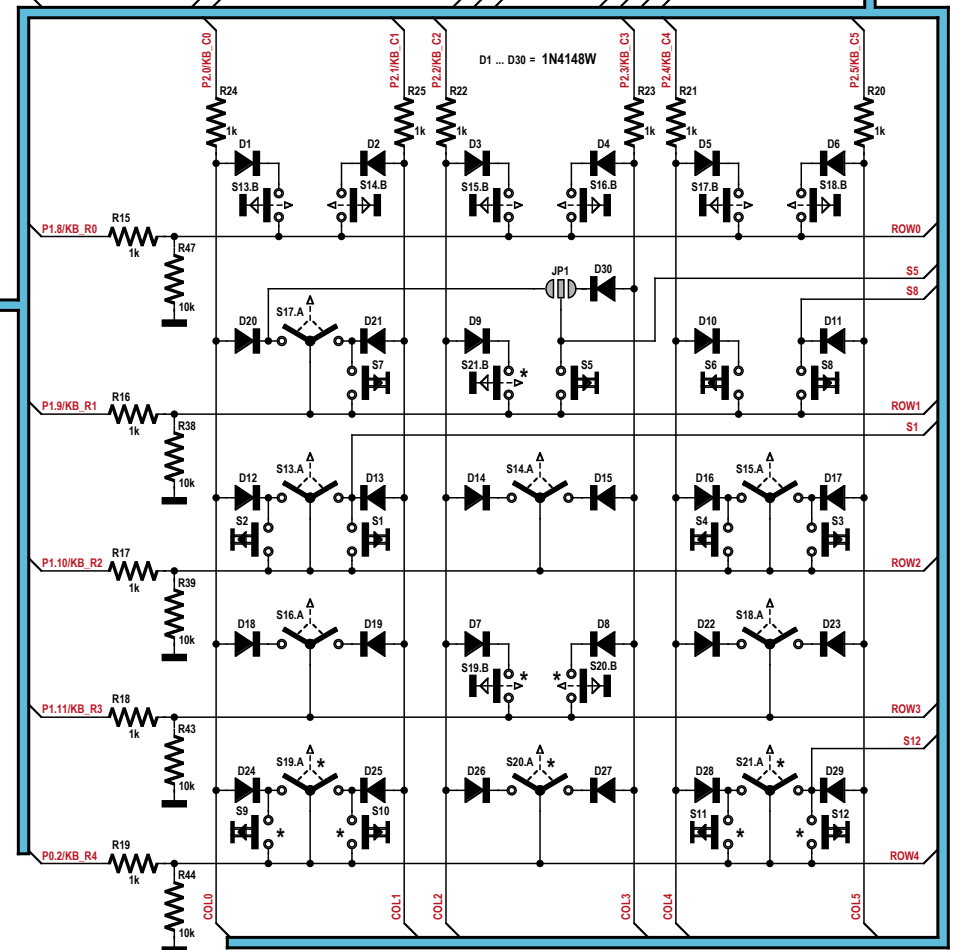
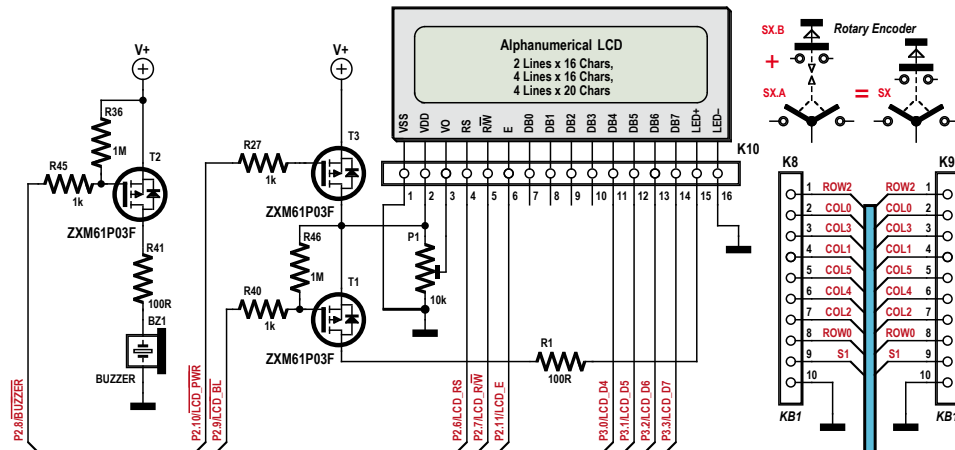


Figure 2. Circuit diagram. The construction file (Eagle files, component list, software, etc.) is available on [1].



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Note that there is a bug in the LPC1343's built-in USB driver, which means you have to wait around 30 s before Windows will detect the "stick" the first time you connect it for a programming session. After that, the detection takes place normally for as long as the microcontroller remains powered. The microcontroller can also be programmed via an SWD (Serial Wire Debug) port, a sort of serial JTAG. Connector K3 has been provided for this purpose, wired in such a way as to be compatible with the LPC-Link used by the free LPCxpresso programming environment. The LED (D34), connected to PIO0.7, is also LPCxpresso compatible, which means that the little test program LPCxpresso1343_blinky included in the IDE ought to work without any modification.

Keypad

The keypad consists in principle of twelve switches, four to the left of the display, four to the right, and four below (with a 2 × 16 display). The idea is to also be able to use rotary encoders in place of switches; an encoder of this type with built-in push-button is equivalent to three switches. Three encoders take up the same space as four switches. To leave as much freedom as possible in positioning the switches and encoders, I decided to allow up to nine encoders (in point of fact, I have an application that needs that many rotary encoders). So nine encoders with built-in buttons correspond to 27 keys, thus a 5 × 6 matrix is needed to connect all the keys using a minimum of I/Os. The matrix is wired in such a way that if you are only using one of the three groups of four keys (left, right, or bottom), only four I/Os are needed for scanning these four keys. The I/Os freed up in this way are available for some other function. JP1 makes it possible to optimize the position of S5 in the matrix.

I have used diodes to avoid the problem of phantom keys if several keys are pressed at once – a situation that can easily arise when you're turning two encoders at the same time. The diodes are in a SOD323 package, allowing them to be replaced by resistors, in case you might want, for example, to fit one or more LEDs in place of certain keys. The main function of resistors R38, R39,

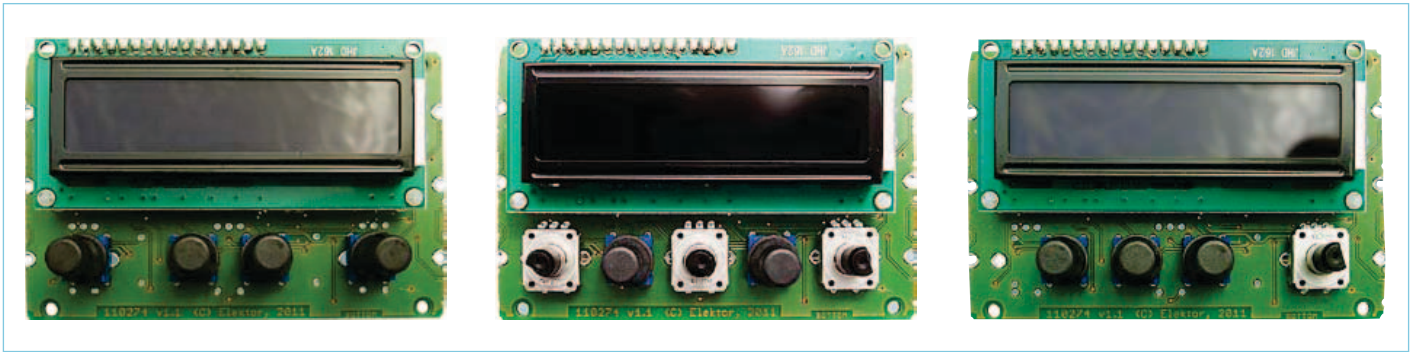


Figure 3. Different variations on the 2×16 LCD theme. Note that the keyswitches can be offset.

R43, and R44 is to enable the board to be turned on using one of the buttons S1, S5, S8, or S12. If one of these keys is fitted with its corresponding bridge (R32, R35, R37, or R42), the resistors provide the voltage needed to turn on T5 when the key is pressed. The circuit can be turned on this way if powered by battery. The function of R47 is to avoid a wiring asymmetry in the matrix; it is not used for an on/off button.

All the matrix lines have a current-limiting resistor (R15–R25). Its value is not very important, just so long as it doesn't impede the detection of the key presses. Finally, note that two footprint are available on the circuit board for S9–S11 and S19–S21.

Display

The board offers the possibility of fitting a 2 line by 16 character ('2×16') display, a 4 line by 20 character (4 × 20) type, and even a rather less common 4 line by 16 character (4×16) type — just so long as the display has a standard connector with a single row of 14 or 16 contacts at the top left. This configuration is very common. Versions of the 4×20 displays also exist with two of these connectors, allowing them to be fitted either way up.

This type of display is normally powered at 5 V, which is not really a problem when the board is connected to an external 5 V supply (USB for example), but to allow battery powering, I've added a voltage booster that steps the voltage up to 5 V on the board. T3 offers the possibility of turning off the power to the LCD, which is handy for resetting the display or for limiting the circuit's overall power consumption. For this same reason, the backlight is also driven by a transistor (T1), with R1 to limit the current. This resistor is in the 1206 format for

better heat dissipation. Its value is not critical and depends on the brightness required.

Buzzer

A standard 12-mm diameter piezo buzzer (with leads on a 6.5 mm pitch) offers the possibility of producing sounds and alarms. It is driven by T2. Resistor R36 avoids spuri-

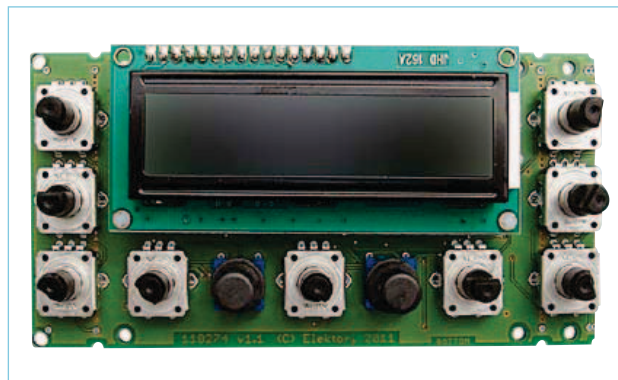


Figure 4. The maximum: nine rotary encoders and two buttons — a total of 29 switches!

ous squealing when PIO2.8 is configured as an input during programming of the microcontroller. R41 is not necessarily useful for a buzzer, but does allow T2 to be used to drive something else like a relay or an LED. Like R1, it too is in a 1206 package.

Powering

The board's main power rail (V+) is 5 V. This voltage is needed for the display, as the microcontroller itself is powered at 3.3 V and everything is connected to the microcontroller. The 3.3 V is derived from the 5 V rail by way of a low voltage drop regulator IC3. R48 allows this rail to be disconnected so the power supply can be tested without any risk to the microcontroller.

The 5 V can come from three sources: an external supply connected to K7, the

USB port (K4), or IC2. The latter is a voltage booster which accepts an input voltage from 0.9–4.5 V and hence offers the possibility of powering the board from a rechargeable battery or one or more individual 1.5 V cells (K5). The microcontroller does not use much power (60 mW in normal operating mode, clocked at 72 MHz) and a single 1.5 V cell is enough for long hours of operation. For information, the microcontroller operates with a supply voltage between 2 and 3.6 V, so a 3 V regulator is not indispensable, given that a 3 V lithium battery or primary cells is amply sufficient.

In the event of using a Lipo battery (< 4.5 V) — for example, out of a mobile phone — a battery charger (IC4) can be fitted to the board, powered by USB (or K7).

The microcontroller is capable of measuring the battery level by way of resistors R11 and R12.

If the board is powered from an external supply only, there's no need to fit all of the power supply.

In this event, fit just D32, C3, C4, C5, IC3, and R48. Note that in this case, the software-driven on/off function will not be available.

USB and extensions

Let's finish our description of the circuit by the extension and communication ports.

K4 is a mini USB connector mounted on the board. It is used above all during the development phase for programming the microcontroller in ISP mode via a USB stick. For a finished application, this connector is probably not in the right place, which is why there is connector K7 which makes it possible to remote the USB connector. T4 is driven by the microcontroller to indicate to the computer that a USB peripheral has been connected.

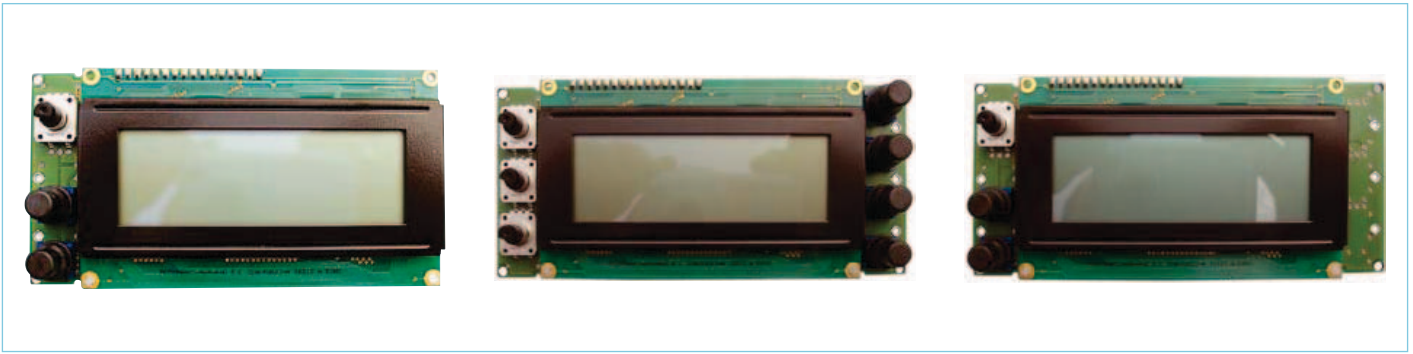


Figure 5. Plenty of possibilities too with a 4×20 character display.

Virtually all the microcontroller I/Os are directly connected to extension connectors K1, K2, and K6. We can also use K8, normally used for connecting the display. A few I/Os are available only via a transistor (PIO0.6, PIO2.8, PIO2.9, and PIO2.10), PIO0.1 is available on JP2 and PIO0.7 on D34. In all cases, each I/O is connected to a pad.

K1 and K2 carry the signals from the communication ports like the I²C, SPI, and UART. Here too are the I/Os not used by the matrix keypad or the LCD. For those who have a USB/TTL adaptor cable from FTDI (Elektor ref. 080213 [8]), you will be interested to know that K1 is compatible with this cable.

Note that port PIO1.4 has a special function in the microcontroller's 'deep power-down' mode, which is why it has a pull-up resistor R10. Note too that two pull-up resistors (R4 and R5) can be fitted for the I²C port.

K6 offers access to most of the ports used for the keypad. A certain number of these signals are also available on K8 and K9, but these two connectors are intended for instances where one might want to split off a mini 4-key keypad for mounting elsewhere.

Construction

None of the SMD devices on the board are too difficult to solder. The microcontroller could prove trickiest, but armed with a bit of desolder braid, it's easy enough to get rid of any surplus solder.

We find more difficulty with the inductors, as they're not always easy to source. Hence I opted for mixed sizes, more or less suited to the types from Coilcraft (try their excellent sample service! [9]), from Coiltronics (distributed by Farnell, for example) and through-hole types on a 3.5 mm pitch.

Different types from other manufacturers might well also be suitable.

In principle, the buzzer, LED, connector K8, and all the keyswitches are fitted on the solder side of the board.

The switches are modular types, consisting of a body onto which can be clipped caps of different colors, shapes, and sizes. Thus

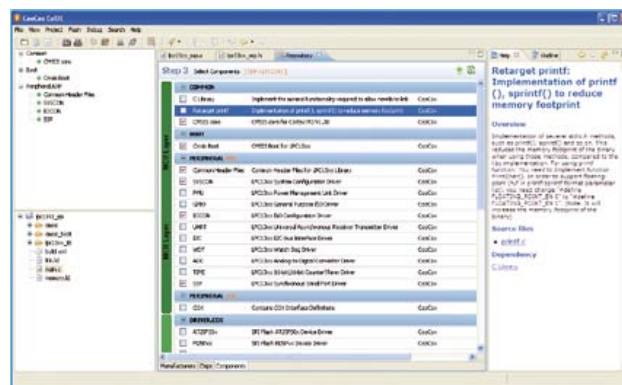


Figure 6. CoCoX CoIDE [7], a powerful free IDE for ARM Cortex-M0 and M3 processors from several manufacturers.

each constructor can use keyswitches suitable for their application and their taste. Depending on the configuration of the keyswitches and display adopted, the board can be split so as to make it more compact. Pre-drilled dotted lines make it easier to split the board to suit the dimensions of the chosen case. The whole board will fit into a case from Bopla (ref. 26160000). Using a 2×16 display and four buttons below, the board is smaller than a 4×20 display. Because of the removable keypad, the board with a 4×20 display is almost the same size as the 4×20 display itself.

Implementation

The board described in this article is compatible with the LPCXpresso from NXP,

Embedded Artists, and Code Red [2, 3, 4] integrated development environments (IDE). This free IDE is without restrictions for the LPC1343 and is supplied with numerous examples and several libraries. The IDE is complemented by a number of LPCXpresso boards that include a programmer/debugger named LPC-Link, which is to a greater

or lesser extent detachable, and a variable microcontroller part. There is also an LPCXpresso board based on the LPC1343 and our board is compatible with this.

If you have an LPCXpresso board, cut off the LPC-Link part and consult the article "Getting Started with your Free LPCXpresso Board" published in the 2011 double issue [5]. In this article, replace all references to the "1114" by "1343" and connect the LPC-Link to K3 on our board. If you have fitted the LED, all you have to do now is follow the instructions to make it flash.

If you don't have the LPCXpresso board, you can still use the IDE by using the microcontroller's ISP via

USB stick mode. To do this, all you have to do is configure the IDE to produce an executable file in the right format.

To do this, in the menu, click on *Project*, then *Properties*. Click on the + in front of *C/C++ Build* and select *Settings*, then click the *Build Steps* tab. In the *Post-build steps* group, enter the following into the *Command* box:

```
arm-none-eabi-size
${BuildArtifactFileName}; arm-
none-eabi-objcopy -O ihex
${BuildArtifactFileName}
${BuildArtifactFileName}.
hex; arm-none-eabi-
objcopy -O binary
${BuildArtifactFileName}
firmware.bin; checksum
firmware.bin;
```



Source: Taco Zip 3 – Heavy kunst (1992) by Fritzgerald, Jakketoë & Cromheecke. Made available free of charge by Luc Cromheecke. Translated from the Dutch by Elektor.

This is in fact a series of commands, some of which are already present (but watch out for the '#' characters which must be deleted). What's important here is that you end up with the file produced called **firmware.bin** and that the checksum is added to it (otherwise the executable won't be recognized by the microcontroller). End by clicking on 'OK'.

From now on, the IDE will produce an executable that you'll be able to copy onto the USB stick (which always contains just a single file named **firmware.bin**). Don't forget about the bug in the LPC1343's USB driver which means that it sometimes takes 30 or more seconds before the stick is recognized. Apart from LPCXpresso, there are also other free possibilities. To start with, there is the microBuilder website [6] which describes how to prepare a programming environment for the LPC1343 bases on Yagarto. This site also offers a library to help you get

Internet Links

- [1] www.elektor.com/110274
- [2] <http://ics.nxp.com/lpcxpresso/>
- [3] www.embeddedartists.com/products/lpcxpresso/
- [4] <http://lpcxpresso.code-red-tech.com/LPCXpresso/Home>
- [5] www.elektor.com/110448
- [6] www.microbuilder.eu/projects/LPC1343ReferenceDesign/LPC1343Toolchain.aspx
- [7] www.coocox.org/
- [8] www.elektor.com/080213
- [9] www.coilcraft.com
- [10] <http://elektorembdedded.blogspot.com>

started quickly with the microcontroller. I made use of this library in developing my test program [1]. Closer to LPCXpresso, there is CooCox ColDE [7] (**figure 6**). Just like LPCXpresso, this IDE is based on Eclipse and it includes numerous drivers for the microcontroller peripherals and lots more besides, like the CoOS RTOS. A programming and debug-

ging probe is also available, based on the LPC1343. You can buy it (watch out for the carriage charges!), but you can also build it yourself, as it's an open-hardware project. Here, the microcontroller's ISP via USB stick option avoids getting into a chicken-and-egg situation. Note that neither ColDE nor LPCXpresso calculates the checksum for the executable automatically.

Who's afraid of 32 bits?

I'm aware that many of our readers don't feel comfortable with 32-bit microcontrollers, even though nowadays they are easier to implement than 8-bit microcontrollers, and what's more, cheaper. For these readers, in a future (the next?) issue I'll be presenting a board similar to the one described here, but simplified and based on an 8-bit AVR microcontroller. It won't use SMD components and — the icing on the cake — it will be Arduino, Mikroelektronika, and BASCOM-AVR compatible.

(110274)

Modifications to the microBuilder library

As mentioned in this article, I based my test application on the open source library for LPC1343 from microBuilder [6]. My program, also open source, is available from [1]. I've had to modify the microBuilder library, as it had a few drawbacks. So it's no longer possible to use the original library. Here are the main modifications I've made:

- **gpioSetValue**: now uses the bit masked version of GPIO_nDATA to avoid conflicts when this function is called from an interrupt service routine;
- **UART**: the `uartRxBuffer` buffer has been replaced by a more universal buffer called `uartBuffer`. Interrupt-controlled transmission has been added;
- **SPI**: numerous modifications have been made;
- **cmd.c**: a mechanism was lacking for avoiding the message buffer memory's overflowing.

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FT232R USB/ Serial Bridge/BOB

By Antoine Authier (Elektor Labs)

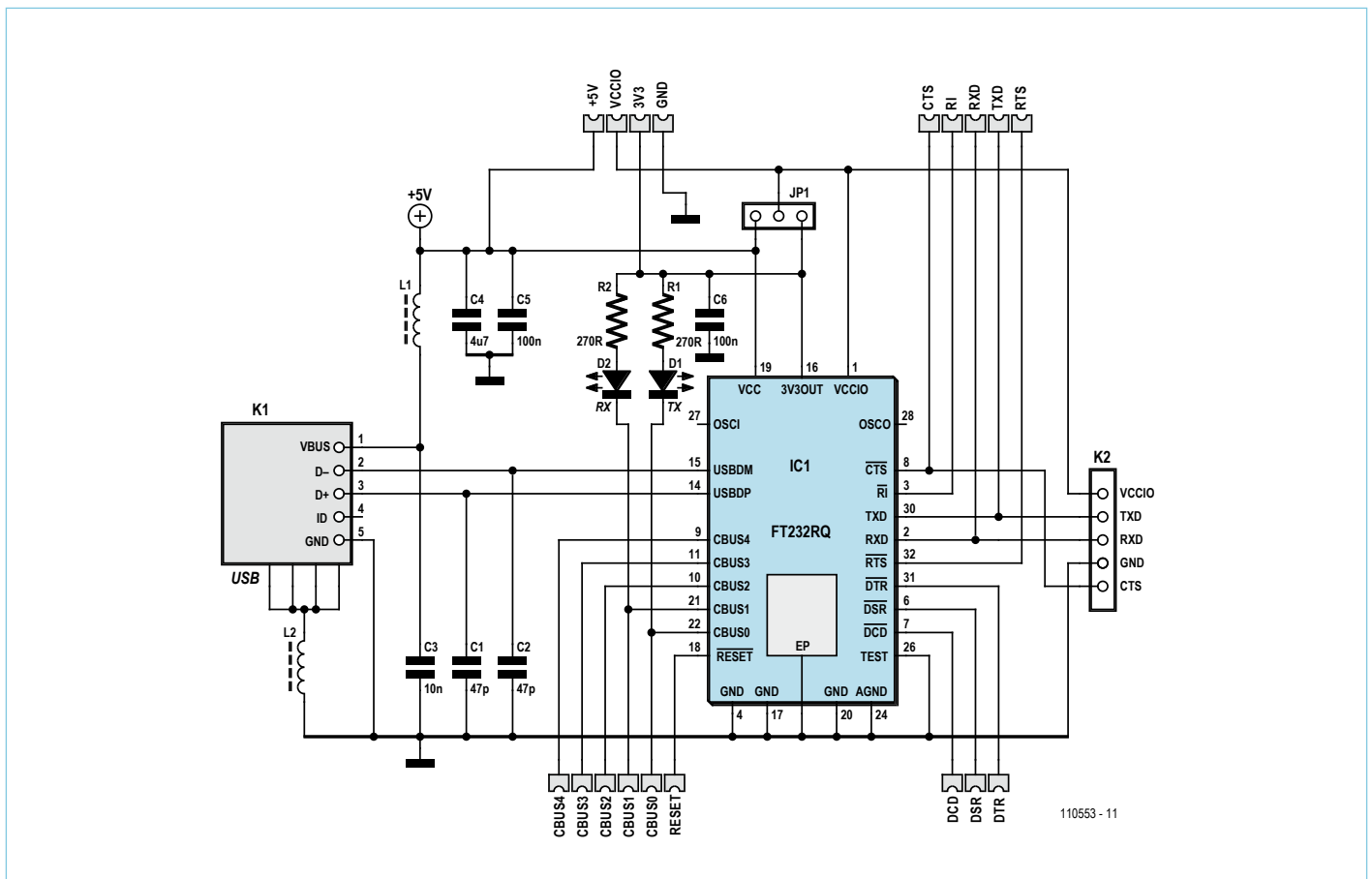
You'll be surprised first and foremost by the size of this USB/serial converter — no larger than the moulded plug on a USB cable!

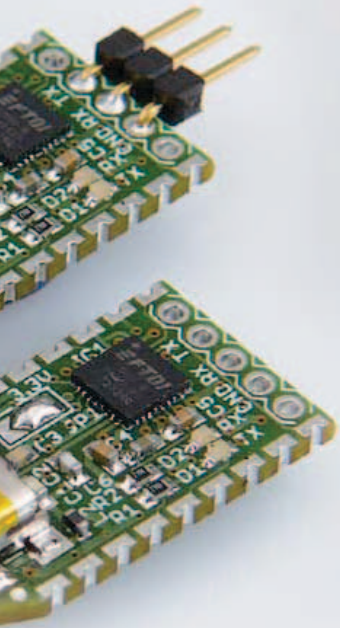
And you're also bound to appreciate that fact that it's practical, quick to implement, reusable, and multi-platform (Windows, Linux, etc.) — and yet for all that, not too expensive.

I don't think much of the various commercially-available FT232R-based modules. Too expensive, too bulky, badly designed, ... That's why I set myself the challenge to design this miniature in the form of a breakout board (BOB). One meaning of breakout is to escape, and in some ways, this board

enables all the normally inaccessible signals within complex circuitry to 'escape' to the outside world so they can be accessed. Here, the complex circuitry is the legendary FT232R. The very one encapsulated within the plastic of the USB/TTL cables from FTDI, see [1][2].

The circuit diagram is based on the information in the FT232R data sheet [5] and makes it possible to produce all the applications described by FTDI (RS-232, RS-485, etc.), along with other ideas (JTAG, BitBang, etc.) which I may be suggesting to you in a later article.





The ferrite beads protect the circuit against electromagnetic interference from the USB cable.

Capacitors C3–C6 decouple the IC power supply.

The two LEDs light when data is being transferred over the serial link seen by the module (host). If the device connected to the bridge transmits a byte to it, the RX receive LED lights. Conversely, when a byte is sent from the computer via the bridge, it's the TX transmit LED that lights.

The circuit doesn't include any fuses, because I'm not sold on polyfuses (resettable chemical fuses) — the only plausible solution here. They reduce the voltage available, which, in my various experiments, dropped below 5 V. I prefer leaving all the voltage and power available to your circuit, which will come in very useful if, for example, you are thinking of including a 5 V/500 mA battery charger further down the line. So it's up to you to protect your circuit if necessary with fuses or power supply monitors downstream of the bridge.

The 5 V rail comes directly from the USB connector at the front of the board, and offers a maximum of 500 mA for a USB 2.0 port (150 mA for a USB 1.x). The 3.3 V rail is provided by the FT232R: take care not to draw more than 50 mA from it. Above this limit, the only signals you'll get will be smoke signals.

Did you notice JP1? It's the jumper printed on the board, and requires a solder bridge to configure the input/output signal volt-

EagleCAD library

This library is useful in that it makes it easier for you to incorporate the bridge within your own projects. It's easy to use:



1. installation

- create the sub-directories “library/Elektor” in the installation directory “eagle” (subsequently called \$EAGLEDIR).
- unzip the downloaded file into this new directory.
- In Eagle's “Options / Directories” menu, add “:\$EAGLEDIR/library/ELEKTOR” to the “Libraries” field. If the “:” doesn't work, try using “;”.

And now let's get down to serious business!

2. Available

8 PCB footprints and 6 associated symbols for getting started quickly:

- BOB-FT232R-MIN minimalist through-hole version with three pins: GND / TX / RX
- BOB-FT232R-TINY minimal version with I/O voltage available: GND / TX / RX / VCCIO
- BOB-FT232R-CABLE version equivalent to the FTDI USB-to-TTL cable, through-hole, six pins
- BOB-FT232R-WIDE complete reverse side of the bridge, through-hole, seven pins
- BOB-FT232R-EDGE connectors on both sides, through-hole and piggy-back mounting
- BOB-FT232R-FULL complete through-hole version (just in case)

3. Use

In EagleCAD select the required symbol, choose one of the associated PCB layouts, where applicable, click on *add* to add the symbol to your circuit diagram.

The layout corresponding to your choice will then be available in the board design window, all that remains for you to do is route it correctly.

Software peripherals

1. Microsoft Windows

To access the bridge via a COM port (in the good old-fashioned way), FTDI offers a COM port emulation driver (Virtual COM Port Driver) available from the address www.ftdichip.com/Drivers/VCP.htm.

You just have to install it for the bridge to be accessible via a COMx.

To emulate a terminal, we recommend TeraTerm or HTerm.

You can also install and use the D2XX drivers in order to directly access the FT232R core, but that's a whole other story...

2. Linux (core version 2.6.31 and above)

Linux cores in versions 2.6.31 or above incorporate the latest virtual port emulation drivers for the FT232R (ftdi_sio modules). There is nothing to install, and this probably holds good for older versions of the core too.

The bridge is accessible via the peripheral `/dev/ttyUSBx`.

To emulate a terminal, we recommend GTKTerm or HTerm.

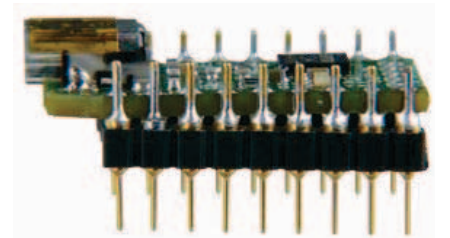
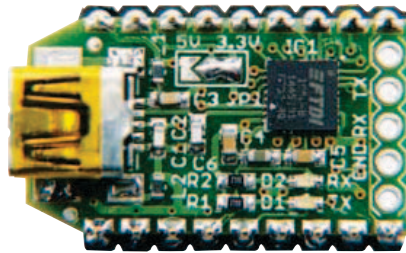
3. MAC OSX

in order to access the bridge on your MAC, install the COM port emulation driver (Virtual COM Port Driver) offered by FTDI at the address: www.ftdichip.com/Drivers/VCP.htm.

The bridge will be accessible via the peripheral `/dev/tty.usbserialx`.

It is possible to emulate a terminal using the program *screen* supplied with MAC OSX.

Buy the FT232R USB/Serial Bridge/BOB at: www.elektor.com/110553



ages: 3.3 V or 5 V. This needs to be set correctly **before** using the board: using a tiny blob of solder, connect the central contact to one of the two contacts on either side; the selected voltage is printed on the PCB: 5 V on the USB connector side, 3.3 V on the other. Above all, short only one contact at a time, as only one voltage is possible. Any other configuration would be fatal.

The simplest way of using the module consists in soldering a 3-way 2.54 mm (0.1") pitch pin header to the GND/RX/TX signals opposite the USB connector. In this way you will obtain a USB-UART bridge that is simple, effective, and can be used in almost all circuits.

Then, depending on your needs, you can use a larger pin header, to have access to more signals: the track layout at the rear of the board lets you obtain the equivalent of an FTDI cable [1][2][3]. Along the sides, you'll find the other signals and the power for the FT232R, accessible via copper contacts on both sides of the board and on the plated edge (!), in the 15.24 mm (0.6") wide DIP18 format. This way, you can solder two straight pinheaders there and use it within other circuits, on a test board, or plugged into a PCB-mounted socket.

You can also solder the bridge board-to-board, piggyback fashion, directly onto the circuit with which you wish to use it. You'll be able to quickly and easily incorporate this module into your circuit thanks to an EagleCAD library available on the article web page [4]. You'll also find there a detailed but condensed data sheet — an essential companion when designing and debugging your application.

COMPONENT LIST

Resistors

R1, R2 = 270Ω (0603)

Capacitors

C1 = 10nF (0603)
 C2, C3 = 47pF (0603)
 C4 = 4.7μF 6.3V (0603)
 C5, C6 = 100nF (0603)

Inductors

L1, L2 = ferrite bead >30Ω @ 100 MHz / 1.5 A (0603)

Semiconductors

IC1 = FT232RQ
 D1 (TX) = LED, green (0603)
 D2 (RX) = LED, red (0603)

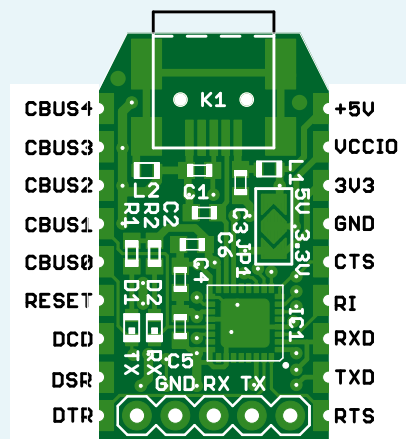
Miscellaneous

K1 = USB mini-B connector
 18-pin (2x9) pinheader, right angled
 Pinheader

Even an experienced electronics technician with good eyesight and equipped with suitable tools (in particular, a hot-air soldering iron) will also need to have confirmed masochistic tendencies to set about — and above all pull off — the construction of their own prototype. And those with trembling hands had better steer well clear!

The task is so tricky, in fact, that we're offering (and recommending) the circuit pre-assembled, ready to use, with the various extension connectors as a bonus. See the product page for further details [4].

(110553)



200% of real size

Internet links

- [1] *USB-to-TTL Serial Cable*, June 2008, and associated cables in 5.0 V and 3.3 V versions (Elektor ref. 080213-71 & 080213-72): www.elektor.com/080213.
- [2] *USB <-> RS-232 cable*, July/August 2008 (Elektor ref. 080470): www.elektor.com/080470
- [3] *USB/TTL serial cable, extension & supplement*, July/August 2010 (Elektor ref. 100007): www.elektor.com/100007
- [4] BOB-FT232R: www.elektor.com/110553
- [5] Web page for FT232R IC: www.ftdichip.com/Products/ICs/FT232R.htm

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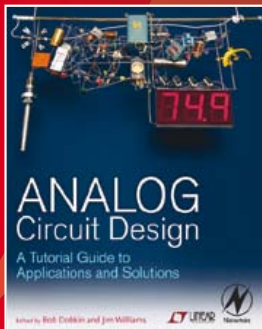
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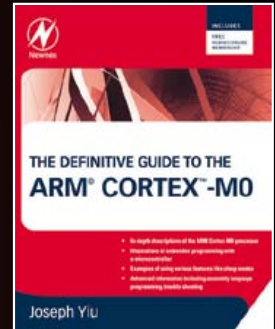
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Audio DSP Course (3)

Part 3: DSP board

By Alexander Potchinkov (Germany)

In this installment we present the DSP board. It is the platform for the applications that will be described in later installments of this series, and it is also intended to enable you to develop your own initial digital audio signal processing applications, which we hope will be followed by many more. The DSP board can be used stand-alone as is, and even though it is an ideal learning platform, with its 24-bit signal processing capability for sampling rates up to 192 kHz and its high-performance interfaces, it is also suitable for applications with very stringent quality requirements for both signal to noise ratio and DSP computing power.

The DSP board is intended to be used for processing audio signals with a digital signal processor. The signals to be processed may be analog, digital, or a combination of the two.

Figure 1 shows the block diagram of the circuit. The selected components allow the hardware to be limited to 13 ICs on a PCB measuring 97 by 66 mm, despite the impressive performance capability. Two-channel ADC and DAC ICs with 24-bit resolution and sampling rates up to 192 kHz are provided for processing analog signals. These converters were selected on the basis of price, the lowest possible peripheral component count, and availability. They are suitable for operation under hardware control and do not require different configurations for different sampling rates.

Figure 2 shows the audio signal paths supported by the DSP board. The DSP is the audio master, and on the input side it receives digital audio signals and analog audio signals converted into I²S format. On the output side it provides signals for simultaneous conversion into analog and digital audio signals. If you consider only the audio signal paths and ignore the signal processing functions, the DSP can be imagined to act as a three-position source selection

switch. In position 1 it supplies analog audio signals to the audio outputs, in position 2 it supplies digital audio signals, and in position 3 it supplies signals generated by the DSP itself.

Signal processing and signal transmission both require the use of the DSP.

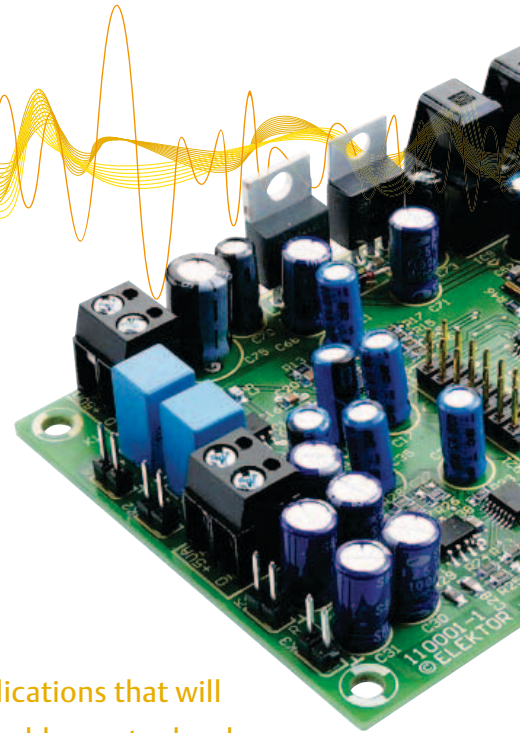
Digital signals can be input and output using optical or electrical ports at the user's choice. On the input side these two modes (optical and electrical) are mutually exclusive, while on the output side both modes can be used in parallel. An asynchronous sample rate converter (SRC) on the input side converts digital signals having a wide range of sampling rates into digital signals that are sampled at the rate used for digital signal processing. The 'professional quality' sampling rate of 48 kHz is used for applications described in this series of articles because it allows sufficient bandwidth along with high computing power.

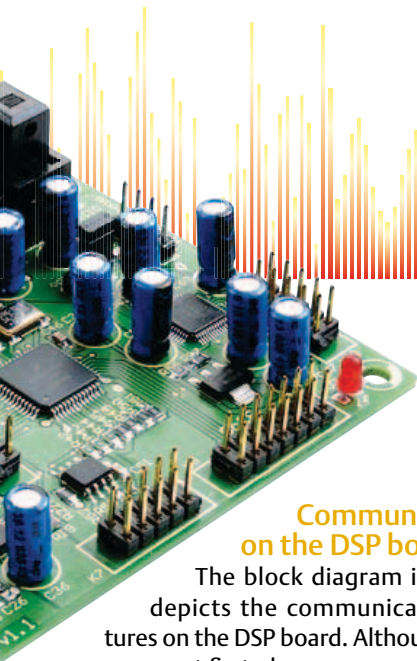
Signal processing is performed by a Freescale DSP56347, which is specifically designed for audio signal processing and can be programmed to perform any desired function. If you wish to perform digital signal processing at a different sampling rate,

all that is necessary is to change the settings of two interface configuration registers (e.g. for 96 kHz sampling, only one bit in each register needs to be changed).

Many different applications are possible with the DSP board. For example, you can connect a CD player directly to the board and use it with a LED board described in this series of articles to construct a VU meter; you can connect a digital microphone and an amplifier (with speakers) to the board and use it to suppress feedback howl; or you can use the board to compute the harmonic distortion level of an analog signal and show the result on a display.

Despite the manifold application possibilities of the DSP board, it needs only a relatively small number of components — thanks to the advanced state of development of modern digital audio IC technology. The block diagram shows four signal processing blocks: audio signal input and output, digital signal input and output, the DSP block, and the DSP peripherals. These blocks are described below to give you an understanding of what is on the DSP board and what can be implemented using the board.





Communication on the DSP board

The block diagram in **Figure 3** depicts the communication structures on the DSP board. Although this figure may at first glance appear surprisingly complex in light of the small size of the board, it provides a good indication of the versatility and application diversity of the design. There are two communication channels: an I²S audio bus for audio data, and an SPI bus for control and miscellaneous data. The audio bus has five nodes, with the DSP acting as bus master and the other four nodes acting as slaves. The audio bus clock lines are shown in black and divided into two groups, although clock lines of the same type can be joined together on the DSP board. This is indicated symbolically on the drawing by labels in parentheses and dashed connecting lines. We split the clock signals into the clock signals used on the board and the clock signals connected to I²S port K6 to allow this port to also be used for GPIO if an audio port is not needed. If the port is used as an I²S port, the following clock lines can be interconnected on the DSP board: HCKR to HCKT, FSR to FST, and SCKR to SCKT.

The upper six line of the audio bus lines the audio data lines. Three of them are used internally on the board, while the other three are connected to port K6. The connections to the analog and digital audio interfaces of the board are shown below the I²S bus in the figure.

The second bus is the SPI bus, which has four nodes. Here again the DSP is the bus master and provides the bit clock for shift register operations. The three slave nodes are the SEEPROM (which acts as rewritable nonvolatile memory with low access speed), the sample rate converter, and SPI port K7, to which any desired external SPI slave device can be connected. In this course we use this port to supply data to a LED bargraph display.

Slave nodes on an SPI bus must be enabled or disabled by chip select signals to prevent

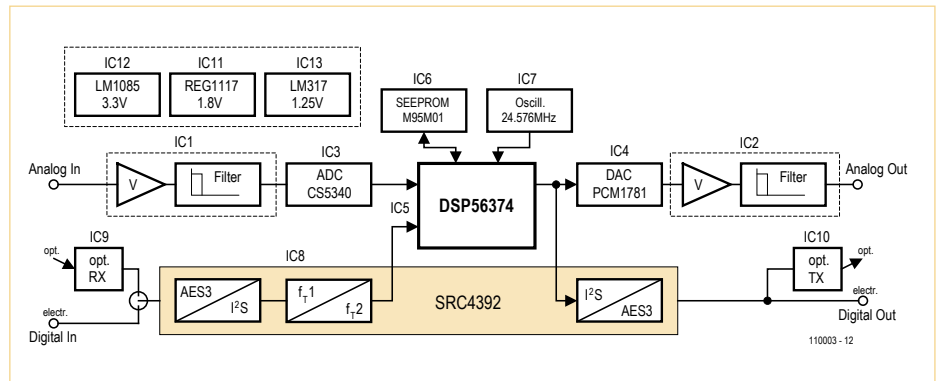


Figure 1. Circuit block diagram. The signal interfaces support two-channel audio.

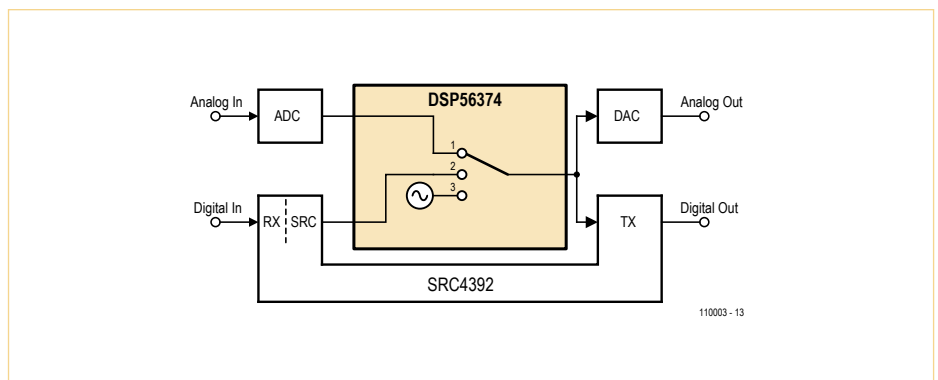


Figure 2. Audio signal paths.

them from concurrently driving the MISO line. These chip select signals are generated by the DSP. Additional lines are used for SRC control and handshaking. One of these lines is used to reset the SRC, which for example must be done before it is configured. The SRC uses the other line to indicate to the DSP that a digital audio signal is present on its digital audio input.

Analog signal inputs and outputs (IC1-IC4)

The two-channel analog signal input stage with pin headers K1 and K2 is built around operational amplifiers IC1a and IC1b and ADC IC3 (type CS5430); see **Figure 4**. The analog portion of the ADC is powered from the 5 V supply rail. The two operational

amplifiers are wired for unity gain and add a DC offset equal to half the supply voltage to the input signals after AC coupling capacitors C1 and C2. They also serve as low-impedance signal sources for the ADC and the analog anti-aliasing subfilter of the oversampling ADC.

The ADC operates with fixed settings as an audio slave device, which means that the DSP provides the necessary audio clocks, consisting of the master clock, the bit clock and the left/right (LR) clock, which corresponds to the sampling rate. The ADC is operated in one of three modes depending on the desired sampling rate: single-speed, double-speed or quad-speed. For each of these modes, specific ratios between the master and LR clock frequencies can be

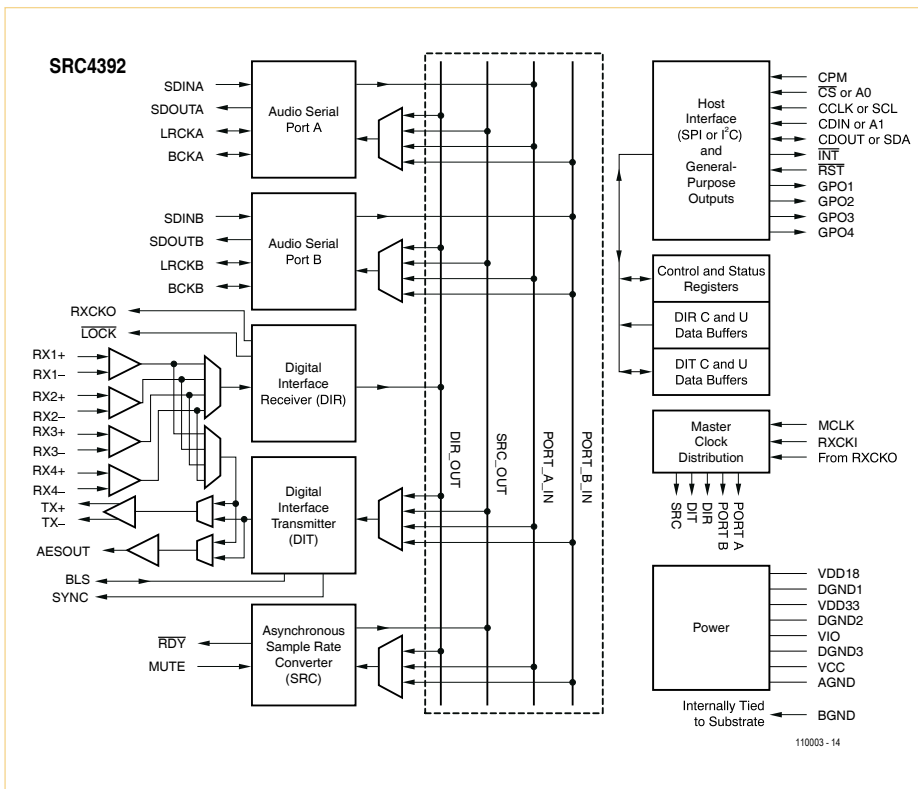


Figure 3. Communication on the DSP board.

specified over a range of 64 to 512. The ADC is able to automatically detect the ratio of the clock signals generated by the DSP, which is determined by the DSP firmware. According to the data sheet, the ADC has a dynamic range of 101 dB and a THD + N level of -94 dB, which is sufficient even for applications with stringent requirements. The peak-to-peak signal level with a sinusoidal signal is 0.53 to 0.59 times the supply voltage, with an average level of 2.8 V. On the digital side of the ADC, which is powered from the 3.3 V supply rail for digital peripheral devices, I²S audio mode is selected by pull-up resistor R14 connected to pin 4. I²S audio mode is used for all audio signals on the DSP board. Power-up reset is provided by network R13/C20. The two-channel audio signal output stage with pin headers K3 and K4 is built around DAC IC4 (type PCM1781) and operational amplifiers IC2a and IC2b. With an audio word width of 24 bits, the DAC has a dynamic range of 106 dB and a typical THD + N level of 0.002%, equivalent to approximately -94 dB. It can be operated at sampling rates ranging from 5 kHz to 200 kHz. The DAC is configured for I²S and is controlled by the DSP as an audio slave.

The audio clocks generated by the DSP are the same for all audio interfaces (ADC, DAC and SRC). The four configuration pins (1–4) are configured for I²S, de-emphasis off, and mute off. The DAC can automatically detect the ratio of the master and LR clock signals generated by the DSP, which allows it to be used without separate configuration. The reconstruction filters (low-pass filters used to convert the oversampled digital signals into analog signals) are implemented using the two operational amplifiers. They are second-order Butterworth filters with a DC gain (A_0) of 1. The stop frequency is approximately 30 kHz with the specified component values. The stop frequency has intentionally been set relatively low because DACs of this sort generate predominately high-frequency noise, so the bandwidth should be kept as small as possible. Changing the filter characteristics is not difficult. If you wish to maintain the Butterworth characteristic, the Q (quality) factor is 0.7071 ($1/\sqrt{2}$). Start by specifying the DC gain, the value of capacitors C26 (for the left channel filter) and C27 (for the right channel), and the stop frequency f_0 or ω_0 ($= 2\pi f_0$). The values of the other components can then be calculated (taking the left chan-

nel as an example) using the formulas

$$C28 = C26 / (4Q^2 \times (1 + A_0)),$$

$$R24 = 2Q / (\omega_0 \times C26),$$

$$R25 = (1 + A_0) \times R24,$$

$$R23 = (1 + A_0) \times R24 / A_0.$$

If $Q = 0.7071$ and $A_0 = 1$, these formulas simplify to

$$C28 = C26/4,$$

$$R24 = 1.4142 / (\omega_0 \cdot C26),$$

$$R23 = R25 = 2 \times R24.$$

The component values for the right channel filter can be calculated in the same way. The DC offset for the filters is taken from pin 13 of the DAC.

Particular attention has been given to protecting the analog outputs from damage if they are connected to microphone inputs with a phantom supply voltage of up to 48 V. To provide sufficient tolerance in both directions against DC voltages up to these levels, the output capacitors have a suitably high rated voltage and are connected in reverse series. The dual Schottky diodes D1 and D2 protect the operational amplifiers against the effects of an output cable short in such a situation, which would otherwise cause the capacitors (charged to around 48 V) to discharge through the operational amplifiers. At the full-scale DAC output level, the output voltage level with a sinusoidal signal is approximately 3.9 V peak to peak.

Digital signal inputs and outputs (IC8–IC10)

Audio data is transported internally on the DSP board in I²S format. The I²S bus is a synchronous serial bus with three bus lines: LR clock, bit clock, and audio data. A different format called Digital Audio must be used for signals entering or leaving the board. It is designed to allow data to be transmitted using a single fibre link. This requires two converters, which convert Digital Audio signals to I²S signals or the other way around. These two converters, which are known as the receiver (RX) and the transmitter (TX) below, are housed in the SRC4392 (IC8). Before describing the operation and control of IC8, we should first briefly describe the digital audio interfaces of the DSP board. An

optical receiver (IC9) and an optical transmitter (IC10) are located on the board. They can be connected to the RX and TX stages of IC8. The board also has ports for electrical signals. Either the optical input or the electrical input can be selected by a jumper on pin header JP1. In order to use the optical or coaxial input, a jumper must be fitted between pins 1 and 2 of pin header K9 (connecting the minus input terminal to ground) so that the RX1 input of the SRC is tied to ground via C54. This jumper should be removed if a balanced input signal is used.

Either an unbalanced signal or a balanced signal can be connected to pin header K9, which has a 75 Ω termination (R54). To comply with the relevant standard, a balanced signal should be input using a standard pulse transformer and two 18-Ω resistors wired directly to the XLR input connector. You can make your own pulse transformer from a ferrite ring core and a few centimeters of enamelled copper wire. A differential RS422 signal output is available on pin header K10. It can be used together with a pulse transformer and a 110-Ω resistor to provide an AES-3 balanced output, or with a resistor and a 10-nF capacitor to provide an unbalanced S/PDIF output. Additional I²S ports that can be controlled by the DSP are also brought out to pin header K6. They can be used for connection to standard ICs with an I²S interface. IC8 is a very high-performance interface IC described by its manufacturer as a ‘two-channel asynchronous sample rate converter with integrated digital audio interface receiver and transmitter’. Its block diagram (see Figure 5) shows several function blocks and four audio data busses. The blocks for digital audio input are on the left side.

The two Audio Serial Ports (A and B), of which only one (port A) is used on the DSP board, provide the links to the DSP. Port A is operated in I²S mode and provides the audio input and output paths for the DSP. Two signal paths for digital audio signal input and output are available in the SRC (IC8) on the DSP board. The first path runs from the differential digital inputs pins (RX1+ and RX1-) of the Digital Interface Receiver (DIR) over the DIR_OUT bus to the Asynchronous Sample Rate Converter (SRC), and from there

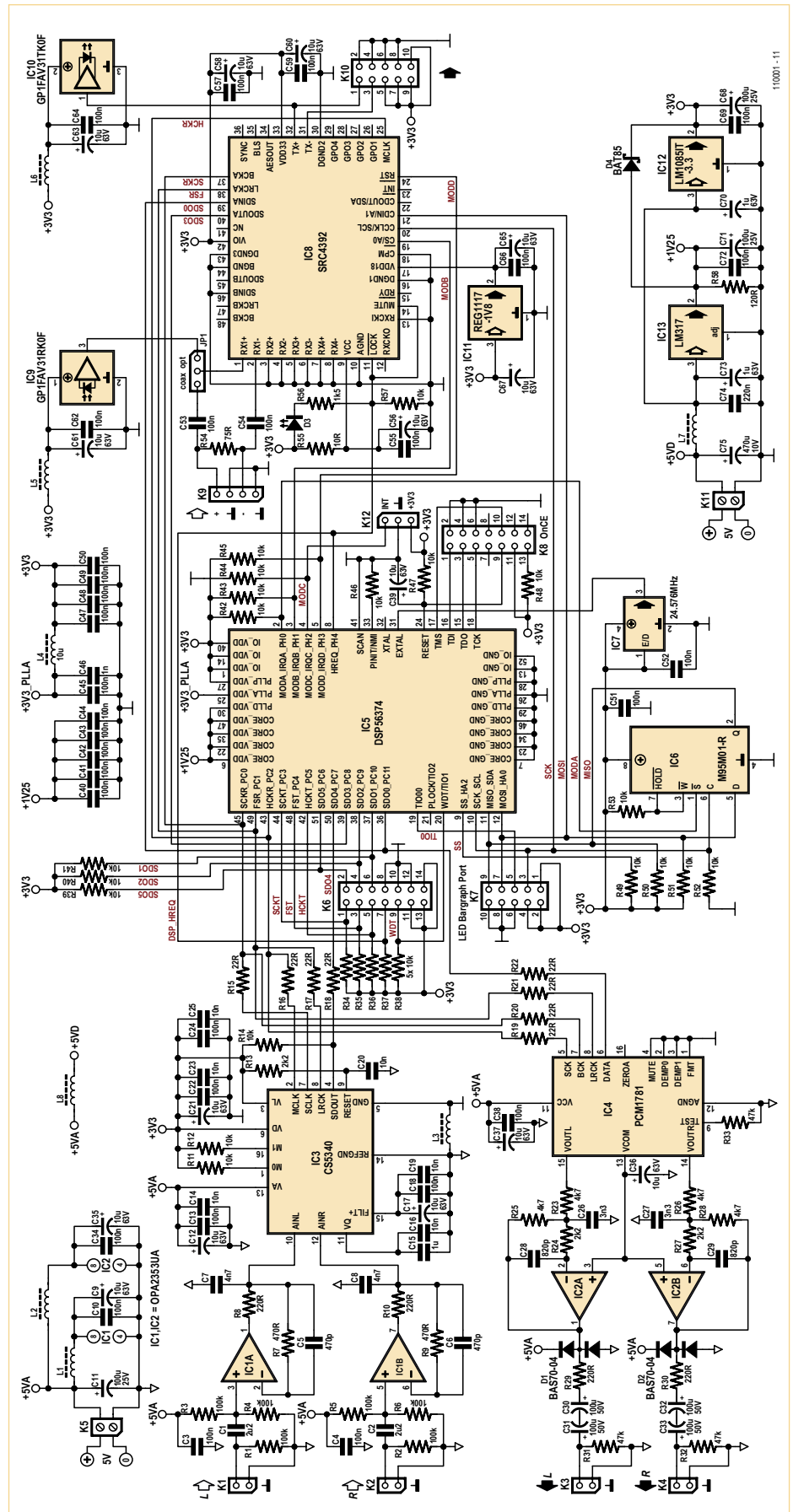


Figure 4. Complete circuit diagram of the DSP board.

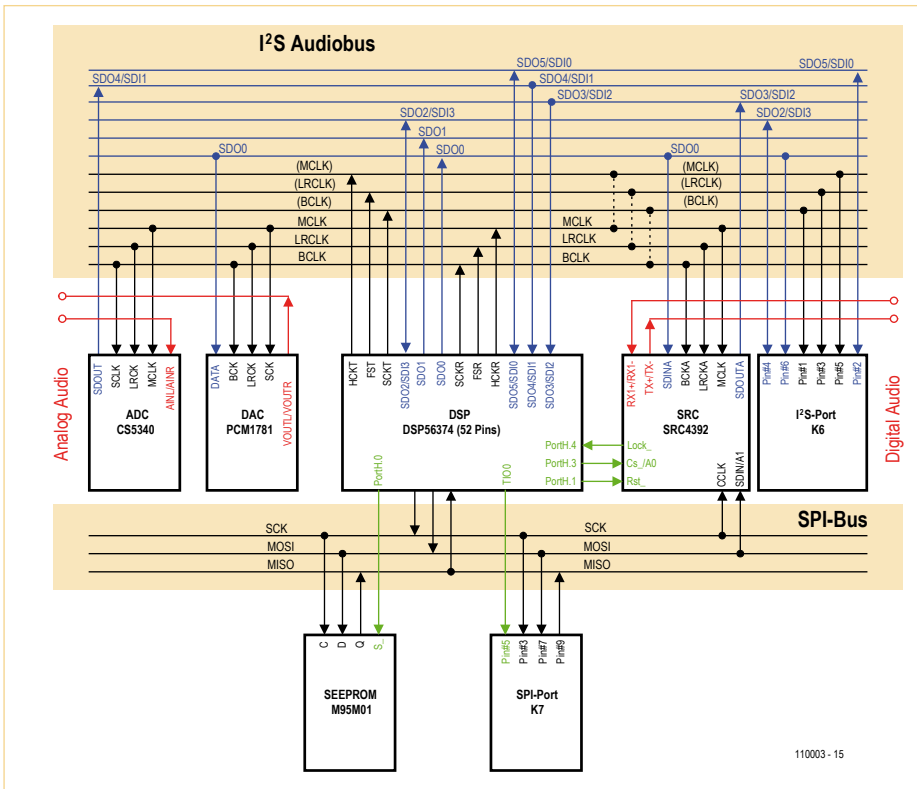


Figure 5. Block diagram of the sample rate converter.

over the SRC_OUT bus to Audio Serial Port A and its data output pin SDOUTA, which is connected to the DSP.

Audio data from the DSP follows the second path, which starts with audio data input into Port A. From there it is transported over the PORT_A_IN bus to the Digital Interface Transmitter (DIT), where it is converted to Digital Audio format for output from the board.

The DIR converts audio signals in Digital Audio format to audio signals in an internal format that can be read by the SRC, and it synchronizes the input port of the SRC. The output port of the SRC is synchronized by the DSP, which sends audio clock signals Port A of IC8.

The Asynchronous SRC interpolates the audio signals. This is done by generating a quasi-continuous signal, similar to an analog signal, from the incoming audio signal and sampling this signal at a different sampling rate to form the output signal. Interpolation can be performed as a purely digital process because it does not require an analog signal.

The SRC can process audio signals with sampling rates ranging from 20 kHz to 216 kHz and convert them to a different sampling rate, such as 48 kHz or 96 kHz. These rates

are commonly used in professional applications, and they are used by the DSP for audio signal processing. The DSP is supplied with audio data from Port A, and it returns audio data to the SPDINA pin on the same port. If you consider the functional scope and audio quality (24 bits, equivalent to 140 dB) of the selected SRC component, you can see that it belongs to the top end of the performance range of comparable ICs. As you might imagine, there's also a downside to this: a device with this degree of complexity cannot operate under hardware control; it requires configuration under software control. This is done by writing 52 bytes to the control register bank, which is done using the SPI protocol. The relevant registers and their functions are shown in table 1.

The remaining registers are filled with zeros. Two \$01 bytes must be sent before actual register configuration starts with register \$01, so a total of 54 bytes must be transmitted. The byte sequence is stored in the file `src4392.tab`.

The Lock signal on pin 11 of IC8 is important because it indicates whether a valid digital audio signal is present at the receiver input. This signal is used in the DSP firmware to determine whether to select digital input

or analog input. If a valid digital input signal is present, the SRC output signal is processed; otherwise the ADC output signal is processed. The presence of a valid digital input signal is indicated by LED D3.

IC8 operates from a separate 1.8 V supply voltage generated by low-dropout voltage regulator IC11 from the 3.3 V supply voltage.

DSP and clock oscillator (IC5 and IC7)

The audio DSP, a Freescale DSP56374, is a highly integrated IC requiring only a few peripheral devices. The DSP clock is derived from the 24.576 MHz clock generated by crystal oscillator IC7, which is multiplied by a factor of 6 in the PLL frequency multiplier circuit integrated in the DSP to produce a 147.456 MHz clock signal. At an audio signal sampling rate of 48 kHz, 3072 instruction clock cycles are therefore available to the user in each sampling interval for signal processing.

The audio clocks — master clock, bit clock and LR clock — used by the ADC, DAC and SRC are derived from the processor clock signal by dividers in the DSP. The DSP acts as audio master, which among other things allows the sampling rate to be set to 48 kHz, 96 kHz or 192 kHz. Incidentally, the latter rate has little technical relevance and tends to be used by marketing strategists to promote ADC and DAC devices that do not support 24-bit audio resolution and therefore try to convince potential users by boasting especially high (but unnecessary) maximum sampling rates.

The schematic symbol for the DSP in Figure 4 has the pins arranged in various groups according to their function. The pins for the supply voltages and ground connections are shown at the top and bottom. The DSP uses a supply voltage of 3.3 V for its peripheral circuitry and a lower supply voltage of 1.25 V for the processor core. This allows the power consumption to be kept relatively low, even at a high processor clock frequency.

A group of 12 pins for audio interface functions is located on the left side. Half of them are used for the data lines of six I²S ports

Table 1. Programming the functions of the SRC.

Address	Content	Block	Function
\$01	\$37	Alle	Enabling Port A, TX, RX and SRC
\$03	\$31	PortA	Format I2S, Source=SRC, Slave, Mute off
\$07	\$60	TX	Source=PortA, ClockRatio=512, ClockSource=MCLK
\$09	\$03	TX	BufferSource=SPI
\$0D	\$08	RX	Input RX1, reference clock=MCLK
\$0E	\$10	RX	Clock free runs after loss of clock
\$0F	\$22	RX	Reference clock=24.576MHz
\$1B	\$07	GPO1	Receiver non-valid data active high
\$2D	\$42	SRC	Source = DIR, reference clock = MCLK, mute off, tracking on
\$2E	\$03	SRC	64 samples group delay, true decimation, de-emphasis off

that serve as inputs and outputs, of which at most four ports can be used as inputs. The other half provide the audio clock signals, consisting of two sets of three clock pins. It is possible to clock the inputs and outputs separately, which among other things allows users to work with two different sampling rates. We do not make use of this possibility; the same clock signals are used for the inputs and the outputs on the DSP board. Accordingly, the SCKR, FSR and HCKR outputs provide the I2S bit clock, LR clock and master clock signals. The DSP software can be used to set the clock signals as desired by configuring the peripheral device registers appropriately.

The I2S signal on SDO0 (pin 36) is used on the DSP board to drive the DAC and the SRC TX stage, which converts audio data to Digital Audio format in the SRC. Pin SDO4, which is configured as an input, connects the output of the ADC to the DSP, while pin SDO3 connects the output of SRC RX stage in IC8 to the DSP. This gives the DSP access to both of the board's signal inputs (analog and digital). The three clock lines are used by IC3, IC4 and IC8, so the ADC, DAC and SRC operate synchronously. Pins TIO0 and WDT/TIO1 in the adjacent set of pins are fed out to pin headers and can be used for the DSP timer system, for a watchdog timer, or as GPIO.

The set of pins from SS_HA2 to MOSI_HA0 forms a synchronous serial port, which is used on the board as a bidirectional SPI interface for communication with various peripheral devices. This includes writing configuration data to IC8, which is selected by the signal on the MODB pin of the DSP. The serial EEPROM is also connected to the SPI bus and can be read and written. It is selected by the signal on the MODA

pin of the DSP. Finally, in one of the projects described in this course we use the SPI bus to write data to a LED board with two 40-LED bargraph displays.

Naturally, other SPI peripheral devices can also be connected to SPI pin header K7, such as a microcontroller with user interface components and a display, which could be used to enter configuration settings in the DSP program and show them on the display. The set of pins at the top right consists of MODA_IRQA to MODD_IRQD. After the DSP is reset, the processor reads the voltage levels on these pins and uses this information to select the boot mode. The combination of pull-up resistors R42, R43 and R45 and pull-down resistor R44 selects booting from the on-board SEEPROM over the SPI bus. After the DSP has been booted, these pins can be used for hardware interrupts or GPIO. Three of them are used on the board for GPIO. The HREQ pin is connected to the Lock output of IC8, which indicates whether a valid audio signal is present on the digital audio input. The MODD pin can be used reset IC8, which must be done before it is configured. DSP terminal MODC_IRQC is available on connector K12, allowing a method for hardware interrupts to be created. However, if this is used, be sure to avoid conflicts with booting via the SEEPROM in bootstrap mode 11. This mode requires the logic level at this pin to be Low briefly after a reset, which is implemented with the aid of resistor R44 on the DSP board.

The signals on pins 31, 32 and 33 are not relevant to signal processing. They provide a connection point for the clock generator and determine whether the PLL clock multiplier in the DSP is active after the DSP is reset. The final set of pins (15 to 18) forms the

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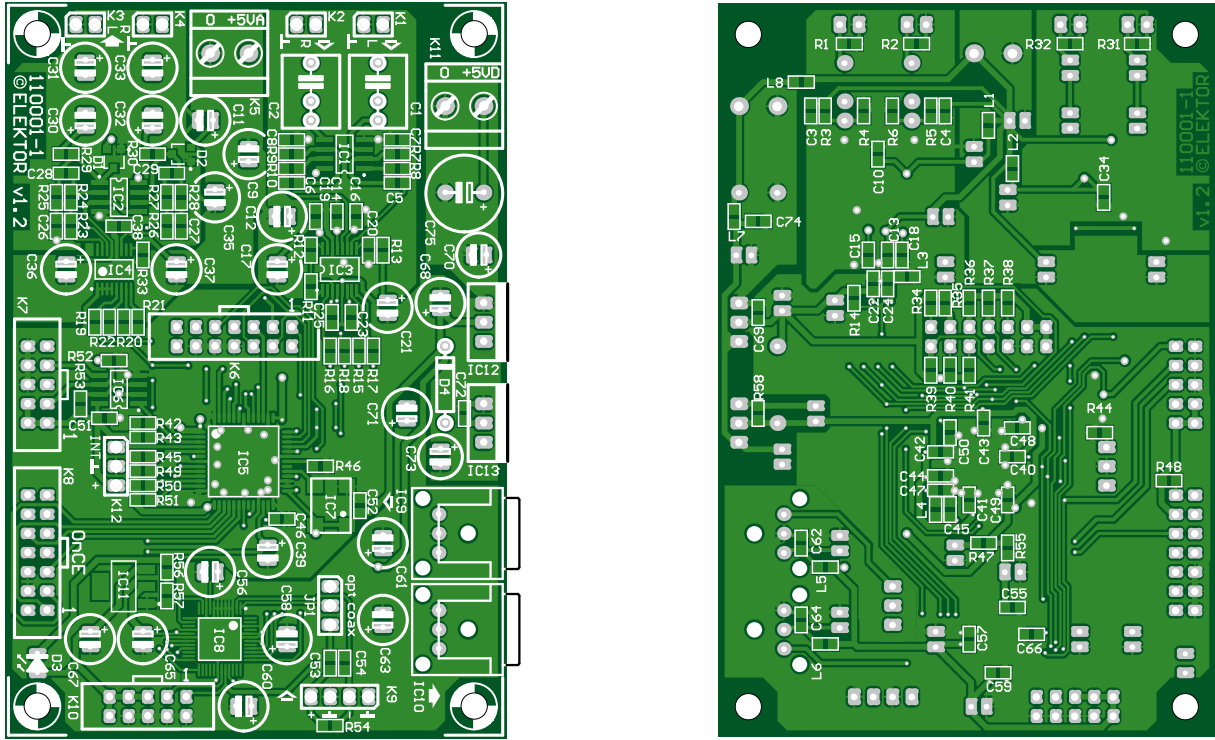


Figure 6. Component layout of both sides of the DSP board (see www.elektor.com/110003 for the components list).

debug port, which is fed out to pin header K8. It is used for communication with a debug program running on a PC, which can be used to download program code, to read all of the DSP registers, and to read and write the DSP's internal volatile memory.

DSP peripheral devices (IC6 and IC7)

The DSP peripheral devices can be described in just a few words because they consist of only two ICs: the previously mentioned clock oscillator (IC7) and IC6, a type M95M01 serial SPI 1-Mbit EEPROM.

The DSP has three banks of 6-Kword RAM with a total capacity of 442,368 bits ($3 \times 6,144 \times 24$), which provide less than half the storage capacity of the SEEPROM. Most applications do not require writing the entire DSP RAM with data from the SEEPROM when the board boots up. Furthermore, the SEEPROM can be read and writ-

ten while the DSP is running. Although this is very slow compared to the DSP clock rate, it allows specific settings or the like to be read and written using data transmission over the SPI bus between a microcontroller-based user interface and the DSP board. However, writing data to the SEEPROM using the special auto increment addressing mode requires some programming effort due to the paged structure of the SEEPROM, since the page structure must be taken into account when large volumes of data are read or written.

Power supply (IC11, IC12, IC13)

Finally, a few words about the power supply for the DSP board. The board has two separate 5-V power connectors: one for the analog supply voltage (connector K5) and the other for the digital supply voltage (connector K11). These two connectors are linked by inductor L8, so only connector K11 of the

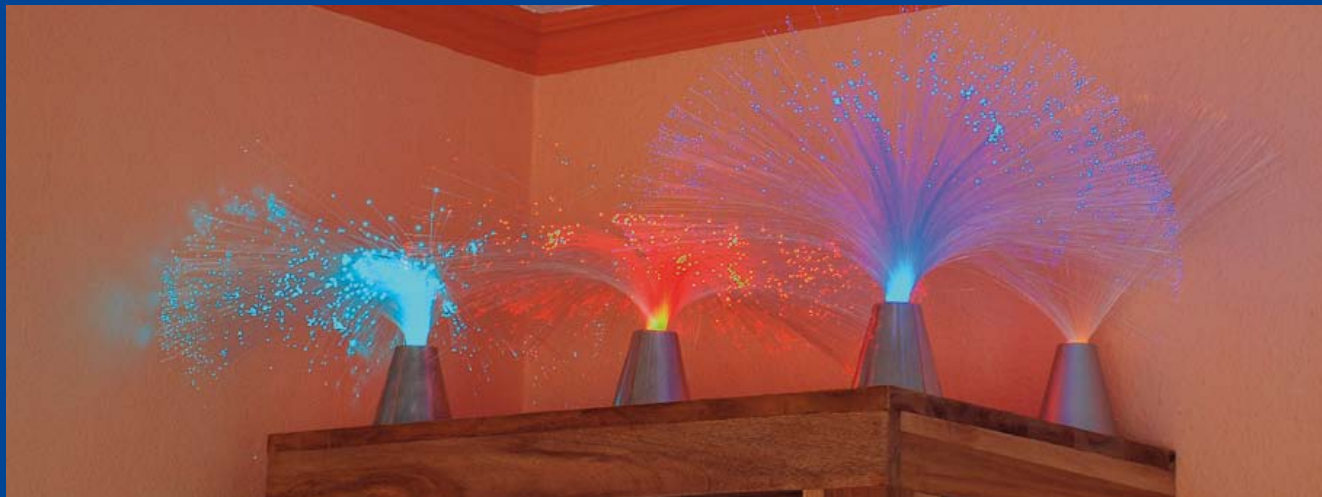
board supplied by Elektor needs to be connected to an external 5 V power supply. It may be possible to obtain a better signal to noise ratio for analog signals by using separate power supplies, although this depends primarily on the quality of the power supply (or supplies). The other three supply voltages needed for the digital components — 3.3 V for the digital circuits, 1.5 V for the DSP core and 1.8 V for IC8 — are generated by linear voltage regulators IC11, IC12 and IC13.

The DSP board

As already mentioned, the DSP board is available from Elektor fully assembled and tested. Next month we will take our first steps on the way to putting the board to good use and describe a number of test routines. We will also say more about the necessary PC software and how to use it.

(110003)

A ghost in the machine

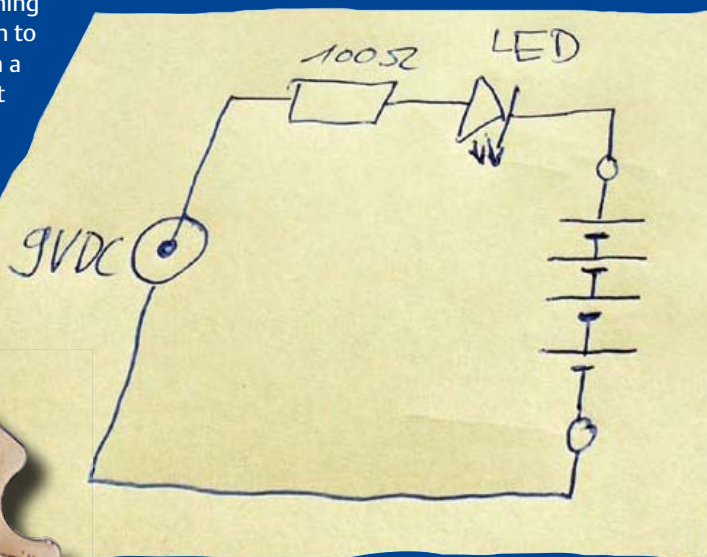


By Dr. Thomas Scherer (Germany)

It must have been about a year ago when I first noticed it. I plugged my electric corkscrew (what, doesn't every engineer carry one in their toolbox?) into its charging station as usual but this time the charging LED began flashing on and off. Odd, I thought, it's never done that before; the charger circuit must be more sophisticated than I'd imagined. The irregular flashing continued and the LED started to change color from green to yellow/green. Curiosity got the better of me, armed with a screwdriver I set about dismantling the unit. Inside I couldn't see any sign of a chip, transistor or even a capacitor or coil in fact there was just an LED and a series resistor.

The circuit (shown here) really was as dumb as I had first thought. The circuit diagram shows that charging current for the four batteries flows direct from the 9 V AC power adapter through the LED, limited by a series resistor. I carefully de-soldered the LED and connected it to a bench power supply; sure enough it started blinking again, I turned up the current and the blink rate increased until at about 70 mA it gave up the ghost. Although a little surprised, I replaced the charger LED and increased the value of the series resistor to 470 Ω . For sure, this would produce a continuous charge current of around 5 mA which should be enough to keep the batteries charged. I had almost forgotten the whole episode until recently when

my wife called me into our living room to point out that one of the red power LEDs in a lamp on top of our cabinet had started flashing. The spirit of the dying LED had made an unwelcome return. In this case the irregular flashing only lasted for about 15 minutes before it departed for good. Once again the circuit was just an LED and a series resistor. The photo of the dead



LED doesn't give many clues although it does show definite signs of stress. Incidentally it turned out that I was the culprit responsible for its early demise; I had forgotten the thermal paste when I first assembled the lamp in the cabinet.

Unfortunately this does not explain why an LED starts to flash when it's about to give up the ghost. Can anyone explain the mechanism at work here? I'm intrigued. Send in your answers to Jan at editor@elektor.com; we will publish the best.

(110459)

Alibaba

By Thijs Beckers (Elektor Netherlands Editorial)

Don't you think that the world seems to get smaller every day? Whereas in the days of Jules Verne it was unthinkable to travel round the world in 80 days, nowadays it's considered on the slow side to do it in 80 hours. I remember that when I was a child we occasionally visited 'distant' family. In this case, 'distant' meant a 160-mile trip in our Mini Cooper Station, which was quite an experience in those days!

These days we 'nip' over to the stock exchange in London or New York and holidays should be taken in a different state or preferably on another continent. Most of the electronic parts and equipment are no longer manufactured in Europe or the US, but are made in one of the low-wage countries and subsequently transported halfway round the world.

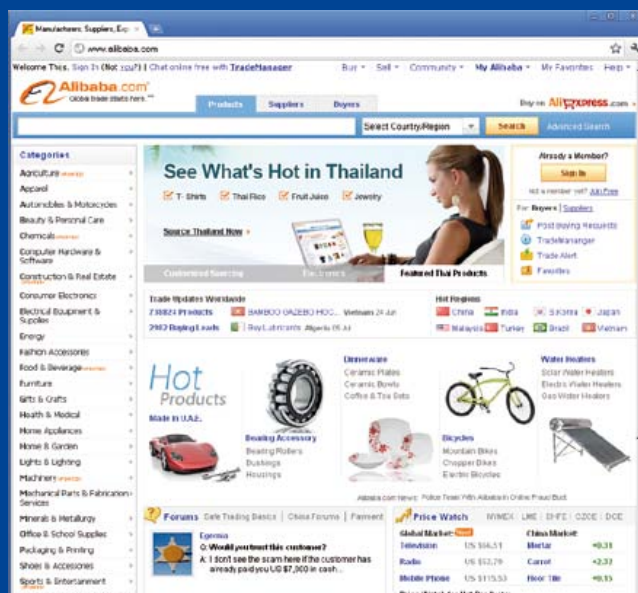
The latter affects one of the jobs that you also have to do as a designer, which is the search for suppliers of the components you plan to use in the circuit you're designing. During a recent search I stumbled across a website called alibaba.com. Perhaps you heard of it already? It is a type of 'portal' for worldwide traders. You can find just about anything there: from rice to cars, from chemicals to golf accessories. And last but not least, electronic parts from China. You do understand why I ended up at this site?

A very useful feature of this site is that it lets you chat online with an employee of the relevant supplier. This way you can ask questions directly about the product and discuss the delivery options. I put this into practice for a future project and made an agreement with a Chinese supplier regarding component samples and the supply to Elektor readers around the world. I won't yet give away for which component this was, since the project is still in its early design stages. But if the project proves successful with the intended components, then the availability of the parts will at least be guaranteed.

Since the Alibaba website is used by suppliers from all over the world you do have to take account of the time-difference and any possible national holidays at the supplier's location before you make contact with them. I have to admit that the whole experience of this site has left a positive impression on me. Doing business over long distances has never been as easy as it is now. The age of information technology certainly has made life easier in this respect.

The world obviously hasn't literally become smaller, but distances no longer seem to matter as much, which is very useful for designers. We'll just have to hope that the Forty Thieves don't make an appearance...

(110549)



Perfect pizzas

By Thijs Beckers / Jan Visser
Elektor Netherlands Editorial / Elektor Labs)

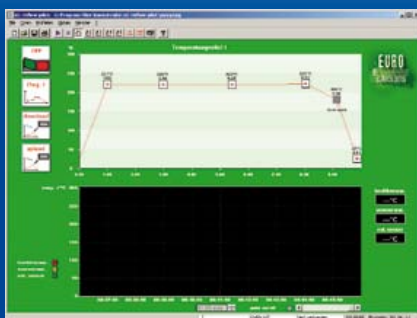
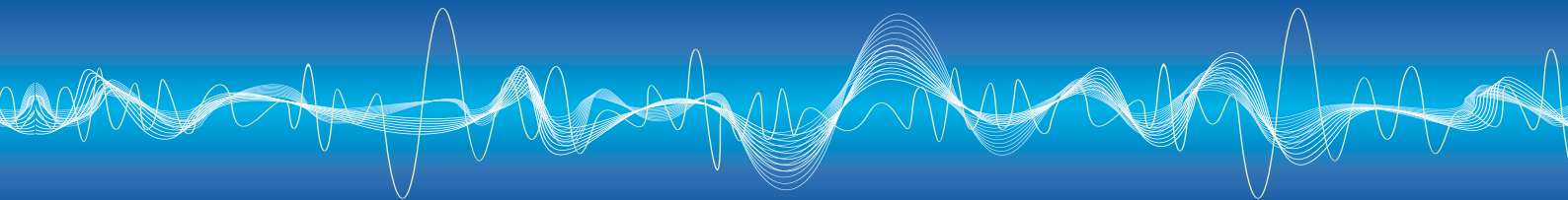
No, we haven't made any drastic changes to our area of interest and plunged ourselves into the writing of recipes or cooking courses. Neither are we reporting on our experiences with the local bistros and pizzerias while we were holidaying in Italy! No, we are talking here about our new, high-tech SMD oven.

In another article in this edition you have already had the opportunity to study the specifications of this swanky baking machine. What you haven't been able to read, are the types of tests that the new machine was subjected to by our lab

colleague Jan Visser. By far the nicest, or better: the tastiest, was the heating up of lunch, which was, especially for this purpose, unearthed from the freezer at the supermarket.

To be able to heat the pizza just perfect, Jan, after some trial and error (such punishment!), was able to establish the optimal curve for heating his lunch. Never again will you have to suffer charred pizzas with black edges and shrivelled up mushrooms. And this makes nice change from the usual smoke of molten solder and scorched flux that permeates the lab.

Jan: "To ensure that the pizza is heated as fast and as uniformly as possible, we first pre-heat the oven so that it is already warmed up. We do this by allowing the oven to heat up without



anything in it, that is, by running it through a so-called short curve. While the oven is going through this heating cycle we use this opportunity to retrieve the pizza from the freezer and unwrap it.

Because of the progressively wound spirals of the heating elements, which, in addition, are also positioned in specifically selected places, the oven has an extremely favorable and balanced temperature distribution, so that even large surfaces are heated uniformly.

When placing the pizza in the oven, you need to ensure that the pizza is placed neatly in the middle of the oven so that the heating process will progress as uniformly as possible. The upper and lower temperature sensors are not allowed to ‘see’ each other. So therefore put the pizza exactly between them. With mini-pizzas this can be a bit of a challenge.

Since our pizza has a preparation time of 8 minutes at 220 degrees Celsius, we adjusted the curve in our program so that this temperature is reached after 1 minute and is then held constant for exactly 8 minutes. The external temperature sensor can in this case be used to measure the outside of the crust, so that we can be ensured of obtaining a “crispy crust”.

When shopping for a pizza make sure that you buy a pizza with a short preparation time, somewhere around 8 minutes. Pizzas

with a longer preparation time will need a different curve, of course. Pizzas which are thicker than an inch must be avoided, because these would touch the top temperature sensor, and as a consequence a perfect result will not be obtained.

There is no point in making the leading edge of the pizza-temperature curve very steep, because the pizza itself needs time to warm up and can’t follow such a curve quickly enough. Obviously, the supplied PCB holders are not used and it is a good idea to put baking paper underneath the pizza to prevent leaks. After 9 minutes our Italian delicacy is ready and the door of the oven opens automatically. The forced cooling period that the SMD oven normally goes through when soldering printed circuit boards must be avoided, of course, and therefore we immediately have to get busy with the pizza cutter to share the hot pieces of pizza with our hungry colleagues, who in the meantime have been attracted by the aroma.

Have you become hungry? Our pizza-curve is available as a download for everyone who would like to experiment with it, you can get it at www.elektor.nl/110537. Enjoy your meal!

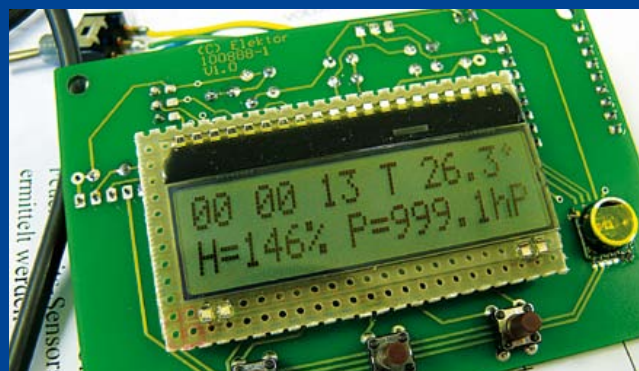
(110537)

Problems under pressure

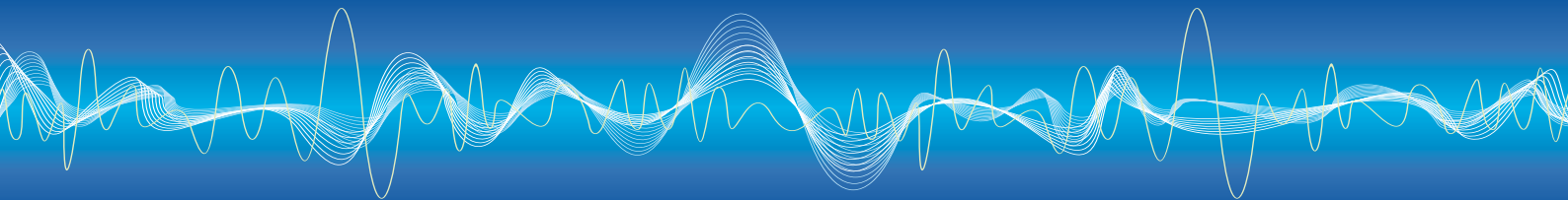
By Luc Lemmens & Thijs Beckers (Elektor Labs)

Here at Elektor Labs, while testing a prototype of the USB Weather Station we came across a strange phenomenon. When measuring the relative humidity, the frequency generated by the sensor is subjected to a calculation in order to arrive at the displayed value. The prototype found the environment to be extremely humid, because we read a value of more than 150% on the display! Although the basement of our castle, where the lab is located, is quite humid, 150% is, of course, not possible. The strange thing was that our prototype used to work correctly (or at the least: indicated no value above 100% — it actually displayed a value that was too low). There had to be something else going on.

The prototype we received from the author was already on its way back to him, because that (also) indicated a value that was



too low and the author was keen to investigate that further. So a comparison between the two assembled circuits was a bit difficult at this time. In addition, the deadline for this issue was breathing down our neck and there was not enough time to



have the author return his prototype to us again. The calculation in the software was checked once again, the PCB was checked (for the umpteenth time) for potential errors and short circuits. But everything appeared to be all right. The only other thing Luc could come up with was that either the calibration value (stored in the EEPROM of the sensor) was corrupted, which is very unlikely since a second sensor module

gave exactly the same error, or that the software was reading the calibration value from an incorrect address. At the time of this edition going to press the problem hasn't been solved, but we trust that this will definitely be the case by the time you read this magazine and that the software-download for this article will be 100% functional.

(110383)-I

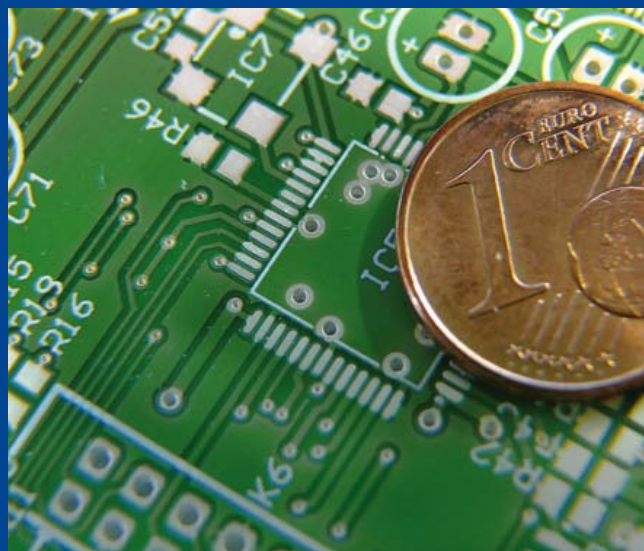
Small pitfalls

By Thijs Beckers & Ton Giesberts (Elektor Labs)

You will, of course, have already read the latest article in our DSP series with much interest. There we have attempted to explain nearly all the ins and outs as comprehensibly as possible. Nearly all, that is. For some details there was no space in the article. However there are a few practical details that we do not wish to keep from you.

A few years ago, from the time of our famous Class-D Clarity amplifier, we, as designers, did not have much experience ourselves using SMD components in PCB designs. Because the Class-D amplifier operates with large currents and at high frequencies it was important that the PCB as small and compact is possible. One method was to avoid separate vias by combining them with the pads of the resistors and capacitors. When using our product assembly service for placing the SMD components on the PCB, the relevant company pointed out the potential production problems this could cause. There is the risk of 'tomb-stoning', i.e. the components standing up on end during soldering. This is caused by the capillary action of one via, which will pull an SMD component upright. Fortunately we had none of these problems on this particular PCB. We have, however, avoided doing this since then.

In addition to tomb-stoning the DSP board has another issue that we would like to pay some attention to. We used an IC in a so-called HTSSOP package, which contains a Thermal Pad (the TLC5926 LED driver). This type of package has an 'exposed pad' on the bottom of the package. This enables the internal heat generated by the IC to be conducted to the outside, where this surface is usually also the ground connection of the IC. The intention therefore is for this pad to be soldered to the plane the PCB designer is supposed to pour under the IC. This carries the potential risk of the component 'floating away' when the solder liquefies during the reflow process. This risk is bigger if too much solder paste is applied. On the other hand, using insufficient paste is undesirable as well since it reduces the coupling with the (ground) plane and therefore worsens the heat transfer. The best way is to apply the solder paste with the aid of a stencil: a sheet of a certain thickness and perforations at those places that need to have solder applied. By filling all the perforations with solder and subsequently wiping the sheet we



apply exactly the correct quantity of solder paste. In some cases it is even more difficult: for example, with our DSP board, there is the odd via in planes directly underneath ICs. This improves the heat transfer even more (additionally making it easier for the heat to be dissipated by the copper plane on the other side of the board). But there is the risk that the solder will flow away to the other side through these vias and not enough remaining on the exposed pad to ensure that the IC is properly connected to the PCB.

Placing a solder mask around the vias is one solution to ensure that the solder will not flow away through the via. Another potential way to avoiding this is to keep the vias as small as possible. The smaller the hole in the PCB, the harder it is for the solder paste to flow away through the via.

While on small vias: did you know that our PCB manufacturer did not allow us to make the vias smaller than 0.25 mm? This also requires a minimum copper annulus of 0.15 mm, so that the entire via is a little bigger than 0.5 mm in diameter. The big boys are probably laughing at this, but you have a look at the photo yourself where the scale will be clear...

(110551)

E-Blocks go Twitter

Using embedded wireless networks

By Ben Rowland (UK)

In this project we look at how you can easily link a wireless network card to your microcontroller system to develop a website containing useful information about the environment and even post messages on Twitter.



At our local sailing club there are more than 1000 members. One of their difficulties is that they do not know when the conditions are suitable for sailing. It's not just that there has to be wind for sailing, but health and safety regulations dictate that a qualified life guard (one of the members) be present when anyone is on the lake. To solve this problem we proposed that a website could be created to inform members whenever the lifeguard enters or leaves their post at the sailing club, along with local weather conditions and other sailing information. Also on the website is a link to the popular social networking site Twitter [1], so that one member can let others know that he/she is going to the club and that conditions are suitable. It was also proposed that the website should include a web camera, mounted to a web visitor controlled servo motor. Ideally, to provide visual information, the servo motor must also respond to control commands from the visitors of the website.

Hardware used

To get the project up and running on the bench I used a selection of E-blocks that

you can see in **Figure 1**. This consists of an EB006 Multiprogrammer fitted with a

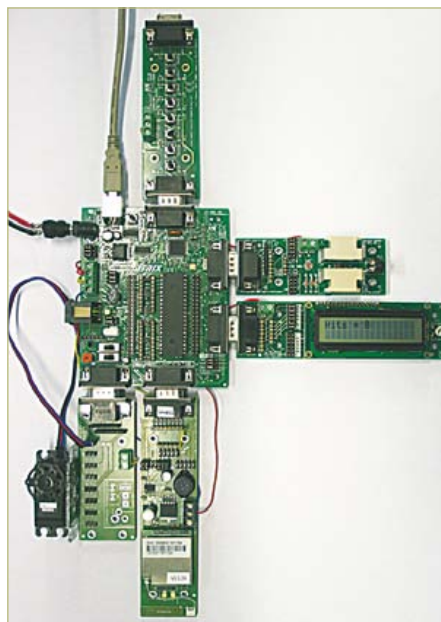


Figure 1. The prototype system based on E-blocks.

PIC18F4455, an EB003 Sensor board, an EB007 Switch board, an EB005 LCD board, an EB059 Servo interface board and an EB069 Wireless LAN board. For the sake of the prototype the temperature reading comes from a stainless steel temperature probe inserted into the sensor board.

The light and wind-speed readings come from the LDR and potentiometer on the sensor board. Finally, the lifeguard sensor is simply a switch (SW0) from the EB007 board. This switch could then eventually be placed under the lifeguard's seat to allow the Twitter messages to be sent out automatically with no user interaction.

The Matrix Multimedia Wireless LAN E-blocks board is a key part of the system: this allows easy access to the sailing club's wireless network and is fully supported by Flowcode V4. The E-block can be used to host a wireless network or join an existing wireless network. In the network host mode there is no simple way of allowing Internet access so for the purposes of this article we will be using the client mode.

Elektor Products & Services

- E-Block Multiprogrammer (EB006)
(Note: PIC18F4455 not included)
- E-Block Sensor Board (EB003)
- E-Block Switch Board (EB007)

- E-Block LCD Board (EB005)
 - E-Block Servo Interface Board (EB059)
 - E-Block Wireless LAN Board (EB069)
 - Flowcode for dsPIC/PIC24: #TEDSSI4
 - Flowcode program file: 110388-11.zip (see [2])
- Pricing and ordering details at www.elektor.com/e-blocks

Setting up the wireless LAN board

In this article we want to be able to communicate with the E-blocks system via the Internet, so to begin with we first need to connect the wireless E-block to the existing local wireless network as seen in **Figure 2**.

The WLAN board can act as a server, serving pages wirelessly to other wireless LAN devices, or as a client device communicating with a remote server. To begin this process you first configure the Wireless LAN component to be an end device. For most systems the Flowcode WLAN component property configuration shown in **Figure 3** will be correct. To allow WLAN Internet requests, you

unsecured, then an empty null string can be used for the key. You can see this program in **Figure 5**.

Configuring your router

Once the system is up and running, you should be able to view web pages served by the embedded system on the local network. To see the pages on the local network you will first have to discover the IP address of the WLAN module, which should be shown in the DHCP client list on your router. Entering the IP address of the WLAN module into an Internet browser will reveal the WLAN configuration utility. This is similar to the configuration utility on a standard router and will allow you to check all of the Flow-

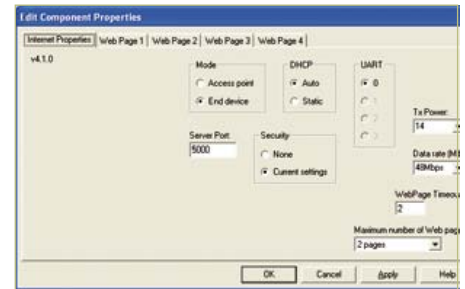


Figure 3. Wireless LAN Flowcode dialog.

server port is 5000:

<http://192.168.0.4:5000/>

Connecting to the Internet

Once we have confirmed that the WLAN module is serving pages correctly we can then configure the router to allow the module to be addressed via the Internet. Doing this means you can access the embedded system from anywhere in the world. To aid in configuring your specific router there is a website at <http://portforward.com> that guides you through the steps you need to

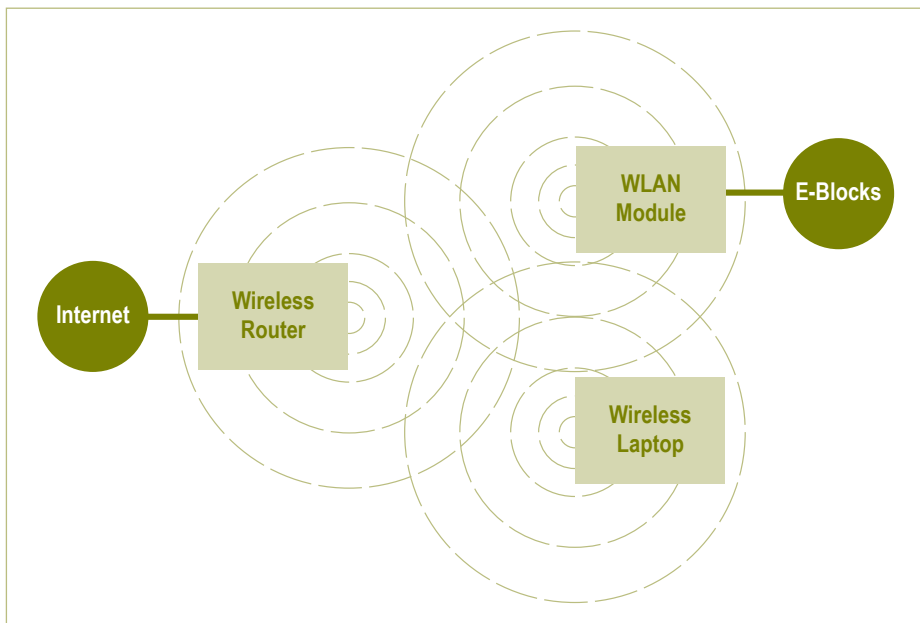


Figure 2. Local area network (LAN) wireless configuration.

have to initialize the WLAN module, which involves resetting the device and passing the set of Flowcode initialization properties to it. You can see the routine for this in **Figure 4**. Once this has been done, the Connect_To_SSID component macro is used to connect the module to a host wireless router. The connect macro requires two parameters, the first being the network name (SSID) and the second being the wireless security key. If the network is

code settings have been loaded into the module correctly.

To see actual data pages served by the system you need to manually add the specified server port to your browser URL. Here is an example URL address where the WLAN module's IP address is 192.168.0.4 and the

Figure 6. Wireless LAN Flowcode HTML page.

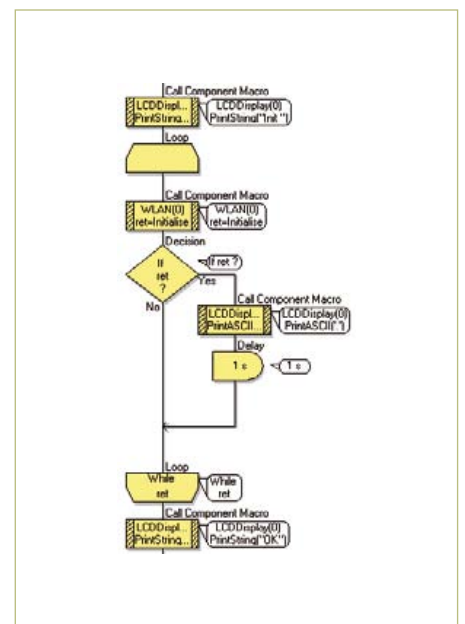


Figure 4. WLAN Initializing in Flowcode.

perform to allow web access to the embedded system. They also offer a paid service to help you getting up and running. Your router manual will also contain a good source of information on how this is done for your hardware.

To connect to the embedded system via the Internet, you must enter the URL of your local Internet connection as detailed by your router. As the IP address supplied by your Internet service provider can change regularly, there are free services such as <http://no-ip.com> that will provide you a free static domain name that will automatically forward you to your current IP address. The WLAN module directly supports this kind of functionality named Dynamic Domain Name System (DDNS) so you can enter your no-ip username and password into the module's configuration utility and this will automatically keep your IP address synchronized to your domain name.

Setting up the web pages in Flowcode

The web page content is configured by entering HTML and Javascript code directly into the Flowcode WLAN component. You can see an example of this in **Figure 6**. The variables used in the web page like temperature and wind speed link directly to Flowcode program variables. Outgoing variables are controlled using a Flowcode component macro and inserted into the HTML using a percentage character '%' followed by an index number. E.g.,

```
Temperature = %0.
```

On the other hand, incoming variables are controlled by adding the variable's index and value to the URL — similar to how variables are passed in PHP. E.g.,

```
index.htm?0=255&1=39
```

Page requests are serviced by regularly calling the Check_For_Page_Requests component macro within the Flowcode program. You now have a versatile microcontroller system that can communicate over wireless with local networks and the Internet alike, and you're able to pass values in and



Figure 7. Sailing Club Weather Report.



Figure 8. Sailing Club Camera Control.

out of the system. Examples of the web pages served from the microcontroller can be seen in **Figures 7** and **8**. The main page

direction of the camera. The main page also shows a Twitter link which can be used by one member to send an 'attendance' message to all other Twitter feed subscribers.

Creating a Twitter link

Next, to create the Twitter post detailing what is happening in the system for all feed members. This was done by creating a Twitter button on the web page and populating this with the data collected by the sensors. Then when users visit the website and click the Twitter button, they can send out a message to any of their followers detailing the conditions at the club. I did try to get the system to automatically send out Twitter messages whenever the lifeguard entered or left the club, but I could not get this to work reliably so it was dropped for the time being.

Conclusion

All this kit is now up and running on the bench and neatly communicating to the web. The next step is to get hold of an anemometer and to take the hardware into the field...

The Flowcode programs are — as always — available from the Elektor website [2].

(110388)

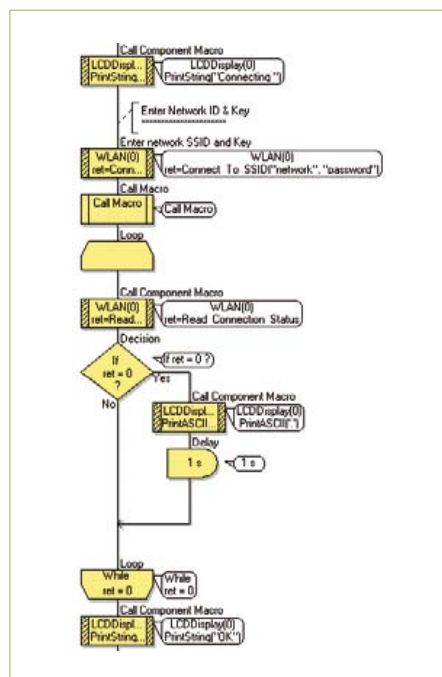
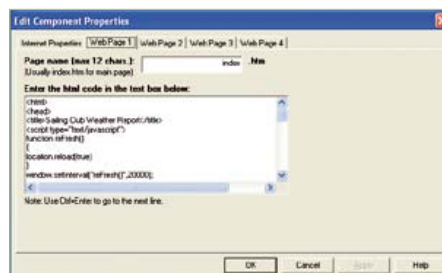


Figure 5. WLAN Connect to SSID.



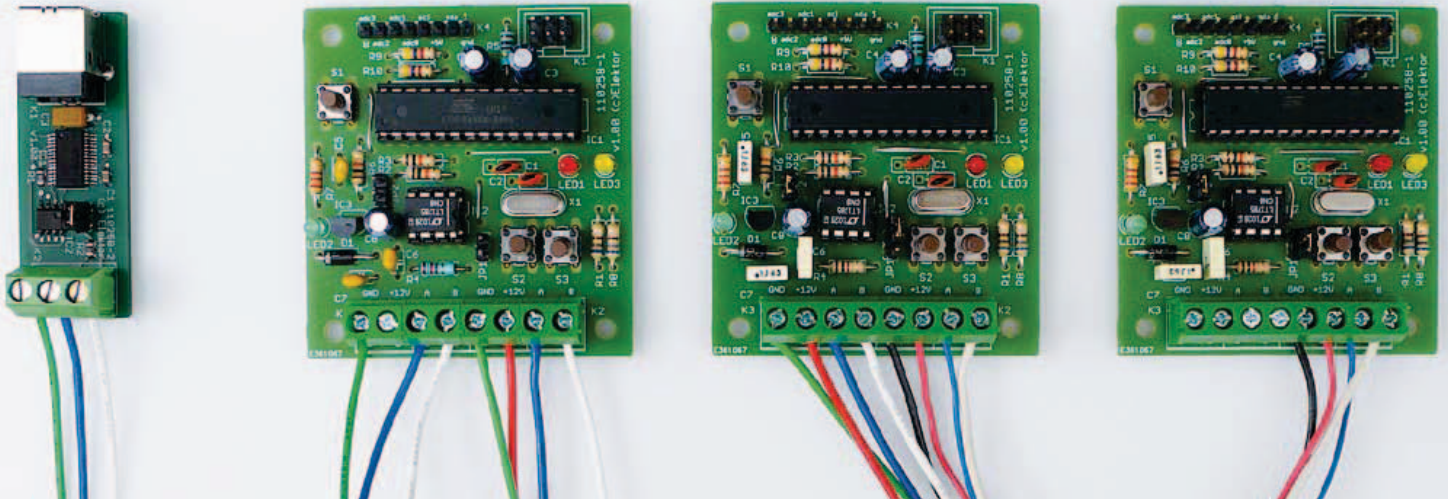
shows the weather information and a link to a sub page which allows users to control the

Internet Links & Literature

- [1] www.twitter.com
- [2] www.elektor.com/110388
<http://portforward.com>
<http://no-ip.com>

Here Comes the Bus! (7)

A simple application protocol



After a brief pause for the summer holidays our bus resumes its normal timetable. In this article we describe a simple protocol that allows up to four set-points and corresponding instantaneous values to be transmitted simultaneously. The result is ideal not just for home automation applications, but more generally for measurement and control. Also, for the first time, we look at programming in C with AVR Studio.

By Jens Nickel (Elektor Germany Editorial)

In previous installments in this series we presented a simple frame protocol which allowed a payload to be sent from a transmitter to an addressable receiver device. Take a look at **Figure 1** to remind yourself of the details. A message in the Elektor Message Protocol essentially consists of sixteen bytes, where byte 0 always has the value AA_{hex} (170 decimal) for synchronization purposes. If both bits 7 and 6 of the following mode byte are zero, bytes 2 to 5 are used for addressing. Since bytes E and F are reserved for the optional checksum, it is possible to use up to eight bytes for the payload.

Previously we also looked at a simple way to regulate the traffic on the bus ('hybrid mode'). Nodes that have a message to send on a regular basis (such as sensors)

are interrogated in turn by a scheduler. Between these times are the so-called 'free bus phases' during which nodes are allowed to speak without specifically being asked. Collisions can occur during this period and so 'non-scheduled messages' (in other words, messages transmitted during the free bus phase) must be acknowledged by their recipient. This is done by sending an 'acknowledge message' back to the sender.

Non-scheduled messages are particularly required when a node needs to communicate something as a result of an external event but could otherwise perfectly well remain silent. In the interests of efficiency it is better not to poll such a node regularly. An example of such a node in the area of home automation might be a light switch. Equally, a sensor that only needs to report when a value has gone outside pre-

set thresholds would fall into this category, an example of such a sensor being a water level detector.

Sub-nodes

Hybrid mode is particularly useful when a node both has to be interrogated regularly **and** needs to send event-triggered messages during the free bus phase. Think for example of a temperature sensor that regularly reports the current temperature reading but which also monitors these readings against a threshold. This possibility was not explicitly covered in the previous installment: in the demonstration software presented there I drew a strict distinction between 'polled nodes' (perhaps better described as 'scheduled nodes') and 'free bus nodes' [1]. An on-the-ball reader immediately suggested to me that it was possible for a node to have both behaviors

Elektor Products & Services

- Experimental nodes (printed circuit board 110258-1; set of three boards 110258-1C3)
- USB-to-RS485 converter (ready built and tested 110258-91)

- Free software download (firmware in BASCOM and C plus PC software)

All products and downloads are available via the web pages accompanying this article: <http://www.elektor.com/110382>

simultaneously. Francis Stevenson also put forward the suggestion that such a sensor node should always first report the fact that a threshold value has been crossed, whether during a regular interrogation or during the free bus phase. This is a good idea, especially for particularly urgent messages. Francis and I also discussed the possibility of being able to have more than one 'device' on the same physical node. A node board would then respond to more than one address, and hardware costs could be reduced. The firmware running in the microcontroller must make sure that messages are correctly routed to the sub-units within the node. The same basic principle was used in the demonstration software in the last installment [1], where the PC simultaneously took on the roles of scheduler (address 0) and master (address 10).

More channels

However, if we only have a couple of simple sensors and/or actuators on a single node, the splitting into devices each with their own address is not necessary. Indeed, it would be inefficient if each sensor had to send a separate message from its own transmitter address to the master to communicate just one value. A better approach in such cases is to use 'channels' (hello DMX!). Since we have eight payload bytes available in a message, we can easily send four temperature values (each consisting of two bytes) at the same time without extra overhead. That fits very neatly with our experimental node hardware, which has four ADC inputs available on header K4.

Which bytes in the payload correspond to which channel (and hence to which sensor) is then simply a function of their position: the value for channel 0 is sent first, followed by that for channel 1, and so on (see Figure 2). Using the same idea we can also control four actuators using a single message, always assuming, of course, that each control value can be expressed in two bytes. In the demonstration software in the previous installment we used two bytes to communicate one of the ten-bit values read from the microcontroller's ADC. We packed the lower seven bits of the result into one payload byte and the upper three bits into

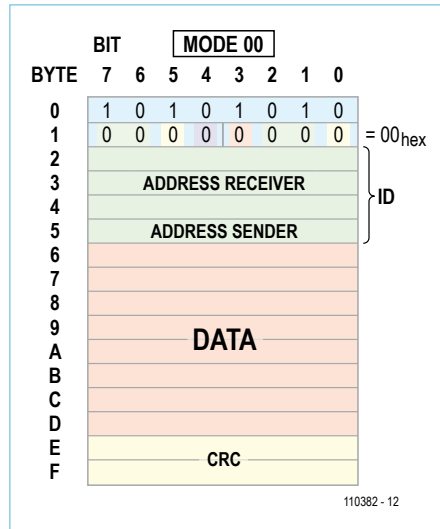


Figure 1. The Elektor Message Protocol defines only where the payload is located within the frame [6].

the next payload byte. This has the advantage that the value AA_{hex} can be prevented from ever occurring as a payload byte, which would otherwise confuse our simple synchronization system. We can use the same trick for each of our channel values: and already we are half-way into defining our application protocol!

The Elektor Application Protocol

So we need an application protocol mutually understood by the nodes on the bus (both sensors and actuators) and which will allow easy expansion to accommodate new hardware. So that we do not have to reinvent the protocol every few months, we have kept the Elektor Application Protocol relatively simple and yet also flexible, fulfilling the following requirements as a minimum.

- Transmission of ten-bit values plus sign, either a reading from a sensor or, in the other direction, a control value to an actuator.
- The option to use twenty-bit values plus sign, for which we need a four-byte-per-channel mode.

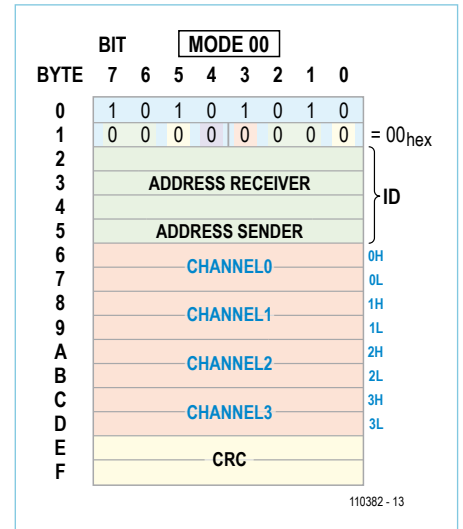
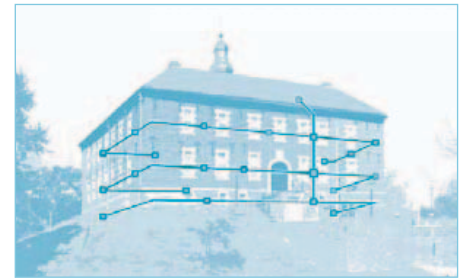


Figure 2. Our application protocol divides the eight payload bytes into four consecutive byte pairs. Values are transmitted in one of four channels (for sensors and actuators attached to a node).

- Setting of units and scaling factors for smart sensor nodes.
- Setting of measurement interval for sensor nodes.
- Setting of multiple thresholds.
- Notification of above- or below-threshold alarms.
- Configuration and calling-up of default presets (for actuators).
- Distinguishing between an acknowledge message, which contains the received values sent back to the transmitter for checking, and the original message. (We have already implemented this feature in the software presented in the previous installment.)

The protocol should also not be limited either to use with hybrid mode or to home automation applications. It should, for example, be perfectly suitable for remote interrogation of a meter or other point-to-point applications (in which collisions can be completely avoided).

Control with ten bits

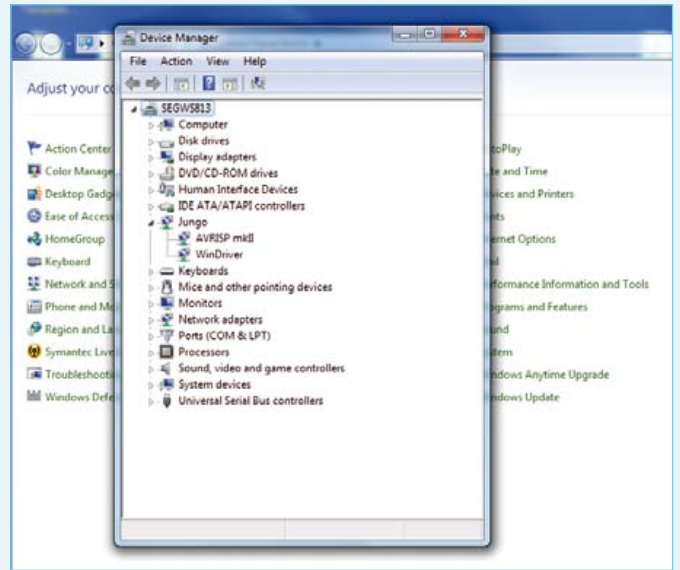
To make this article more than just a bald datasheet we will look at the functions

Using AVR Studio and BASCOM in parallel

With the double summer edition of Elektor put to bed I set to work on fulfilling my promise that we would be presenting some C code for the system. The newest version (5.0) of the AVR Studio development environment includes an integrated C compiler (AVRGCC) behind its powerful and user-friendly interface; it is free to download (after registration) from the Atmel website [3].

The first problem was to get the AVR Studio environment to talk to the AVRISP mkII programmer. Although I had already installed the necessary driver when installing the development environment itself, at first things did not work properly. The problem was that the programmer was bound to the libusb driver which I had installed for use with BASCOM. Uninstalling the libusb driver solved the problem, and I was able to program devices from AVR Studio without further difficulty, simply by plugging the programmer into a USB port. The screenshot shows how things appear in the Windows 7 Device Manager when correctly set up. Of course, I wanted to use BASCOM at the same time, and this can also be made to work: the libusb driver has to be installed as a so-called 'filter driver'. There is a discussion of how to do this at [4].

When setting up a new project in AVR Studio it is necessary to specify the target processor. Fortunately there is not a lot else to configure. A tap of F7 (or 'Build Solution' in the menus) creates a hex file from the source code and any referenced libraries. The programmer is thus insulated from the difficulty of writing a makefile to control the build process.



To flash the target device click on the button with the lightning icon. In the programmer window that opens first click on the 'Apply' button towards the top (with the settings Tool=AVRISP mkII, Device=ATmega88, Interface=ISP). The 'Program' button is located under 'Memories'. The path to the hex file should first be entered into the combo box above.

listed above step by step.

We start with the communication of ten-bit values which, as we mentioned above, are divided between the two bytes forming channel 0. We call the two parts 0H (for 'high') and 0L (for 'low'). As **Figure 3** shows, bits 0H.7 and 0L.7 (the most significant bits of the two payload bytes) are always zero, so that the byte value AA_{hex} cannot occur. This uses up 50 % of the possible values for each byte, but we can always use the remaining possible values for special functions later if we wish.

We reserve bit 0H.3 for the sign of the value: 1 representing negative, 0 positive. The data bits D9 down to D0 are then packed as described above. Three bits are left over, which we use as follows.

Bit 0H.6 determines whether two bytes or four bytes are being used for the channel. The four-byte mode will be used later to send more precise data values and for certain special functions.

Bit 0H.5 says whether the data value is a set-point or an instantaneous reading (1 indicating set-point, 0 an instantaneous reading).

Bit 0H.4, when set, indicates that this is an acknowledge message.

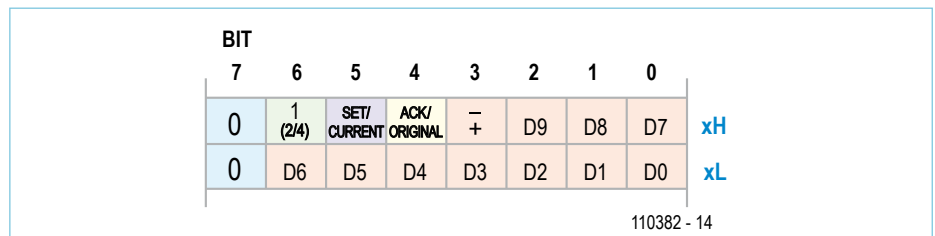


Figure 3. The two bytes forming one channel in more detail. We can transmit values with up to ten bits of precision, plus a sign bit.

As an example, consider a Venetian blind which a home automation master controller wants to set to a 30 % closed position. (For this example ten bits of precision are more than enough!)

The master and the blind controller must have agreed beforehand on how the 30 % closed position is represented numerically: we will look at scaling factors in a later installment. Let us suppose that we encode the percentage directly as an integer, and that we can communicate with the blind controller on channel 0. In bytes 6 and 7 of the Elektor Message Protocol packet the master will then send the following two bytes:

0-1-1-0-0-0-0-0 0-0-0-1-1-1-1-0
(00011110_{bin}=30_{dec})

The blind controller replies with an acknowledge message, having the acknowledge bit set:

0-1-1-1-0-0-0-0 0-0-0-1-1-1-1-0

An intelligent blind controller could of course determine the instantaneous position of the blind and report this value. It would in any case be wise to have it report an instantaneous value of 30 % when the process of moving the blind has completed:

0-1-0-0-0-0-0-0 0-0-0-1-1-1-1-0

First experiments in C

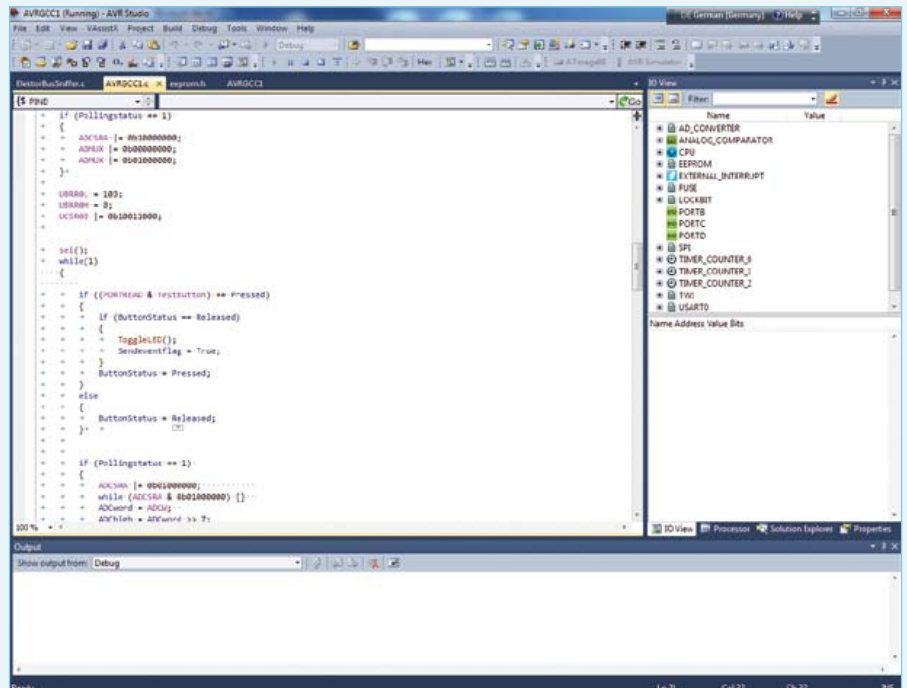
I found the Internet a great ally in my first experiments in embedded C programming. The pons asinorum was to get some LEDs flashing; then I moved to reading values from the ADC and outputting a few bytes onto the bus using the microcontroller's UART, which I read back into the PC and displayed using the Terminal.exe terminal program. It is important to be wary when copy-and-pasting programs from the Internet as you can find code for a range of different AVR microcontrollers which cannot always be used directly on the ATmega88 without checking first against its datasheet [5]. For example, the naming of registers can vary between different microcontroller types: UDR (the register that accepts bytes to be transmitted and holds received bytes) is called UDR0 on the ATmega88.

A particularly nasty trap is the naming of the interrupt vector which is used to specify the routine to be called when a character is received by the UART. Many Internet code examples give the incantation 'ISR(USART_RXC_vect) { ... }', the use of which has the unfortunate effect of hanging the microcontroller. After a good hour of head-scratching I discovered that the correct form for the ATmega88 is 'ISR(USART_RX_vect) { ... }'.

Anyone coming from the world of BASCOM or BASIC more generally should be particularly aware of the following types of error which the compiler will not always complain about. One schoolboy error is to confuse a doubled equals sign (used to indicate an equality comparison) with a single equals sign (used to indicate an assignment). The C language is also absolutely strict when it comes to case sensitivity, both in variable names and in keywords such as 'if'. A pair of brackets is essential after a function name to indicate a call to that function (e.g., 'ToggleLED()'), and a misplaced semi-colon can lead to all sorts of surprising error messages. It is a good idea to check over the program syntax carefully before setting the compiler loose on your code.

The next exercise was to translate the BASCOM demonstration software into C. The result can be found on the project web pages [2]. To make comparison as easy as possible, I have tried to adhere to the structure of the original code as far as possible. There are of course many opportunities for optimization, and old hands at C are encouraged to send in improved versions!

It is apparent from a side-by-side comparison that programming in C requires getting closer to the hardware. BASCOM hides a lot of the nitty-gritty behind commands like 'Start ADC', 'Enable Urcx' and 'Printbin'. However, having to learn what the microcontroller's registers do is not necessarily a disadvantage, and the extra programming effort can be more than outweighed by the advantage of having a set of reusable, made-to-measure routines. As we de-



velop the firmware further these subroutines will be packaged into a small library.

A further important point for beginners in C is that ports and other registers (for example for the ADC and UART) must always be addressed as complete bytes. If only one bit is to be set, care must be taken to preserve the others. This can be done using a logical OR operation:

```
PORT = PORT | Bitmask;
```

or more concisely

```
PORT |= Bitmask;
```

To clear a bit, use a logical AND operation with an inverted bit mask:

```
PORT &= ~Bitmask;
```

I have used directives such as

```
#define TestLED 0b00010000
```

to create bit masks and port names corresponding to the LEDs, buttons and port pins. This allows a statement of the form

```
PORT |= TestLED;
```

to be used to light the test LED. Much code found on the Internet uses a slightly different approach, writing

```
#define TestLEDbitposition 4
```

```
...
```

```
PORT |= (1 << TestLEDbitposition);
```

where the expression `1 << TestLEDbitposition` generates the required bit mask by shifting the value 1 left by the appropriate number of places.



Finally the master confirms that this value has been received:

0-1-0-1-0-0-0-0 0-0-0-1-1-1-1-0

Perhaps this communication scheme might only be implemented in a trimmed-down form, but the example nevertheless gives a good demonstration of the use of the set-point and acknowledge bits.

Demonstration software

Again, along with this article we bring you example software for the PC and for the ATmega88 microcontroller used in the experimental node. It is a modified version of the demonstration software from the previous article, allowing all three nodes to report the status of their test LED to the PC software, and one of the nodes to report the voltage read on its ADC0 input. The software, as usual, is available for download from the *Elektor* website as a zip file [2]; for comparison, the previous version is available at [1].

Channel 0 is used to transmit the ADC reading (only from node 2); the LED status information is transmitted on channel 1. One byte in the EEPROM (at address 006) determines whether the node sends ADC values or not; the corresponding variable in the

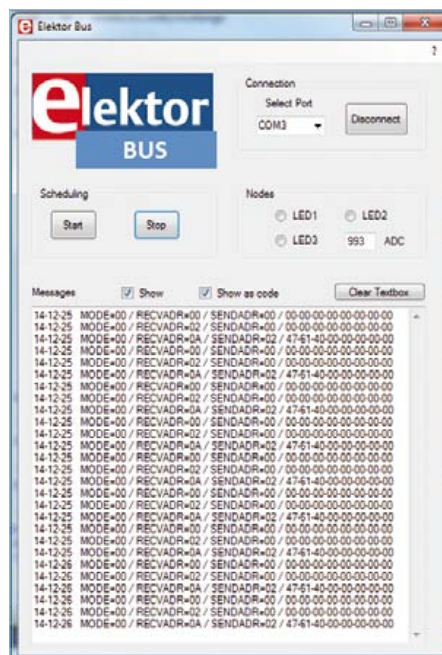


Figure 4. Screenshot of the PC-based software showing the status of the test LEDs on three nodes and the ADC0 value from node 2.

code is called 'Devicemode'. This byte must be set to the value 01 in node 2: this can be done manually using BASCOM. The variable 'Pollingstatus' has been renamed as 'Scheduled' in the code, which better conveys the

idea of whether the node is a 'scheduled node' or a 'free bus node': these are mutually exclusive in this version of the software. For the first time we also include firmware written in C using the new AVR Studio 5.0: the text boxes give the low-down. BASCOM users will also find it worthwhile to see how things are done in C code. More next month!

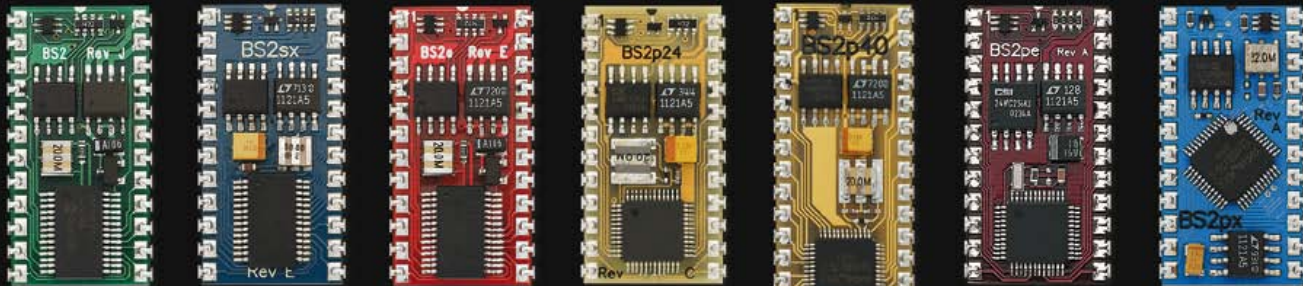
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What do you think? Feel free to write to us with your opinions and ideas.

Internet Links

- [1] www.elektor.com/110258
- [2] www.elektor.com/110382
- [3] www.atmel.com/dyn/products/tools_card.asp?tool_id=17212
- [4] <http://avrhelp.mcselec.com/index.html>
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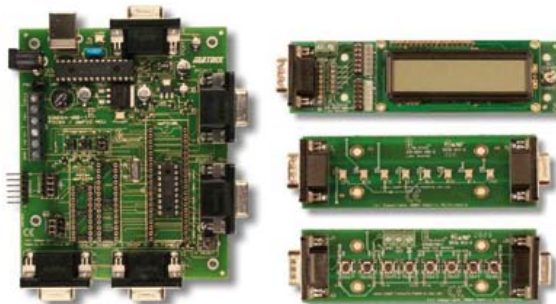
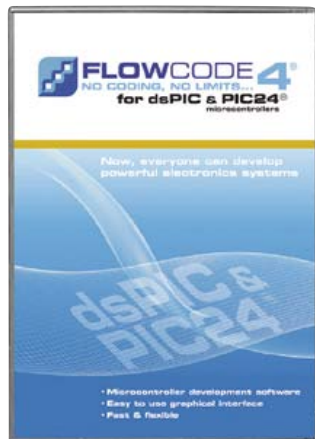
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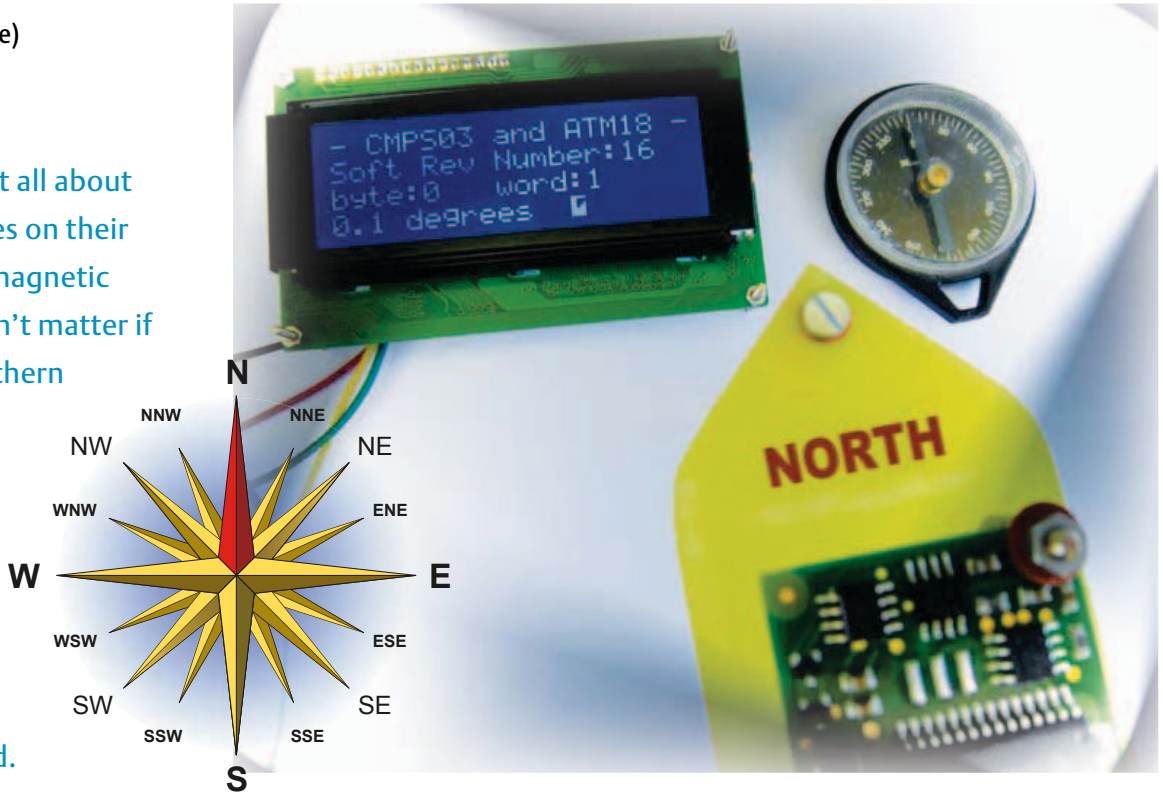
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ATM18 Compass

“You’ll never walk alone”

By Grégory Ester (France)

Now you can forget all about magnetized needles on their pivots for finding magnetic North. And it doesn’t matter if you live in the Southern or Northern hemisphere – all that counts here is that you have both feet firmly on the ground and this little device in your hand.



The CMPS03 OEM module [2] makes it possible to calculate the angle between the direction of the Earth’s magnetic north pole and the direction in which the sensor is pointing (Figure 1).

To do this, it uses two sensors that are sensitive to the magnetic field of good old Earth. The data is recovered from these sensors and the angle calculated by way of a microcontroller incorporated into the board. A bus connection is also employed, and hence it is possible to recover the value of this angle directly by communication over an I²C bus, either in the form of one byte (0 to 255), or in 16 bits (0 to 3,599); in the latter case, a simple division by ten lets you directly read the value of the angle measured (Figure 2).

ATM18 [3] will be given the task of communicating with the CMPS03 module. The two-wire LCD [4] will be used to display the information obtained.

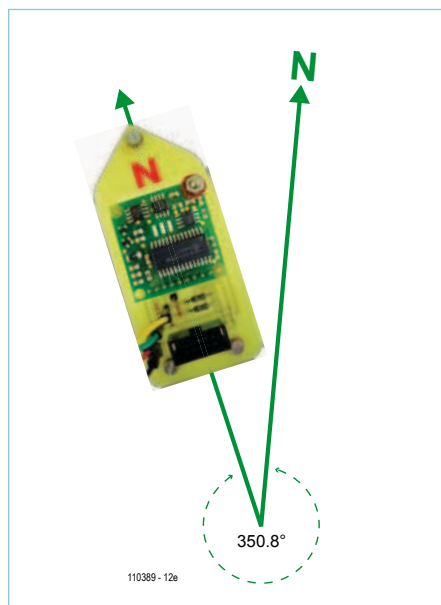


Figure 1. One application that isn’t about to lose its way.

CMPS03 compass module

Don’t worry, you won’t have to wind meters of wire around a bit of ferrite (Mumetal or Permalloy) that is permeable to the Earth’s magnetic field. And no point thinking about a fluxgate system either – that’s not the technique this board uses.

The board is based on the use of two Philips KMZ51 magneto-resistive sensors. Their sensitivity is such that the Earth’s magnetic field is detected by these two chips, mounted perpendicular to one another. Two sensors are needed, as we need to detect both the North-South and East-West variations. They use Permalloy, a material that’s extremely sensitive to magnetic fields, which means the resistance of the sensor changes according to its position with respect to the lines of magnetic flux emitted by the Earth. A Wheatstone bridge on each sensor (Figure 3) makes it possible to accurately determine the value of the vari-

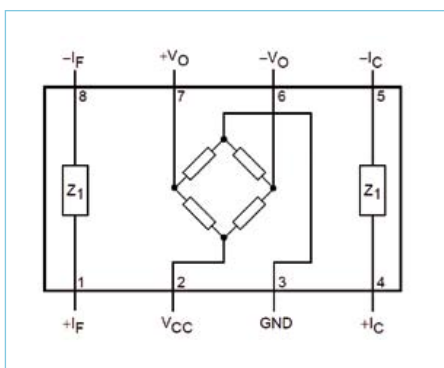


Figure 3. It's all in the KMZ51 chip.

able resistance. The variation in resistance causes a voltage variation which is amplified (LMC6032) and measured (AN0 and AN1 of the PIC) by the CMPS03 sensor electronics. In this way, the magnetic heading is calculated and a microcontroller (PIC18F2321) outputs the result on an I²C compatible bus; all that remains for you to do is to make use of this.

For correct measurement, the module will need to be positioned horizontally with respect to the ground.

Pin 7 on the module makes it possible to correct fluctuations in the signal (jitter) caused by the AC power grid in your home. If this pin is pulled down to ground, the correction is selected for 50 Hz AC; if it is pulled up to 5 V (or left floating), the conversion will be synchronized to a 60 Hz AC supply. The module is supplied factory-calibrated by the manufacturer in the UK (inclination 67°). If you are at a substantially different place on the globe it may be necessary to re-calibrate. This procedure only has to be done once, as the parameters are stored in an EEPROM.

The technical documentation for the module available from the manufacturer's website [5] explains more about this aspect.

Finish first when orienteering!

Start by wiring the circuit by referring to Figure 4, then load the firmware [1], power up, hold the compass horizontal and look for North. How? By turning round holding the circuit. If you are facing exactly North, you'll hear a beep and `Cmps03_bearing_byte` and `Cmps03_bearing_word` will take the value 0. These are the two functions, seen in Listing 1, that let you recover the 8- and 16-bit words; they have been written in accordance with the timing diagram provided by the manufacturer (Figure 5).



Figure 2. Organized display of the measurement results.

For example, if you want to recover the two image bytes of the angle calculated by the CMPS03 module, the function `cmps03_bearing_word` starts by sending a start bit, followed by the module's write address (\$C0) and the value of the register (Table 1)

whose contents has to be read (here, it's 2); then you send a new start bit, followed this time by the module read address (\$C1). Then the MSbyte is read and its reception acknowledged (ACK), and then to conclude, the command `I2crbyte Lo_byte, Nack` lets

Listing 1. The registers reveal their contents.

```
Function Cmps03_soft_revision() As Byte
    I2cstart
    I2cwbyte Cmps03_addr_write
    I2cwbyte 0
    I2crepstart
    I2cwbyte Cmps03_addr_read
    I2crbyte Cmps03_soft_revision , Nack
    I2cstop
End Function

Function Cmps03_bearing_byte() As Byte
    I2cstart
    I2cwbyte Cmps03_addr_write
    I2cwbyte 1
    I2crepstart
    I2cwbyte Cmps03_addr_read
    I2crbyte Cmps03_bearing_byte , Nack
    I2cstop
End Function

Function Cmps03_bearing_word() As Word
    Local Hi_byte As Byte
    Local Lo_byte As Byte
    I2cstart
    I2cwbyte Cmps03_addr_write
    I2cwbyte 2
    I2crepstart
    I2cwbyte Cmps03_addr_read
    I2crbyte Hi_byte , Ack
    I2crbyte Lo_byte , Nack
    I2cstop
    Cmps03_bearing_word = 256 * Hi_byte
    Cmps03_bearing_word = Cmps03_bearing_word + Lo_byte
End Function
```

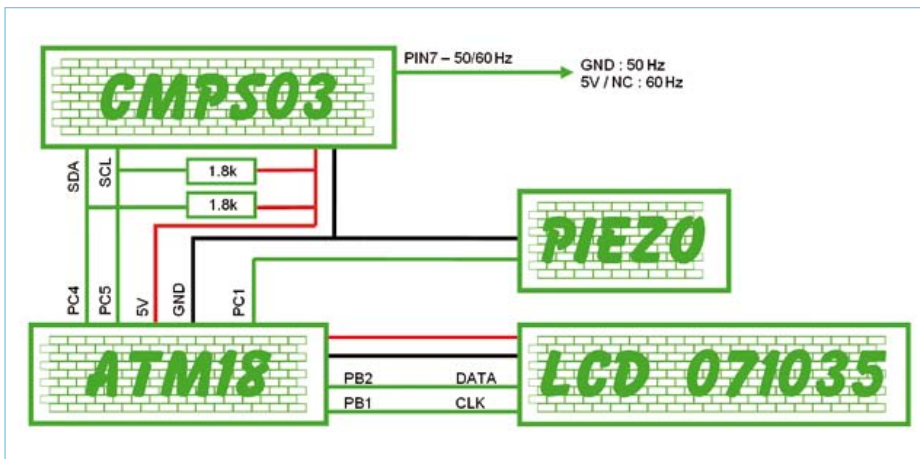


Figure 4. Wiring block diagram.

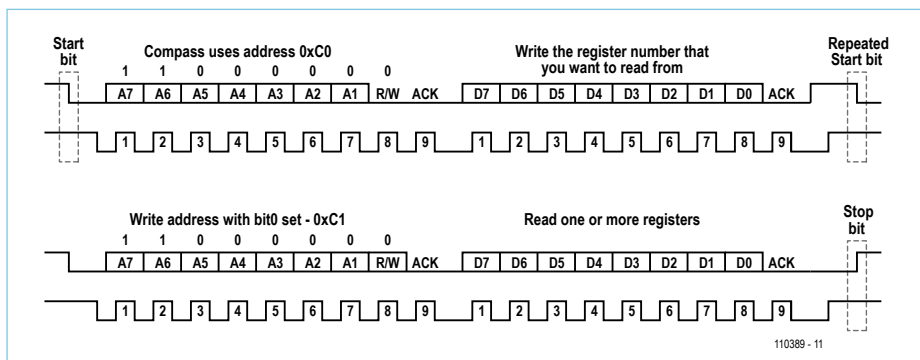


Figure 5. Digital communication with the Robot Electronics CMPS03 module.

you read the value of the LSbyte and store it in the variable `Lo_Byte`. As this is the last piece of data read, it is not acknowledged.

Graphical representation of the compass points

To help navigation, the 360° are divided into eight parts and the cardinal points are displayed graphically. Figures 6 and 7 show that we are facing North-north-east and South-south-west respectively.

The liquid crystal display is fitted with an HD44780 controller, which looks after character generation and driving the LCD. From the user's point of view, this results in lighter code, as all you have to do is send the controller the instructions, the characters,

and the indications to know where to display them.

The special characters in Figures 6 and 7 are not in the LCD controller's CGROM memory. So they need to be created and saved in CGRAM (Character Generator RAM). In this memory, the user-defined character set starts at address \$40 (increments automatically) and contains eight bytes per character. Thus eight custom characters can be stored; these are called for display by sending the ASCII code from 0 to 7 to the LCD.

A 5 × 7 alphanumeric character is formed by seven lines of five dots. There is also an eighth line, which is normally used for positioning the cursor; this will not be modified. BASCOM-AVR provides a tool called LCD Designer (Figures 6 & 7) which

CMPS03 Reader Offer
 By special arrangement with Robot Electronics UK, Elektor readers pay only £14.99 for a CMPS03 module (rrp £22.12). When ordering at www.robot-electronics.co.uk, enter coupon code "Elektor". One discount per order. Offer expires October 31, 2011; not available through distributors.

offers help creating custom characters. As this project uses the two-wire LCD, the command line generated automatically by this tool, `Deflcdchar [0],31,24,25,27,31,31,31,32`, will be entered as a comment, but it does at least enable us to find out the value of the eight bytes corresponding to the character constructed.

For example, in order to create the character seen in Figure 6, we need to send eight bytes each representing one row of dots. The three MSBs are ignored. A pixel is visible if the corresponding bit is set to 1. Listing 2 is an extract from the procedure that lets us store the set of freely-defined characters in CGRAM memory.

Listing 3 reveals part of the contextual procedure designed to position the cursor at the place (X_lcd, Y_lcd) where we want to display the special character. The procedure is called like this: `Call Pointing("NNE", 14, 4)`.

So this natural physical phenomenon, the Earth's magnetic field to which we are all of us constantly subjected, has enabled us to produce this project. Nature can make itself very useful!

This very handy sensor can be incorporated into a mobile robot. However, it will be necessary to keep the module well away from any electromagnetic source likely to interfere with the proper operation of the unit.

(110389)

Table 1. CMPS03 registers used in the firmware.	
Register	Function
0	Version of firmware in the CMPS03's PIC18F2321
1	Angle in one byte: 0 to 255 for a full circle
2, 3	Angle in one word (two bytes): 0 to 3599 for a full circle. Corresponds to direct reading of the angle from 0 to 359.9 degrees.



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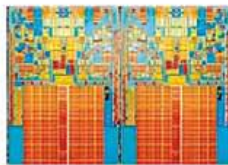
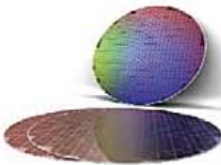
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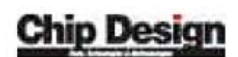
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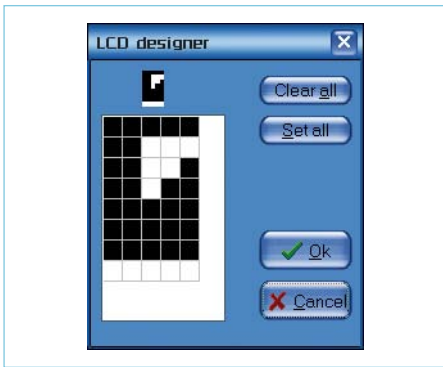


Figure 6. The LCD Designer tool from BASCOM-AVR...

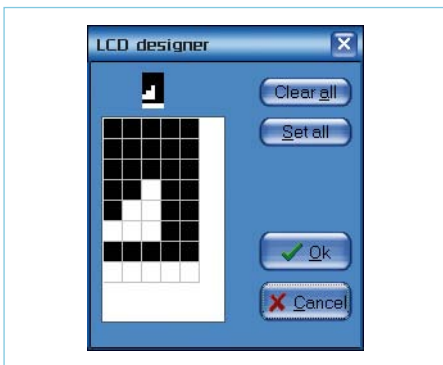


Figure 7. ...for "fine-tuning" your characters.

Internet Links

- [1] www.elektor.com/110389
- [2] www.robot-electronics.co.uk/
- [3] www.elektor.com/atm18
- [4] www.elektor.com/071035
- [5] www.robot-electronics.co.uk/html/cmp-s3tech.htm

Listing 2. Storing custom characters.

```

`ADRESSES CG-RAM A PROGRAMMER
`CHAR1 : $40 à $47
`CHAR2 : $48 à $4F
`CHAR3 : $50 à $57
`...
Sub Lcd_custom_char()
  Rs = 0
  Waitms 20
  Lcd_write_byte &H40      `adresse de base CGRAM
  Rs = 1                   `envoi des données
  Waitms 20
  `-----CHAR1_NNE
  `Deflcdchar [0],31,24,25,27,31,31,31,32
  Lcd_write_byte 31        `$40
  Lcd_write_byte 24        `$41
  Lcd_write_byte 25        `.....
  Lcd_write_byte 27
  Lcd_write_byte 31
  Lcd_write_byte 31
  Lcd_write_byte 31
  Lcd_write_byte 32
  `-----CHAR2_ENE
  Lcd_write_byte 31        `$48
  Lcd_write_byte 30        `$49
  Lcd_write_byte 28        `.....
  Lcd_write_byte 24
  Lcd_write_byte 31
  Lcd_write_byte 31
  Lcd_write_byte 31
  Lcd_write_byte 31
  Lcd_write_byte 32
  `-----CHAR3_ESE
  Lcd_write_byte 31        `$50
  ..
  ..
  ..
End Sub

```

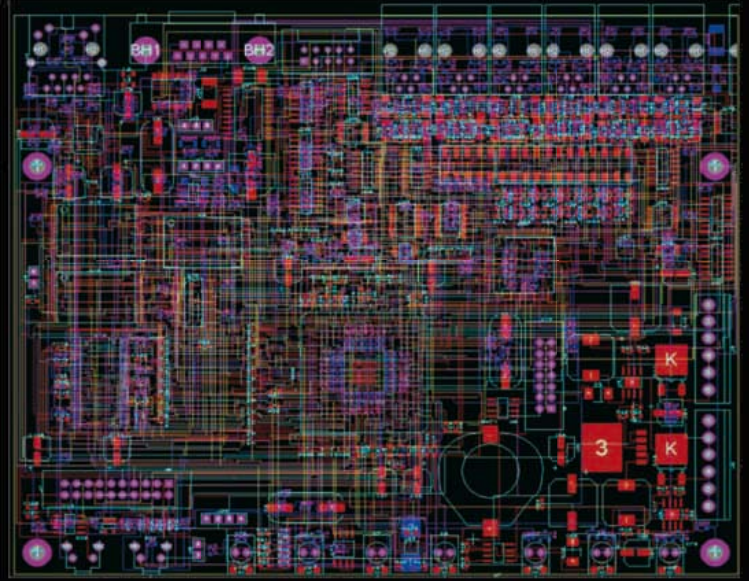
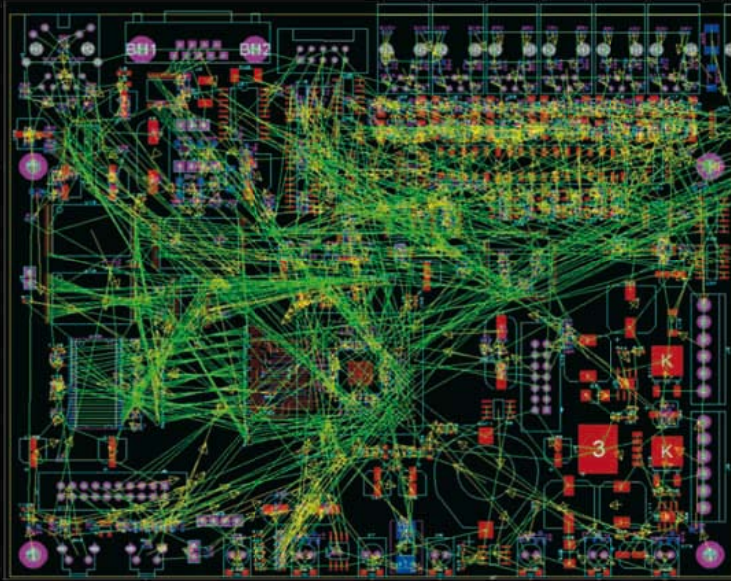
Listing 3. Outputting the custom characters.

```

Sub Pointing(byval Direction As String , Byval X_lcd As Byte , Byval Y_lcd As Byte)
  Lcd_pos X_lcd , Y_lcd
  Select Case Direction
    Case < NNE >
      Rs = 1      ` envoi de données
      Waitms 20
      Lcd_write_byte &H00
    Case < ENE >
      Rs = 1      ` envoi de données
      Waitms 20
      Lcd_write_byte &H01
  ..
  ..
End Select
End Sub

```

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Ultrasonic Directive Speaker

50+ piezo transducers generate audible sound beam

By Kazunori Miura (Japan)

The acronym LRAD sadly and worryingly made it to newspaper stories in connection with Somali pirate attacks on vessels in the Gulf of Aden, and that is how the general public first got word of sound being used as a defence weapon. This article explores the design of a DIY 150-foot range directive sound beam using an array of piezo ultrasonic transducers (up to 200!) driven with a PWM signal, all strictly experimental.



Spurred by the success of their Long Range Acoustic Device® (LRAD) systems, American Technology Corporation changed its name to LRAD Corporation on March 25, 2010 [1]. For non military applications, Audio Spotlight® is a product of Holosonic Research Labs, Inc. [2]. Audio Spotlight produces a very sharp sound beam and has found applications in museums, exhibits and galleries. Those who hear sound from a parametric speaker for the first time are typically surprised and sometimes frightened by the effect. Sounds appear to be heard from extremely nearby, although the person standing right beside you does not hear anything.

Parametric speaker arrays typically employ ultrasonic waves, the same as used in car parking ‘radars’, distance meters, metal analyzers, etc. However it was not until recently that approaching a real parametric speaker is possible using commonly available components.

Principle of the parametric speaker

A parametric speaker achieves high directivity thanks to the almost line-of-sight propagation of sound waves in the supersonic range. Supersonic is often loosely defined as ‘above 20 kHz’ because it exceeds the upper frequency limit of human hearing. In

practice, 14 kHz is commonly found to be the real limit at least for adults.

So how can humans perceive a supersonic sound wave? Several methods have been devised to convert a supersonic wave into a sound wave you can hear. One method is to passively obtain an audible frequency from two supersonic wave sources with a slightly different frequency. For example, an undulating 1 kHz tone is obtained from two supersonic waves of 40 kHz and 41 kHz. As illustrated in **Figure 1**, where two supersonic waves intersect, a sound within the audible domain is perceived. The disadvantage of this method is that only weak audible sounds are produced, by no means

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enough to stun or incapacitate people like the LRAD.

Other ways of producing an audible sound from supersonic waves include amplitude modulation (AM), double sideband modulation (DSB), single sideband modulation (SSB), frequency modulation (FM) all employ the recently developed parametric speaker system.

Inevitably, a 110 dB+ supersonic wave will be irregular in terms of sound pressure distribution as it propagates through a long air mass, and an audible sound seems to appear by itself owing to these non-linear characteristics. As a result, the audible sound perceived is marked by a fair amount

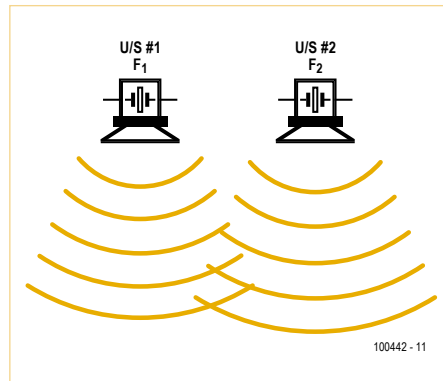


Figure 1. Where ultrasonic waves from sources with frequencies F1 and F2 intersect, audible sounds amounting to $F3 = |F1 - F2|$ may be heard.

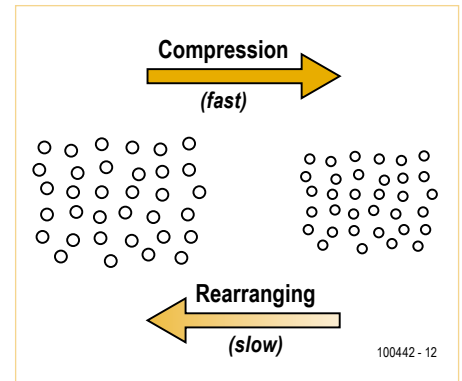


Figure 2. Shock waves come about by air molecules on their way back to their original position colliding with other molecules being compressed at the same time by a sound wave.

of distortion, which is undesirable for 'narrowcasting' applications like in a museum. Manufacturers typically resort to signal

processing using DSPs to reduce distortion to a minimum, often in combination with a highly sophisticated parametric speaker

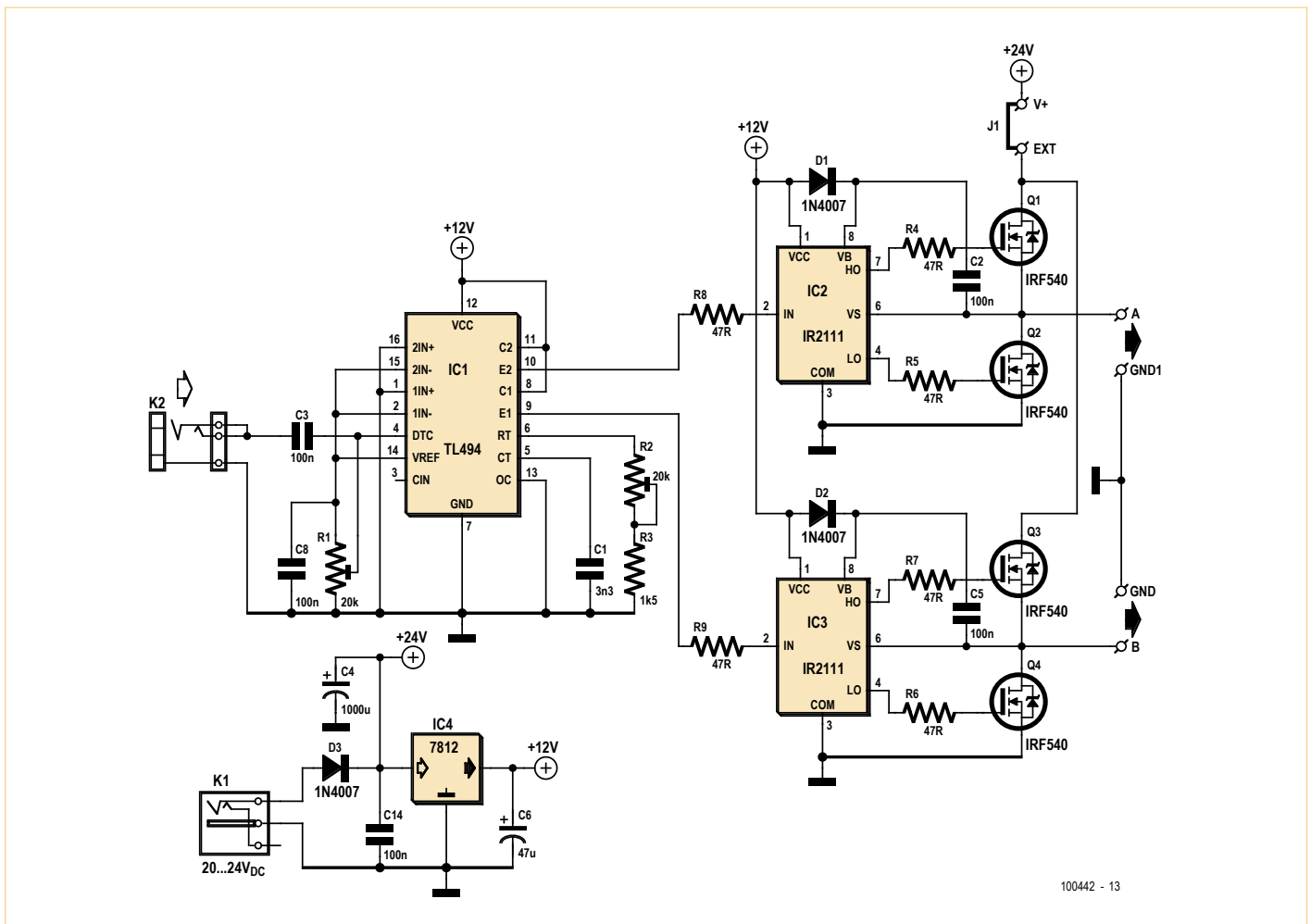


Figure 3. Circuit diagram of the PWM power driver for the ultrasonic parametric speaker unit. The audio input signal is connected to jack socket K2. Channel B is optional.

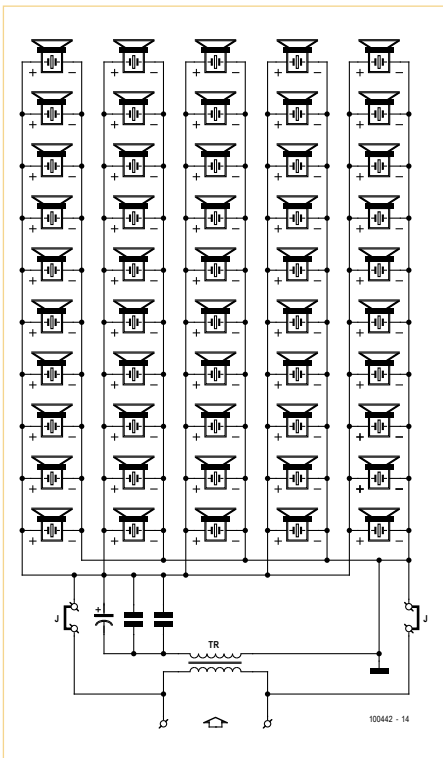


Figure 4. The 'mini' version of the directive loudspeaker consists of 50 ultrasonic piezo transducers connected in parallel and in phase. The step-up transformer and associated resonance caps are optional. The associated PWM driver in its basic form is suitable for up to 200 transducers.

setup.

The 'non linear characteristic' is due to the fact that it takes more time for air molecules to be restored to their original density than to be compressed (Figure 2). When the sound pressure is high, and frequency too, a shock wave may be produced by returning air molecules colliding with the ones being compressed. In fact, an audible sound is produced by any molecule not completely 'returning'. When the frequency of the vibration rises, the 'non-linear characteristic' tends to become noticeable by an effect best described as 'air viscosity'.

There is another reason for the high directivity (i.e. small beamwidth) exhibited by a parametric speaker array. The supersonic wave is actually generated by a large number of small loudspeakers called transducers. The piezo-electric transducer is widely used both as a sensor and a transmitting device in car and home automatic systems. The directivity of the piezo transducer by itself is not too high. However, strength is



Figure 5. A radio ferrite rod makes a good core for winding a 60-160 μH adjustable inductor that enables the largely capacitive transducers to be peaked at their resonant frequency (usually, 40 kHz).

in numbers, meaning the high directivity is due to many small transducers arranged in a plane-like shape. This is essential for making a truly directional speaker unit.

A parametric 2-channel speaker modulator

Double sideband modulation (DSB) is easily implemented using analog switches. Frequency Modulation (FM) has the same effects basically if you look at the way supersonic sound waves compress air and interact.

The author first attempted a DSB modulator. The result: big sound, lots of distortion and the method might be suitable for a sound beam weapon. Next, a PWM system was built. Looking at the net result, PWM is very similar to FM. The audible sound obtained from PWM is weaker than from DSB, but of a better quality. A PWM modulator may be compared to a class-D amplifier without its low pass filter!

The schematic of a 2-channel PWM modu-

lator is given in Figure 3. There are no special components. The TL494 PWM control circuit and the IR2111 half bridge MOSFET driver are used in their standard application circuits. The TL494 has an internal oscillator whose frequency is determined by trimpot R2 and capacitor C1. The basic pulsewidth is adjusted with R1. You need to set up optimum modulation with trimpots R1 and R2.

The audio input signal is connected to K2 (loudspeaker level required, not microphone or line). The board has two outputs, A and B, each driving an array of piezo transducers, optionally through an inductor (see below). Each channel is suitable for up to 200 transducers. The normal supply voltage is 20-24 VDC to K1. The FET stages may be powered by an external supply via the EXT terminal after removing wire link J1. Heatsinks may be required on the IRF540 FETs depending on the supply voltage and the transducers' ratings (up to 60 VDC may be possible).

The U/S speaker schematic is large but unsurprising, see Figure 4. It represents one channel and a 'mini' version with just 50 transducers.

Speaker unit and optional coil

There are several type of ultrasonic transducer around. The author used 16 mm diameter devices specified for 40 kHz and 28 kHz. A minimum of 50 transducers is required to make an effective speaker unit. You need more than 100 transducers if you want to the unit to have any sort of range outdoors. All transducers should be carefully distributed to maintain phase. Remember, the wavelength is about 8 mm so a positioning error of 1 mm causes phase errors and loss of SPL.

Ultrasonic transducers are made from piezoelectric ceramic materials. When a voltage is applied to the device, a special type of foil is deformed inside, generating a supersonic sound wave of a specific frequency. Typically, the transducer's sound output reaches 105-120 dB (at 1 foot distance) when a voltage of 10-20 V_{rms} is applied,



Caution — Health Hazard.
Appropriate measures must be taken to prevent long term exposure to high ultrasonic sound levels.

[1] www.lradx.com
 [2] www.holosonics.com

corresponding to 28–56 V_{pp} and that raises the question if a similarly high supply voltage is needed.

Electrically, an ultrasonic transducer has the properties of a capacitor, which can be made part of a series resonant circuit by putting an inductor in series. Tuning the inductor to about 40 kHz enables the transducer to be driven from a low supply voltage. A step-up transformer as shown in the speaker schematic is another way to get the transducers to operate at resonance. The resonance frequency f_r may be calculated from

$$f_r = 1 / (2\pi \times LC)$$

Each ultrasonic transducer equals about 2,000–3000 pF worth of capacitance. Connecting 50 of them you get roughly 0.1–0.15 μ F. To obtain resonance an inductance of about 60–160 μ H is called for, to connected between the driver's A and B outputs and the respective transducer arrays. Fine tuning is required to peak for resonance and the author produced an adjustable inductor from enamelled copper wire and a ferrite rod (Figure 5). For a 200-trans-

ducer version of the U/S speaker about 55 turns of wire gave best results (60–80 μ H).

The ultrasonic transducers need to be checked individually to determine their polarity (phase). This may be done using an oscillator and a 2-channel oscilloscope as illustrated in Figure 6. One U/S device is connected to an oscillator (or generator) supplying a 40 kHz source signal that's also fed to one channel of the oscilloscope. The 'receiver' device gets connected to scope channel 2. Now you can view the signal and the timing at a glance (Figure 7).

Fun with the parametric speaker

It should be reiterated here that the project is experimental and intended to promote your own experiments. Connect the audio sound source through 3.5 mm jack socket K2, and connect the power supply to K1. You can probably hear a weak sound from the transducer array. Carefully adjust R1 and R2 for optimum sound quality. Check if the sound beam is anything like directive — it should be, even when using one channel (A or B). The author has tentatively indicated a range of about 50 meters (150 ft.) for a 200-transducer (!) system.

(100442)

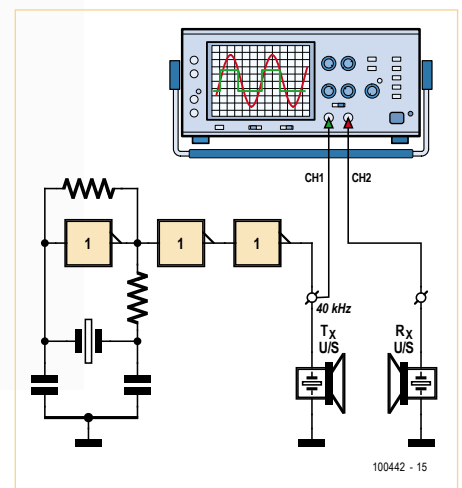


Figure 6. Test arrangement to establish the polarity of each and every piezo transducer used for the parametric array.

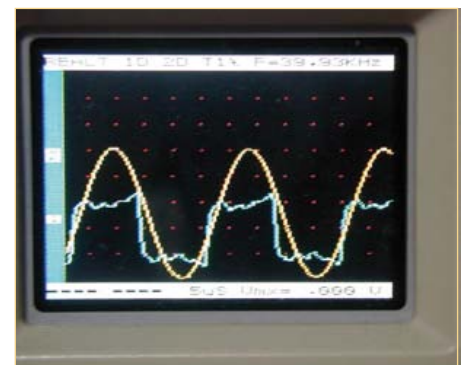


Figure 7. Scope image obtained with correct polarization of the receiving U/S transducer.

Compact Warning Flasher

Better safe than sorry

By Peter Lehmann (USA)

This little project should give peace of mind to bicycle riders pedaling in the dark without street lighting. At the same time it provides early warning to faster, motorized road users to pay attention and pass with care.



The project is primarily intended as a red warning flasher to be mounted on the rear of a bicycle, although it is sure to have many other uses. All parts used should be easy to find and the circuit is highly open to your experiments in terms of LED flash rate, LED types used, and so on.

How it works

In the circuit diagram shown in **Figure 1**, four identical ICs are seen: the “flying capacitor”-type DC voltage converter ICL7660 from Maxim. The ICL7660 (or its ‘Maxim’-ised equivalent the MAX1044) can be configured to invert, double, divide or multiply a positive input voltage — see its datasheet at [1].

In the circuit discussed here, converter IC1 is conventionally configured as a negative voltage generator. The next one, IC2, functions as an SPDT (single-pole double throw)

switch providing or removing supply voltage alternately to converters IC3 and IC4 at about 0.5-second intervals. When converter IC3 is connected to power, flying capacitor C3 is alternately charged and then discharged through series connected LEDs D1 and D3 at about 1/20th of a second intervals. Converter IC4 is connected to power as converter IC3 is disconnected, and then operates in the identical active fashion as IC3 and associated components, i.e. D2 and D4 flashing with electrolytic capacitor C4 acting as the reservoir device in the charge pump.

Two series connected AAA alkaline batteries power the circuit with a nominal voltage of 3 V. When the battery voltage has diminished to less than 2.4 V, the intensity of the LEDs decreases markedly. Fortunately, with respect to a battery voltage of 3.0 V (or fully charged), the average current drain by the

circuit equals 19 mA. So the rate of discharge equals about $C/60$ and the battery voltage drops to less than 2.4 V only well towards the end of the discharging cycle. Ah, yes, C is the nominal capacity of the battery expressed in mA/hour.

Circuit board, box and bicycle

A simple circuit board was designed by the author to accommodate the parts. The component layout and associated copper track are shown in **Figure 2**, as well as provided as files you can download from the project web page [2]. All parts are through hole and mounting and soldering should be a walk in the park provided you work carefully. Due attention should be given to the polarization of the electrolytic capacitors in the circuit.

The proposed enclosure for the project is the Velleman G203 sealed polycarbonate

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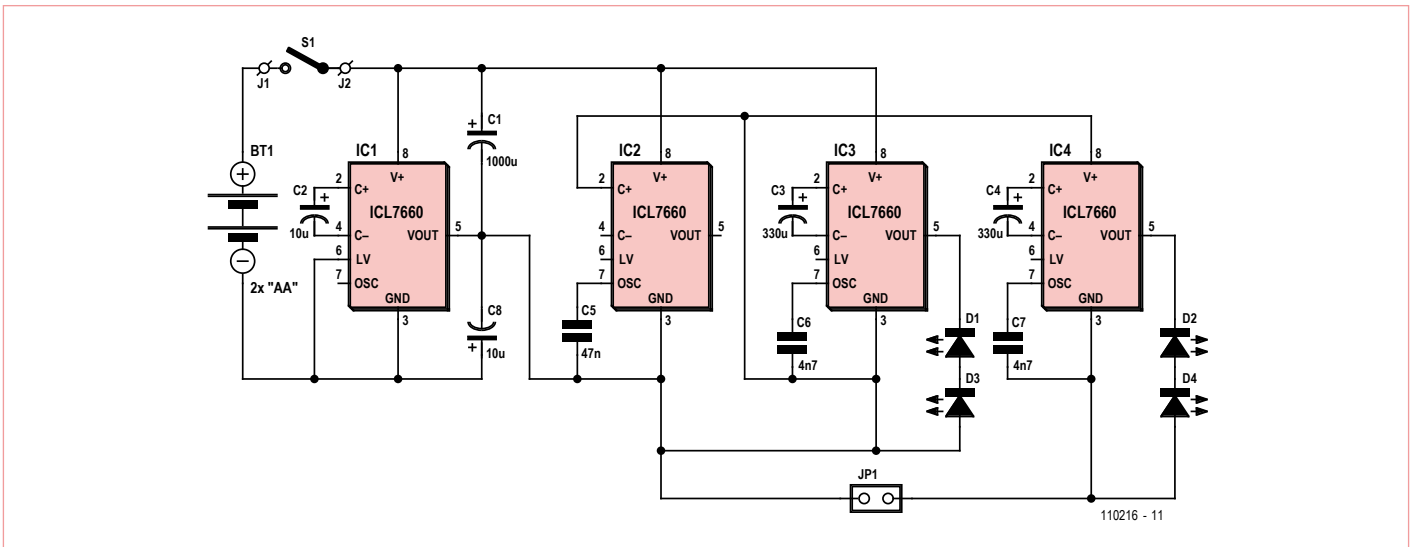


Figure 1. The schematic diagram of the flasher is heavily dominated by four ICL7660 20 mA charge pump ICs.

box with a clear cover. The box measures 115 × 65 × 40 mm (4.5 × 2.5 × 1.6 inch). The component layout includes rectangles at the four corners of the PCB indicating areas to be removed allowing it to fit in the G203 box. The four dots on the PCB indicate the position of mounting holes.

Red LEDs D1-D4 are 10 mm size for two reasons. Firstly, the 10 mm size has greater visibility than 5 mm, 5 mm being almost universally the size of the LEDs of commercially available warning flashers for bikes. Secondly, 5 mm LEDs would look lost in the Velleman G203 box.

A waterproof pushbutton switch was fitted on the sidewall of the bottom half of the box next to IC2 and capacitor C1. The photograph shows one possible method of attaching the flasher to a bicycle. This involves securing a galvanized steel corner brace to the mounting flange of a single bolt seat-post through a hole at one end of the brace. The other leg of the brace is attached to the G203 box by means of a bolt through one of the two pre-existing mounting holes of the G203 box.

(110216)

Caution. This circuit may not be road legal depending on traffic laws and safety regulations in your state or country.

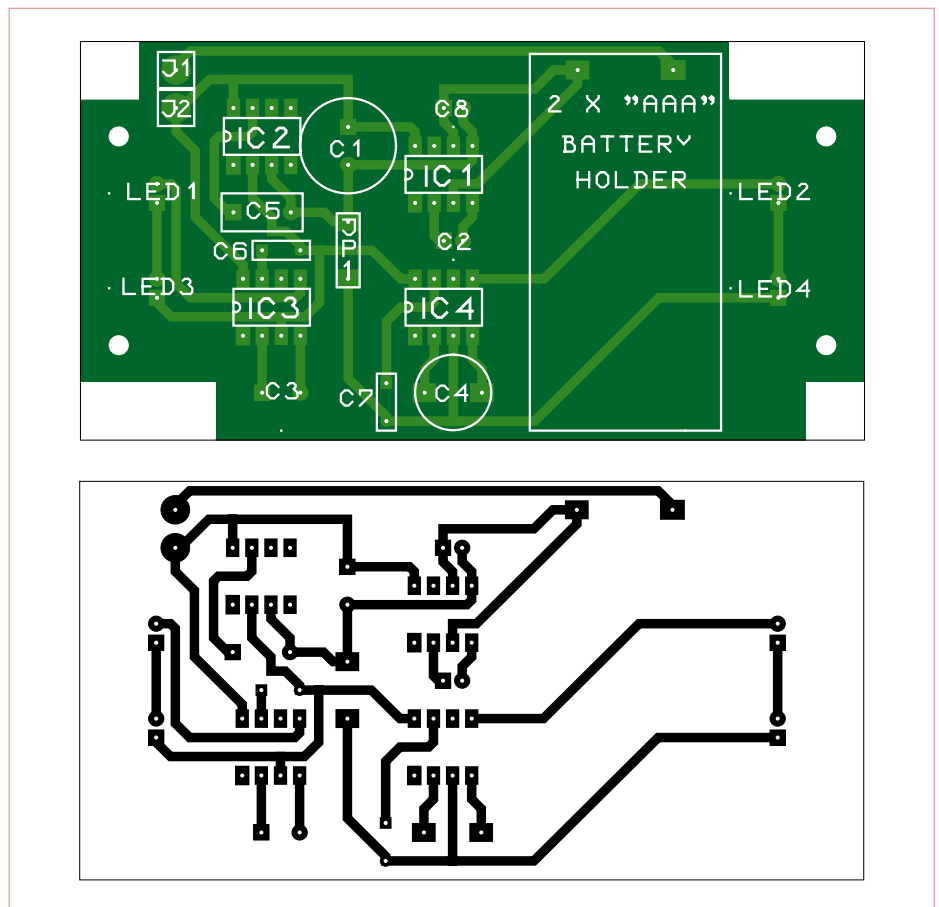


Figure 2. Parts placement of the proposed PCB, top view of board and trace pattern of board, viewed through top of board. (author's board design)

Internet Links and References

- [1] www.maxim-ic.com/datasheet/index.mvp/id/1017/t/al
- [2] www.elektor.com/110216



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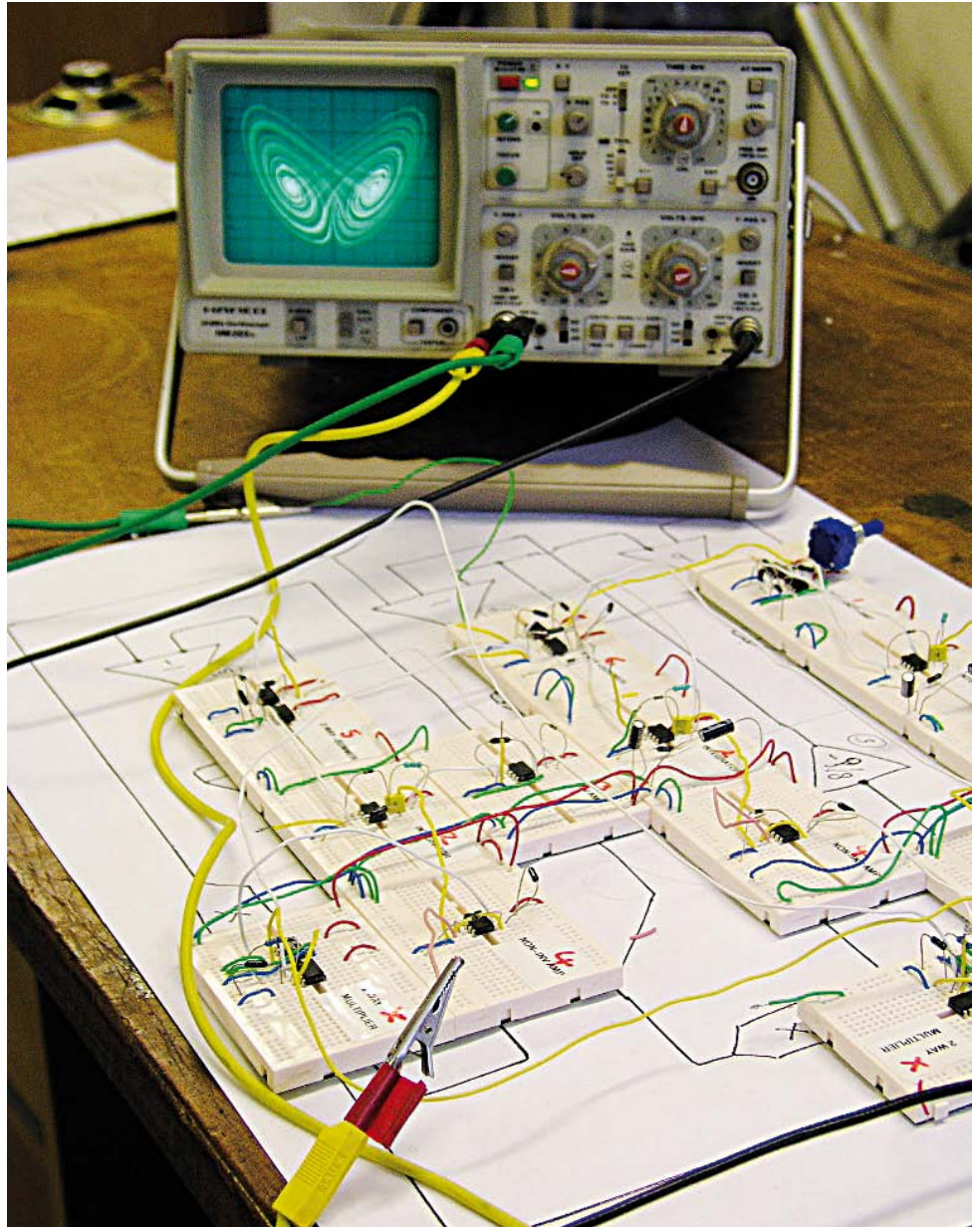


The Chaos Machine

Analog Computing Rediscovered (1)

By Maarten H. P. Ambaum and
R. Giles Harrison
(Department of Meteorology,
University of Reading, UK)

Analog computers provide actual rather than virtual representations of model systems. They are powerful and engaging computing machines that are cheap and simple to build. This two-part Retronics article helps you build (and understand!) your own analog computer to simulate the Lorenz butterfly that's become iconic for Chaos theory. First, however, some history and background.



For some of us it may be surprising that, before the mid sixties, hardly any computing in real-time applications was done by a digital computer. Instead, analog computers were used because of their speed and relative reliability. Analog computers are machines that are built to behave as the system we want to compute. A famous example is the Phillips MONIAC computer from the 1950s [1] (Figure 1) which used water flow through Perspex pipes to model the flow of money in an economy. However, in most practical applications, electronic analogies were used. The word analog refers to the behavior of the computer being analogous to that of the system

we want to simulate. In contrast, the word digital refers to the process of transforming the behavior of a system to a stream of numbers or digits calculated by a numerical algorithm. Although this is the origin of the word analog, its meaning has now evolved to describe anything that is not digital.

Modern analog computers

In the sixties it became clear that the digital computer would rapidly overtake the analog computer. Advances in chip technology made the digital computer reliable and available to a large num-

ber of people and organizations. However, precisely because of the advances in chip technology driven by the digital revolution, we can now build very cheap and very accurate analog computers as well. As part of an art-science collaboration in our Department, we decided to exploit the accuracy of modern analog electronics in an exhibit of an analog computer for the *Lorenz model* which produces the butterfly that became the iconic cartoon for the science of chaos and the unpredictability of weather (See, for example, James Gleick's *Chaos: Making a new science* for a wonderful introduction to chaos theory and its history).

Our building of the analog computer turned out to be an inspiring and illuminating experience. Here we discuss some of the remarkable properties of analog computers, perhaps no longer widely appreciated. In next month's installment we will also describe how to make the analog computer that simulates the Lorenz model. We call it the *Chaos Machine*.

Butterflies; poltergeists; mathematics

The Lorenz equations were developed in 1963 by the meteorologist Ed Lorenz to mimic the flow of air heated from below [2]. They are a set of three coupled equations that describe the time evolution of three variables X , Y , and Z ,

$$dX/dt = \sigma(Y-X)$$

$$dY/dt = \rho X - Y - XZ$$

$$dZ/dt = XY - \beta Z$$

The link of these three equations to actual air flow is rather obscure, and they do not work very well anyway.

What Lorenz did discover was that when he chose the three tunable parameters (σ ; ρ ; β) in his model carefully it would behave in an erratic and unpredictable way: chaos. This was completely unexpected and paved the way to a revolution in science. If the three variables X , Y , and Z are plotted as a moving point in three-dimensional space, we get the famous Lorenz butterfly, a fractal floating in three-dimensional space, see **Figure 2**.

In our Chaos Machine we can feed two of the voltages that represent the X , Y , and Z , to an oscilloscope in XY-display mode to see it draw an electronic version of the butterfly. We can tune the three variables to produce various shapes of the butterfly. We can also feed the channels to an audio amplifier to hear the sound of chaos. This turns out to be a remarkably unsettling experience: the *Chaos Machine* screeches and screams in the most bizarre ways with the soul of an electronic poltergeist.

How do analog computers work?

An electronic analog computer solves equations by representing values of variables by voltages in a circuit. Wires connect modules that perform specific arithmetic operations. For example, a subtraction module will have two input connectors and one output connector where the output voltage equals the difference between the

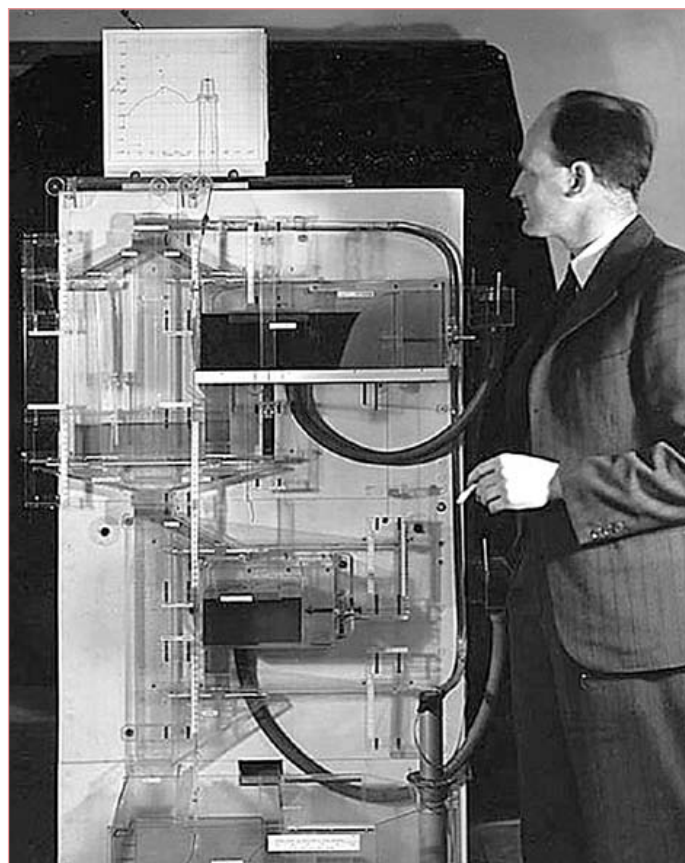


Figure 1. Professor A.W.H (Bill) Phillips was an LSE economist known for the 'Phillips curve' and he developed MONIAC, an analogue computer that modelled economic theory with water flows.
Image: Wikimedia Commons.

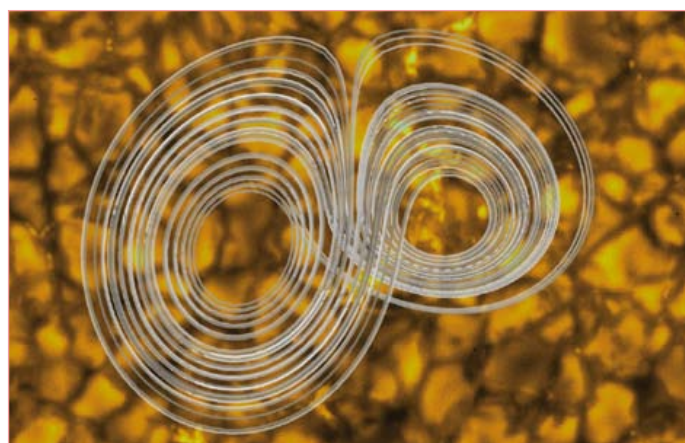


Figure 2. The Lorenz butterfly; the background is an image of solar convection, the original inspiration of the Lorenz equations.

input voltages. This particular module is in fact simply a differential amplifier with unit gain.

The topology of an analog computer is similar to that of our brain with the axons being represented by the wires, the cell body by the arithmetic modules, and the input ports by the dendrites. Contrast this with a digital computer. In a digital computer variables are stored in memory spaces which are then occasionally operated upon by copying these memory spaces to the central processor which then changes the values of variables in other memory spaces. Digital computers only change values of variables if the central processor says this should happen, and if so, they alter successively. In an analog computer values always remain consistent. So, if for three variables a , b , and c we have $a+b = c$ then in an analog computer this will always be the case. There is no internal clock speed; calculations happen instantaneously. In a digital computer this is only valid after the central processor has performed this addition and then only until either a or b are updated again.

Time integration is also a very natural process for an analog computer. The input and the output voltages of a time integrating module are always consistently related: at all times the output voltage is equal to the time-integral of the input voltage. There are no time steps involved, as would be the case for a numerical integration routine. Numerical instability of integration routines is not an issue, nor are computing or storage overheads. The basic circuit of an integration module is shown in **Figure 3**. Integration in time occurs by converting a voltage to a current

through use of an operational amplifier and then using this current to charge a capacitor. The instantaneous voltage across the capacitor is the time-integrated value of the input voltage. The schematic shows an electronic circuit able to perform integration in time of a varying input voltage. It is based on two operational amplifiers A1 and A2 each having inverting (–) and non-inverting (+) inputs and an output terminal. A time varying voltage $V_1(t)$ is applied to A1, which drives the integrator circuit comprising R , C and A2. The output voltage $V_2(t)$ is (minus) the time integral of the input voltage, scaled by $(1/RC)$. A1 is a unit gain buffer stage, included solely to prevent loading of the originating voltage source but permitting a wide choice of values for R . (The additional resistor with A2 is for compensation and does not form part of the functional circuit.) For clarity, the necessary power supplies are not shown.

Other arithmetic operations can also be performed with the help of operational amplifiers. For example, subtracting two voltages is achieved using a differential amplifier of unit gain. Multiplication and other related operations are more complicated to implement,

requiring many op amp stages.

Analog computers do not require a memory to work. This makes them essentially equivalent to the systems we try to simulate. A swinging pendulum does not have a memory of its previous states. One could connect an analog computer to analog-to-digital converters if digital storage or exact measurements are required. This construction can also be used to build a hybrid analog-digital computer. A purist who wants to stay away from any digital technique can use a tape recorder or chart recorder for storage, also circumventing the difficulties of aliasing which arise in a sampled system.

Analog computers are relatively hard to program: programming the computer is the same as building the computer. Clearly this flexibility is where digital computers are far superior. Also, in a digital computer it is easy to allocate memory spaces to store a set of variables, while in an analog computer each variable is associated with

a separate signal wire. Although a digital computer requires much more complex hardware for variable storage, it can use the same hardware configuration to tackle different virtual problems. A digital computer is a universal Turing machine, that is, a machine that can be used to solve different problems; an analog computer can only solve one single problem.

Another fundamental difference between analog and digital computers is that a digital computer calculates an approximated virtual representation of the model system, whereas an analog computer is an actual

electronic copy of the system. If we want to simulate a swinging pendulum with an analog computer, we build an electronic system that oscillates exactly like the swinging pendulum. The computer becomes an electronic version of the swinging pendulum itself. This is a very appealing property of analog computers. Think of the Lorenz system that we use in our *Chaos Machine*. Apart from a very artificial set-up, there is no actual physical representation of the system; it was designed as a mathematical system. Analog computers are the only way we can get genuine physical representations of such mathematical systems.

How fast are they?

People who see an analog computer for the first time often ask: how fast is it compared to a modern digital computer? In fact, their speeds are hard to compare. In a digital computer speed is limited by the clock speed of the processor and the speed at which variables can be loaded into and out of the processor. One such calculation may typically take a nanosecond or so (one thousand millionth of

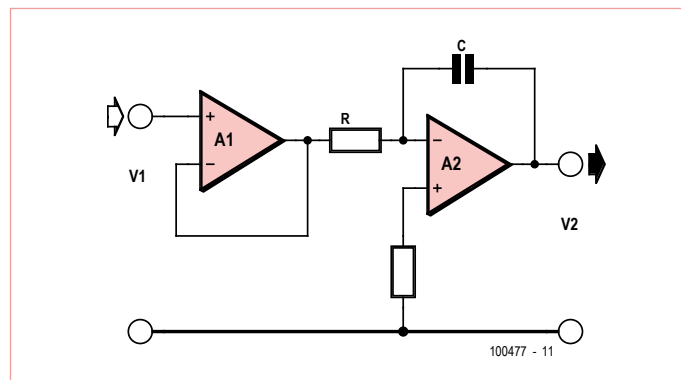


Figure 3. Basic circuit of the time integration module.

a second). In an analog computer the speed is limited by the speed at which the operational amplifiers, the key building blocks of analog computers, can follow changes in input voltages (the *slew rate*). Operational amplifiers can change over time scales of a few nanoseconds and for most practical purposes this does not limit the computer's operation. However, analog computers do not perform calculations as such; they perform simulations. Asking how fast an analog computer calculates is the same as asking how fast the swinging pendulum calculates its motion.

Nevertheless, the 'speed' comparison can be made more precise. An analog time integration module has an intrinsic timescale set by $R \times C$, the resistance and capacitance, respectively, of two components in the module. In other words, speed in a digital computer is limited by its clock speed, while 'speed' in an analog computer can be arbitrarily defined by choosing different components. There is a practical limit to which we can increase the speed of the analog computer set by the finite slew rate of the operational amplifiers and the stray capacitances in the system, both of which act to damp away the very highest frequencies.

Fortunately, dedicated analog function chips are cheaply available which contain optimized log and antilog converters, providing multiplication, divisions, and square roots with excellent accuracy and temperature stability — and truly enormous speed.

Operational amplifiers

Advances in electronic components have had major benefits for many scientific activities, but they also now make the implementation of analog computing straightforward. The key building block of an electronic analog computer is the operational amplifier, a general purpose electronic device which can be configured to perform the different mathematical operations (integration, addition, multiplication, scaling) required. General purpose amplifiers originated in the 1940s from military applications, particularly in anti-aircraft gunnery (although a mechanical analog computer was used as recent as the Vietnam war in the 'Norden' bombsight to target bombs dropped from aircraft). The description *operational amplifier* (or *op amp*), appeared in 1947, and the first commercial op amp — type K2-W — was produced by Philbrick in 1953, based on two dual triode valves, see



Figure 4. The Philbrick K2-W is generally considered the first commercial operational amplifier.

Figure 4 and [3,4]. Solid state op amps followed in the 1960s, with the first integrated circuit op amp in 1965 (Jung's *Op Amp Applications Handbook* provides a good overview of the history and use of op amps).

Comparison between early and modern op amps illustrates how the steady improvements have made analog computing ever more practical. The thermionic K2-W had a specified drift of ± 5 mV per day, whereas the integrated circuit OP97, used in our Lorenz design, has drift dominated by thermal changes, at $0.6 \mu\text{V}/^\circ\text{C}$. The power requirements are also dramatically different. A K2-W required power supplies of ± 300 V and 6.3 V, at about 10 mA and 0.6 A, whereas the OP97 requires ± 15 V at 0.6 mA. Early analog computers therefore had a substantial physical volume associated with each computing stage, as well as power dissipation and heat generation.

Integrated circuit analog computers are now compact, and drift is no longer a characteristic feature. Individual op amp stages are also relatively cheap, allowing complex systems to be readily simulated. A benefit of their low cost is that extra stages can easily be included, which although not essential to the computing function, may relax constraints on the components required.

The final analog computer is an assembly of independent circuit modules, combined to solve one specific problem, but reusable for other applications. With such a modular approach the 'programming' of the computer is a fairly simple job which requires hardly any knowledge of the electronics involved.

Next month's second and final installment discusses the elements that go into building the *Chaos Machine*.

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Internet Links and References

- [1] http://en.wikipedia.org/wiki/MONIAC_Computer
- [2] <http://mathworld.wolfram.com/LorenzAttractor.html>
- [3] www.philbrickarchive.org/
- [4] Philbrick K2-W, the mother of all op amps, *Elektron* (Retronics) October 2009.

Trusting Your Instruments

By Gerard Fonte (USA)

There will occur times when you will doubt the readings your instruments give you. It is vital to know when to trust your measurements. Last time we examined faulty measurements. This time we'll look at faulty thinking in a crisis.

Meltdowns Happen

At four o'clock on the morning of March 28, 1979, the Three Mile Island Nuclear Power Plant in Harrisburg Pennsylvania experienced a problem. As the morning progressed the problem got worse and worse and it became imperative to determine the actual temperature of the reactor core. The very experienced instrumentation engineer, Ivan Porter, grabbed a couple of technicians and decided to directly measure the thermocouples that were built into the core (with long wires leading out of the core).

The first few thermocouples they measured indicated about 700 degrees, which was just below the high temperature limit. Then they got some over 2000 degrees. This was decidedly not normal. There was even one that showed 3700 degrees. And then there were a couple that said 200 degrees---way too low. They re-measured the high readings with a different meter and method, and they were consistent at over 2000 degrees.

Ivan Porter says, "That's impossible. That data is no good." and leaves. (Ref. "The Warning" by M. Gray and I. Rosen, 1982, WW Norton & Company).

Mr. Porter didn't trust his instruments. He refused to believe that the reactor was melting down in front of his eyes. And, surprisingly, this is not that uncommon a reaction in a crisis. I'm sure that the stress of the previous few hours was a factor, as was his long association with the facility. Nevertheless, this accomplished and competent engineer couldn't accept or properly interpret what the measurements meant.

The point is not to criticize Mr. Porter, but rather to show that any engineer or technician may encounter a situation where it's easier to deny reality rather than to accept it. It's important to recognize this in advance, so that when a crisis event does happen, you will be prepared to handle it better than Mr. Porter. (It's like thinking about an accident that submerges your car in water. It probably won't ever happen, but if it does, you know what to do.)

Situational Awareness

When you are faced with important measurements that seem impossible, you absolutely must stop and think it through. It's easy to doubt the readings. We've all seen instruments say things that don't make sense. But just because something has failed in the past, doesn't mean it's failing now. If you don't believe your meter, you must stop and ask yourself why. Why is the meter wrong? What could possibly cause these unbelievable measurements? If you can't answer it, then you have to consider that the readings are correct. And even if you do come up with an answer, you have to think about the likelihood that your answer is correct. And lastly, what if the



readings are correct and you dismiss them? What happens then?

It's also important to think about the big picture. What would you expect to see if the reactor is melting down? It seems self-evident that you would expect abnormal readings.

If part of the core was under water and being cooled, that area would have temperatures that would be reasonable.

If part of the reactor was out of the water and not cooled, it would be very hot. And it is not unreasonable to think that some of the thermocouples in the hot area would fail. They were designed to operate in a "normal" core environment. If there is too much heat or physical damage to the core, it seems like common sense that some of the thermocouples would not function properly. (Fundamentally you can't escape the argument that if the core is operating properly, ALL of the thermocouples should indicate normal temperatures).

The next step is to think about the possible failure modes of thermocouples. If you doubt your readings, ask yourself: "How can a thermocouple indicate too hot a temperature?" A thermocouple is just two wires of different metal connected together that generate a small voltage according to the temperature. If there was a break or short in the wires, it makes sense that the reading could be low. But there is no failure mechanism that allows for a higher voltage than normal. Somehow, a voltage would have to be impressed into the thermocouple. There is no way that can happen in a normally operating reactor core. And given that multiple thermocouples show very hot temperatures makes any contrived possibility incredibly unlikely.

Finally, thermocouples are not complicated machines. They're very reliable, simple, robust and maintenance free. These are ideal characteristics for use in a reactor core. They are buried in the core itself. There is no better way to monitor the core temperature at specific points. So, in order to dismiss their information, you need to show why they are unreliable. That's a hard thing to do.

Trust is a Must

The simple axiom of engineering is that you must trust your instruments unless you have a very specific and clear reason not to. This also means that you must know how your instruments work and their limitations. You have to understand what you are measuring and how different things could affect those measurements, as well. Distrusting instruments is a common theme in crisis situations. It repeatedly happens in aircraft accidents. People get caught up in the moment and create a mind-set that focuses on only certain things. They react instead of think. And if you don't think, it's easy to dismiss critical information that doesn't fit your idea of the situation. Quite simply, people who don't think, fail.

Hopefully you will never be in a crisis event. But if you are, stop and reason things out. Try not to let circumstances run over you. Being correct is usually much more important than being fast.

Of course, all of this is much easier said than done.

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With the summer holidays ended for the most part we can safely return to the monthly dose of Hexadoku to keep you busy for a couple of hours. After the monster puzzle in the July & August edition it's back to the grind with a regular 16 x 16 grid Hexadoku. 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 x 16 boxes, enter numbers such that **all** hexadecimal numbers 0 through F (that's 0-9 and A-F) occur once only in each row, once

in each column and in each of the 4x4 boxes (marked by the thicker black lines). A number of clues are given in the puzzle and these determine the start situation. 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.

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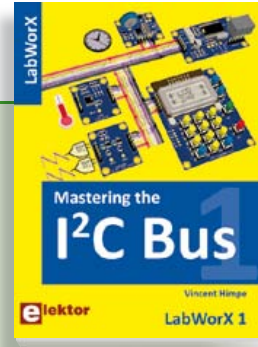
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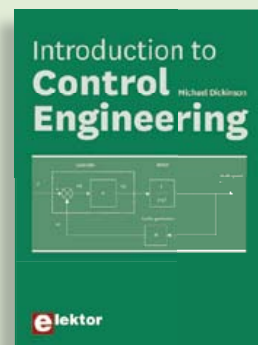
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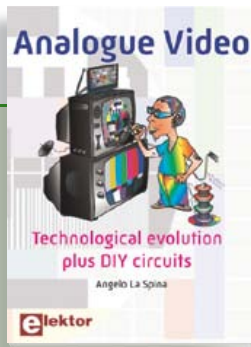
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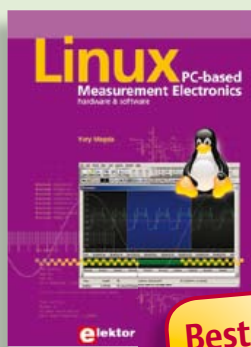


Technological evolution plus DIY circuits

Analogue Video

This book is intended for electronics enthusiasts and professionals alike, who want a much deeper understanding of the incredible technology conquests over the pre-digital decades that created video. It details evolution of analogue video electronics and technology from the first electro-mechanical television, through advancements in Cathode Ray Tubes, transistor circuits and signal processing, up to the latest analogue, colour-rich TV, entertainment devices and calibration equipment.

222 pages • ISBN 978-0-905705-96-5 • \$42.80



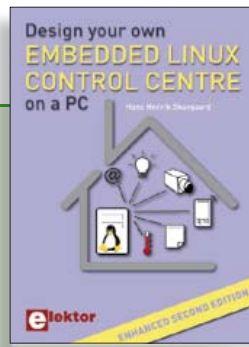
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A highly-practical guide

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.

264 pages • ISBN 978-1-907920-03-5 • \$47.60



Enhanced second edition

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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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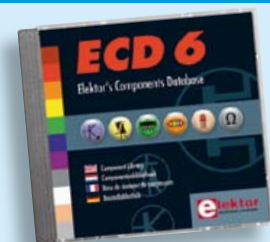
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Circuits, ideas, tips and tricks from Elektor

CD 1001 Circuits

This CD-ROM contains more than 1000 circuits, ideas, tips and tricks from the Summer Circuits 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



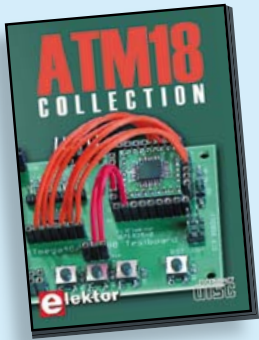
More than 70,000 components

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!

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All articles in Elektor Volume 2010

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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



Bestseller!

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 self-contained 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)



SatFinder

(March 2011)

Those of you who regularly need to realign a satellite TV dish will find this gadget extremely valuable. Caravan owners and campers on long journeys who crave their home TV channels can now keep up with developments in sports, news and the soaps back home with the help of the SatFinder. This GPS based design includes a database containing positional information of a number of popular TV satellites. With the help of GPS data it calculates the precise angles to find the satellite first time!

Kit of parts including Controller, Display and PCB (North American Version)

Art.# 100699-72 • \$114.90



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

September 2011 (No. 33)

\$

+ + + Product Shortlist September: See 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. board25.80

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 DIL814.30

WAV Doorbell

110080-41 Programmed controller ATmega328p DIL2818.60

RGB Solar Lamp

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

Jogging Timer

110160-41 Programmed controller ATTiny44-20PU dip 1414.30

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 board17.60

June 2011 (No. 30)

Elektor OSPV1

110320-91 Kit.....1570.00

Geolocation with the ATM18

071035-91 ATM18 Controller module, partly populated.....15.40

071035-92 ATM18 Testboard, partly populated.....48.30

071035-93 LCD board, SMD populated incl. pinheaders.....37.10

Here comes the Bus! (6)

110258-91 USB/RS485 Converter, ready made module35.70

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EB007..... E-blocks Switch Board23.90

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EB060..... E-blocks RC5 Infrared Board.....49.80

EB064..... E-blocks dsPIC/PIC24 Multiprogrammer159.40

May 2011 (No. 29)

Microphone Conferencing System

100465-1 Printed circuit board.....14.30

Elektor Proton Robot

110263-71 Kit of parts All Inclusive (Body + Head + Audio + Gripper + PIC Add-on).....1745.00

110263-72 Kit of parts All Inclusive (Body + Head + Audio + Gripper + AVR Add-on)1745.00

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Mobile, Text, CallerID

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071035-95 Port extension board, SMD populated26.80

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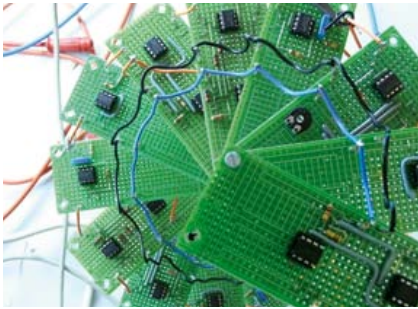
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Retronics: The Chaos Generator (2)

After reading this month's Retronics installment on a chaos generator, the editors (in chaotic fashion) got the idea to put the theory to the test using a handful of opamps soldered on to small boards. It all worked wonderfully well and never before did we see such strange shapes on an oscilloscope screen. From sea horses and butterflies right up to Harvard's latest "business models". The audio signals too produced by the generator proved unnerving at times. You can read all about it in the October 2011 edition.



Platino

In many electronics projects the PCB plays second fiddle to the electronic design. Although it is hard to assemble a circuit without a circuit board, the design of the latter is often forgotten in favor of "how the thing works". To compensate this unjustness we decided to turn the tables. This article is all about the circuit board and the circuit on it is a trifle, really. Ladies and Gentlemen, your warm welcome please for....Platino!



Dreams of flying electrically one day...

... have come true. The first approved-for-air transport aircraft with electric drive has been in production since 2004, while this year Airbus parent company EADS presented "Voltaire", their all-electric propulsion system concept for future commercial aircraft. We report on the current status of the sadly neglected field of electric vehicles as well as on the Green Flight Challenge competition planned for September 25, 2011, which is supported by NASA with prize money amounting to 1.65 million dollars.

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

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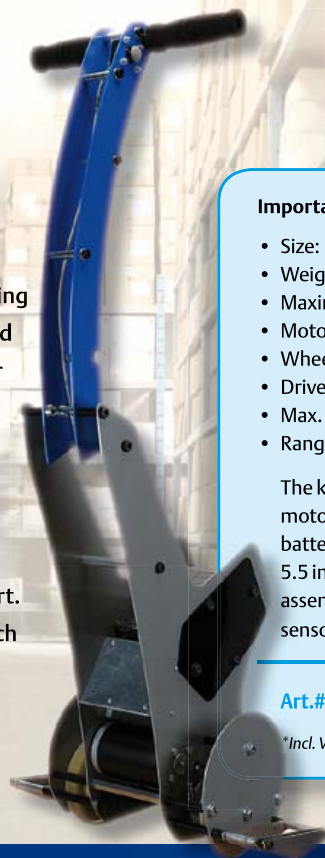
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Elektor OSPV

Open Source Personal Vehicle

Last year we launched the Elektor Wheelie, a self-balancing personal transport device. Our new Elektor OSPV is based on the same concept, but with the difference that it's for indoors, it's easy to steer, it's light and foldable and... it's open source. You can configure or modify it to suit your wishes! The OSPV is primarily intended for moving people, but it doesn't have to be limited to that.

A variety of other uses are conceivable, ranging from an electric wheelbarrow to a handy motorised shopping cart. This is where the advantages of the open source approach come to the fore!



Important specifications:

- Size: 147.2x18.5x18.5 inch (HxWxD)
- Weight: 25lbs
- Maximum load: 200 lbs
- Motors: DC 2 x 200 W
- Wheels: Polyurethane, 5.5 inch dia.
- Drive train: HDT toothed belt
- Max. speed: 9.3 mph
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The kit comprises two 200-watt DC drive motors, two 12-V lead-acid AGM batteries, battery charger, two wheels Polyurethane 5.5 inch, casing, control lever and fully assembled and tested control board with sensor board.

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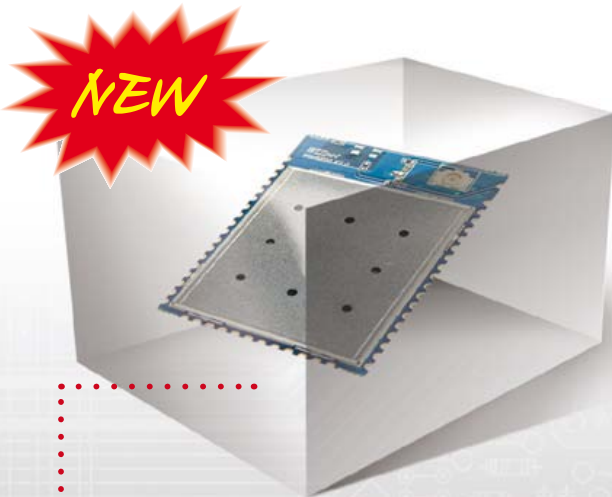
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