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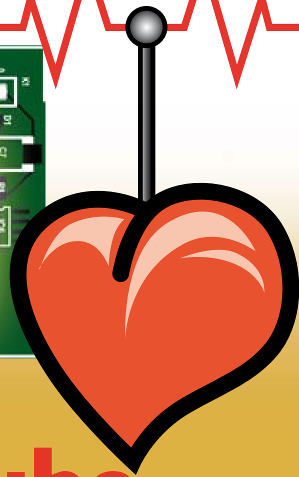

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An energetic edition

If I may offer something to ponder or muse over during the winter holiday period, try "how much energy is wasted trying to devise and publish ways to save energy, or get it from sustainable sources and/or free sources". I'm sure this conundrum will keep you busy, amused, frustrated, curious, excited or even hyperactive for quite a few days. Let's hope it does not cause anxiety; if so, "there's solace in the pages to follow". Whatever direction your thinking, pencilling, calculating and head scratching veers off, it's a comforting thought that you are not alone. When in doubt, write to the editor.

In this edition, in line with our celebrated 2011 Publishing Plan (it's on our website!), we have a focus on all-things-energy — to which I should add 'energetic'. In this edition we cover green energy, energy harvesting (page 14), tips to save energy (page 34, some for a good laugh too), and best of all, free energy (page 52).

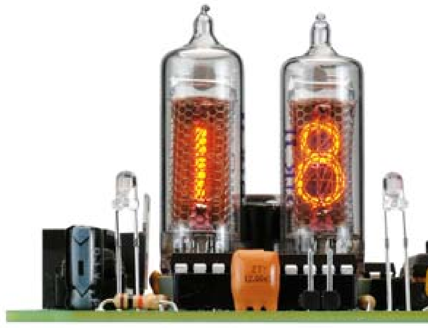
A lot of energy also went into producing the other articles in this edition, which should present a nice mix of traditional electronics, microcontrollers and design ideas. The *Nixie Tube Thermometer* on page 24 bridges 50 years in a single project, happily marrying a 21st century microcontroller and associated programming techniques with tube technology from the 1950s. The result is a project that's sure to draw attention when placed on your desk or mantelpiece.

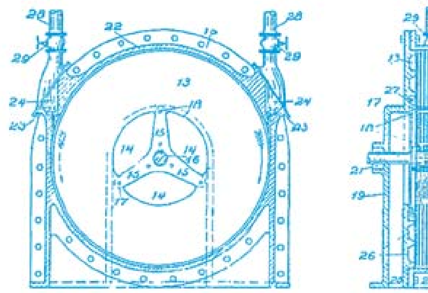
Although I do not recommend bypassing your local physician if you're curious to know your heart condition or other ailments, why not draw your personal electrocardiogram (ECG) with our Zigbee'd cardiac monitor (page 56) and send him your personal ECG graphs by email. If you suspect you're too FAT — go to page 18. Myopic in the dark? — page 62.

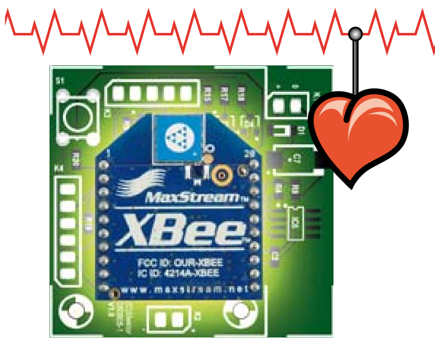
In closing I congratulate my colleagues in Elektor's Dutch department on the 50th Anniversary of their edition. Believe it or not, 'Elektuur' as it was called at the time started out in 1961 and was the mother of all international versions of the magazine, including this the English one born 14 years later. No 'Double Dutch' mockery but a laurel on the front cover of all Elektor editions. *Goed gedaan jochies*!

Jan Buiting, Editor

elektor







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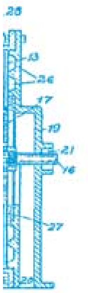

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The PCB Prototyper Spreads Its Wings

By Harry Baggen (Elektor Netherlands Editorial)

Last month we published the first article on the new PCB Prototyper, a general-purpose PCB router whose relatively low price compared to similar machines makes it suitable for users outside the normal target group of schools and companies. Visitors to the recent Elektor Live! event had an opportunity to see a prototype of the machine and several PCBs produced by the machine. They were all impressed by the quality of the routed PCBs, and more than few hobbyists are probably already thinking about other ways to use the machine for their own purposes (and how to explain this to their spouse).

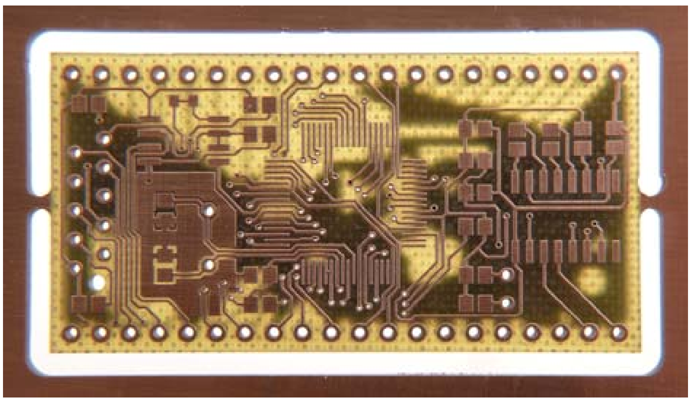
The PCB Prototyper is more than just a PCB router. As mentioned in the previous article, it is designed to be easily adapted to other tasks. This is reflected in the modular architecture of the mechanical construction and the software.

Our first article prompted a variety of responses from readers who saw a lot of potential applications in addition to those originally envisaged by Colinbus and Elektor. However, some of these applications ran into problems due to the dimensions of the machine. This had more to do with the space available under the Plexiglas cover than with the size of the working area. As we explained last month, the aim is to develop a machine that can do much more than just produce high-quality routed PCBs. Users must be able to adapt the machine and the software as desired in order to achieve what is effectively a machine tailored to their specific needs. To avoid unduly restricting the scope of future extensions, the enclosure has been modified to be somewhat larger than originally planned. The new outside dimensions are now 455 × 385 × 360 mm (18 × 15.2 × 14.2 inch) (B × D × H).

Along with the enlarged enclosure, the Y axis has been extended slightly. This does not relate to the area available for PCB routing or the size of the work table, but instead to the space that may be occupied by future accessories. For instance, a camera mounted on the multifunctional head must be able to view the area accessible to the multifunctional head itself (in other words, the working area of the engraving module). Originally this was only possible with a very small camera, but now the PCB Prototyper can also be used with larger cameras, such as those used for scientific purposes. Now there is also more room for fitting a laser or a scanner.

Thanks to input from our readers, the PCB Prototyper is now ready for more than just numerous alternative applications. Several new accessories have also been developed or are presently being developed. They will be described in more detail in a future issue of in Elektor. Readers with interesting ideas or wishes are invited to contact Colinbus or Elektor to make them known. The more we hear from you, the better we can adapt the software and accessories to the wishes of all users.

(100869-I)



For more information on the PCB Prototyper, visit www.elektor.com/pcbprototyper

Step-up DC-DC converter features highest efficiency

austriamicrosystems has introduced the AS1310, an ultra low quiescent current hysteretic step-up DC-DC converter optimized for light loads (60 mA) and the highest efficiency — up to 92 %. With 1 µA the AS1310 step-up converter also features the industry's lowest quiescent current, operates over a wide 0.7 V to 3.6 V battery supply, and provides output voltages between 1.8 V and 3.3 V. Even at loads as light as 100 µA, efficiency still reaches 85%, significantly increasing battery life.

Since the supply voltage of many battery powered applications is moving from 3 V to 1.8 V, the AS1310 boost DC-DC converter was designed to be able to generate both; many competitive DC-DC converters are not able to do so. If the input voltage exceeds the output voltage the device goes into a feed-through mode and the input is directly connected to the output voltage. The features and performance of the AS1310 boost DC-DC converter make it very well suited for single- and dual-cell powered devices, including blood glucose meters, remote controls, hearing aids, wireless mouse or any light-load application. The AS1310 DC-DC converter is an especially good fit for applications in which a lot of time is spent in an idle mode and therefore draws only a small current.

In order to save power the AS1310 also features a shutdown mode in which it draws less than 100 nA. During shutdown, the battery is disconnected from the output. In addition, the AS1310 step-up DC-DC converter allows adjustable low battery detection. If the battery voltage decreases below the threshold defined by two external resistors, the output is pulled to logic low. This signal is used to indicate 'low battery', so no separate supervisory ICs are needed.

The AS1310 boost DC-DC converter is available in a TDFN 8-pin 2x2 mm package and operates over a temperature range of –40°C to +85ºC with a wide power supply range of 0.7 to 3.6 V.

www.austriamicrosystems.com (100820-I)

More applications for Hameg HMP2000 series

Hameg's HMP2000 series High Power Supplies were improved by adding an important feature: Channel 2, till now an auxiliary channel with 0–5.5V output, was upgraded to a full-grown 0–32 V channel. This improves the universal applicability significantly, also with regard to future applications. The HMP2020 now features two identical channels with 0–32V output voltage, one delivering 10 A, the other 5 A. The HMP2030 now has three identical channels with 0–32 V, 0–5 A outputs. Also new are the LabView, CVI, and PLUG&PLAY drivers for all types of the HMP series which also includes the HMP4030 with three, and the HMP4040 with four, identical 0–32 V / 0–10 A channels. Hence all programming systems and interfaces (USB, LAN, IEEE, and RS-232) popular in the ATE world are now being supported. The drivers are available at no cost for downloading from the web page below.

www.hameg.com/HMP2030 (100820-I)

QuickUSB® Module offers 20 megabytes/sec transfer rates

Bitwise Systems, designers and manufacturers of custom embedded systems and PC interface products, has announced the availability of their QuickUSB Module that makes adding Hi-speed USB 2.0 to new or existing products fast and easy.

Under ordinary circumstances, implementing a USB peripheral requires a functional understanding of the USB protocol as well as a considerable amount of firmware and software development and stringent compliance testing. The Bitwise Systems QuickUSB Module provides a very-desirable alternative for adding hi-speed USB 2.0 for speeds as much as 40x faster than USB 1.1. The QuickUSB® QUSB2 module makes adding Hi-Speed USB 2.0 to new or existing products fast and easy by integrating all the hardware, firmware, and software needed to implement a general-purpose USB endpoint into a simple plug-in module and development library. The module may simply be used as a development station when combined with the QuickUSB Adapter Board or QuickUSB Evaluation Board. It may also be designed as a plug-in module for new products, or designed directly into new products and licensed
using the QuickUSB iChipPack or QuickUSB EEPROMs.

The QuickUSB module contains parallel and serial hardware ports that are connected to circuits within the peripheral. The QuickUSB library included with the module provides user-callable software functions that transfer data to and from the hardware ports over the USB. The designer then obtains multiple ports of flexible, high-speed USB connectivity without requiring a prior in-depth knowledge of USB.

QuickUSB differs from other USB modules in that it performs high-speed data transfers of 20 megabytes/sec or more via its high-speed parallel port. This makes QuickUSB the idea interface for high-performance USB peripherals such as FPGA, DSP or microcontroller based data acquisition systems.

The QuickUSB QUSB2 Module is a 2" × 1.5" (50 × 38 mm) circuit board that implements a bus-powered Hi-speed USB 2.0 endpoint terminating in a single 80-pin target inter-

face connector. The target interface consists of:

One 8- or 16-bit high-speed parallel port
Up to five general-purpose 8-bit parallel I/O ports
Two RS-232 ports
One I2C master port
One SPI master port
One FPGA configuration port (Altera PS or Xilinx SS)
2 KB of user-available, non-volatile memory
Software, libraries and drivers for Windows 32/64, Linux and Mac OS X

The QuickUSB Module, QUSB2 is priced at $149.00 ea. It is available immediately in small quantities.

www.quickusb.com (100820-III)

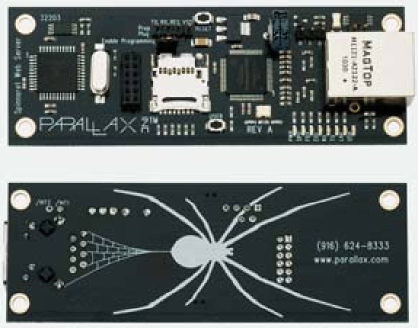
DC/DC LED driver with 48 watts output power in DIP24 package

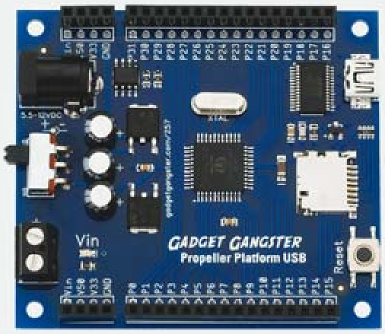
With the release of AMLD-Z, Aimtec launches via MSC Vertriebs GmbH the third series in its line of DC/DC LED Drivers. Offered in a DIP24 packages, the AMLD-Z are feature rich LED drivers and meet the rigorous demands for environment friendly LED lighting solutions. From a wide (8:1) input range of 7–60 VDC, the AMLD-Z series of LED drivers provide constant output currents ranging from 150 to 1000 mA, generating from 6 to 48 watts of power to maintain the constant colour and brightness that is required by today's most demanding LED applications.

The new AMLD-Z series provides remote ON/OFF control function in addition to both PWM and analog voltage dimming control (0–100 %).

Open and short circuit protection works continuously until the short circuit condition is resolved, protecting the converter, the LED lights, and the converter's input circuit from extremely high currents a short to ground causes.
Boasting efficiencies as high as 97 %, Aimtec's LED drivers are designed to be as reliable as the LEDs they drive, allowing

Parallax: Spinneret Web Server and Propeller Platform USB





The new **Spinneret Web Server** from Parallax may be small — at less than 1½ by 4 inches — but it is a feature packed development platform. The built-in MicroSD card socket and real-time clock allow ample room for time-stamped file and data storage, and the oversized EEPROM can store non-volatile data for use when there is no MicroSD card present.
As an open-source hardware design, all design including layout, schematics, and firmware — are available under licenses that allow free distribution and reuse. This means that the Spinneret Web Server's design can be incorporated into new applications royalty free and without a non-disclosure agreement.
The Spinneret Web Server is an Ethernet based development board for the Propeller microcontroller. Web page content, files, and logs can be stored on a MicroSD card. The serial EEPROM has 32 KB for storing a Propeller program and 32 KB for non-volatile data storage, independent of the MicroSD card. There is a real-time clock controller for time stamping files and events and a backup capacitor that will keep the clock running through extended power outages. There is a serial programming header and two auxiliary I/O connections, one for level-shifted open collector communications over a three-pin data/power/ground cable, and a the second is a 12-pin socket for direct 3.3 volt I/O connections. There are eight status LEDs on the PCB, plus two that are repeated on the Ethernet jack. One of the status LEDs is user controllable and shares a line with a button that can be read under user control. A second button resets the Propeller to reload the firmware from the EEPROM. Spinneret retails at $49.99.

Combining a 64 KB EEPROM, 5 MHz removable crystal, 1.5 A power regulation, USB, and a microSD card slot on a compact, breadboard and protoboard friendly module, the **Propeller Platform USB** is an easy-to-use development tool for the multicore Propeller microcontroller. All 32 Propeller I/O are available via pin sockets, along with 5 V and 3.3 V regulated power.
Features include:
80 MHz 8-Core Parallax Propeller P8X32A with removable 5 MHz crystal
64 KB EEPROM for long-term program and data storage
5 V and 3.3 V 1.5A ultra LDO voltage regulators accept 5.5 V minimum power input
USB-to-serial interface for loading and communication
2.1 mm center-positive barrel jack and screw terminal power connections
2.8" x 2.5" footprint with pin sockets to add additional Platform modules or connect to a breadboard.
microSD card slot connected to P0–P3.

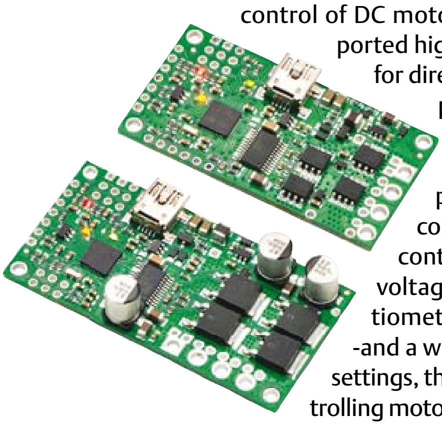
The new Propeller Platform USB retails at $49.99. At www.Parallax.com, search "Propeller Platform."

www.Parallax.com/go/spinneret (100820-V) them to be used at an operating temperature of –40 to +85 degrees Celsius at full load for compatible with a wide range of LEDs applications from variety of manufacturers without the need for any external components.

www.msc-ge.com (100821–IV)

Pololu: simple motor controllers

Pololu announces the release of its Simple Motor Controllers, a line of motor drivers with enhanced capabilities that make basic control of DC motors easy. With four supported high-level interfaces — USB for direct connection to a computer, TTL serial for use with embedded systems, RC hobby servo pulses for use as an RC-controlled electronic speed control (ESC), and analogue voltages for use with a potentiometer or analogue joystick--and a wide array of configurable settings, these devices simplify controlling motors in a variety of projects.



Units can be paired to enable mixed RC or analogue control of differential-drive robots, and they can be daisy-chained with additional Pololu servo and motor controllers on a single serial line.

A free configuration program, available for Windows and Linux, allows for quick controller configuration over USB (no more dip switches or jumpers) and simplifies initial testing. Controller features include: acceleration and deceleration limits to decrease mechanical stress on the system, optional safety controls to avoid unexpectedly powering the motor, a wizard for automatic RC and analogue input calibration, and support for limit switches.

The controller versions offer a wide operating voltage range up to 5.5-40 V and continuous current ratings from 12 A up to 25 A, which means they can deliver up to several hundred watts in a small form factor. The unit prices are $39.95, $43.95, $54.95, and $59.95 for the Simple Motor Controller 18v15 (item #1377), 24v12 (item #1379), 18v25 (item #1381), and 24v23 (item #1383), respectively.

www.pololu.com/smc (100820-VI)

IP67 wall mounted enclosures for harsh environments

The new 1555F range from Hammond Electronics is a family of rugged IP67 sealed enclosures designed for wall mounting PCB-based or DIN rail based equipment such as security components, control equipment and radio repeaters used in harsh industrial environments or outdoor applications. Available in RAL 7035 light gray and moulded in either general purpose ABS or flameproof polycarbonate, the units have a number of innovative features that provide excellent functionality. In use, the lid is secured to the wall or other surface using the slots moulded into the integral flanges. The screws securing the lid to the base are then inaccessible as they are against the surface, giving security against unauthorised tampering. For maximum security, the units can be attached to the wall with tamper-resistant screws. Standoffs are moulded into both the lid and the base and, apart from in the two smallest sizes, DIN rail mounting tabs are also provided. The bottom of the base features a moulded recess for a membrane keyboard or label.

The initial six sizes range from 120 x 66 x 42mm to 159 x 91 x 62mm; all lids are fitted with captive M4 stainless steel screws that engage with stainless steel inserts in the base, allowing repetitive assembly and disassembly. Environmental sealing is achieved through a tongue and groove design and a moulded silicon rubber gasket; all fixings are outside the gasket seal.

www.hammondmfg.com (100820-VII)

mbed Has Landed!

Question: What do you get when you land 75 engineers and boxes of all sorts of electronic components together in a concrete UFO? Answer: You get the biggest mbed hands-on workshop we've ever attempted!

By Simon Ford (UK)

I just arrived back from a trip to Elektor Live!, a daylong Elektor event in Eindhoven, The Netherlands. This was an excellent outing for anyone interested in electronics, and it had the added attraction of being held in the 'Evoluon' conference centre, which is an impressive saucer-shaped building that was actually built as a Science Museum by the Philips company in the 1960s. It was certainly the first time I'd ever been able to ask a taxi driver to "take us to the UFO."

Our mission was to run a hands-on mbed workshop in the morning. Whilst I had originally guessed 15 to 20 people might sign up, the email I had received the week before confirmed Elektor had closed applications on reaching 75 people. Yes, 75! That beats any of our previous workshops by a large margin, and as a result we spent much of the night before collecting together as many electronics kits as we could get our hands on. We arrived with all sorts of SparkFun Electronics breakout boards (accelerometers, gyros, screens, sensors, trackballs, RFID readers, etc.), mbed baseboards, and even some of the robots we used in a recent 'mbed Robot Racing' event. We figured it was certainly enough to keep people busy.

The workshop was a great success. We had an impressive assortment of attendees, ranging from total novices to experts, working with microcontrollers and electronics — all day, every day! This was a great testament to our focus on tackling the requirements of prototyping itself rather than catering to designers with particular skill sets. We want mbed to be a useful tool for novices and experts alike. Given the success, we'll be looking to run these events elsewhere. Tell us if one should be run near you!
While we were there, we bumped in to lots of people who were already mbed users, and it turns out some of them have been working on ideas for the NXP mbed Design Challenge 2010. I managed to get a few of them to reveal what they were up to. If their ideas are anything to go by, we should see a very interesting and diverse range of entries for this competition. I'm really looking forward to seeing people posting their results as these projects come together.

For those of you who haven't seen it yet, note that NXP Semiconductors, *Circuit Cellar*, and *Elektor* launched the NXP mbed Design Challenge in September 2010. The challenge puts up prizes for designers who share reference designs and building blocks that can help other mbed users prototype even faster. After all, the goal of fast innovation and invention is the real motivation behind mbed. We asked ourselves: What can be done to get out of the way and let innovators experiment quickly to invent future applications for microcontrollers?

We want all sorts of entries. Examples include innovative ideas, whacky applications, impressive engineering feats, and simple solutions to real problems. These projects will demonstrate new ideas and techniques. They'll inspire other designers and influence the development of future products, so everyone can do their bit to help move the industry forward. And, if being part of this mission isn't motivation enough, take a look at the *Circuit Cellar* website to see the prizes up for grabs!

The submission deadline is 1 pm EST on February 28, 2011. If you have an mbed, be sure to obtain a Registration Number on the *Circuit Cellar* and then get prototyping. With the rapid way in which the mbed community is growing, there will be lots of people to help you out along the way, so we hope the process will be good fun too. Good luck!

(100873)

Simon Ford, co-creator of mbed, is a lifelong electronics and computer engineer. He works at ARM, and before starting mbed was technical lead for the ARMv7/NEON architecture now found in most new smartphones.

To enter the NXP mbed Design Challenge 2010, go to: www.circuitcellar.com/nxpmbeddesignchallenge/

Economical Energy Harvesting

Every little bit helps

By Rolf Blijleven (Netherlands)

Alternative energy is a hot topic. In this article we describe several options for powering circuits from solar energy. As you can see, significant results can be achieved with a modest investment and a bit of sunlight. What's more, once it works the power is free.

In this article we show you several ways to power your circuits from an alternative energy source instead of batteries or the AC power grid. Here we focus on solar energy, but the methods described here can certainly be used with other energy sources as well. As you can see, quite respectable results can be obtained at a modest cost with a clever combination of modern and less modern components.

Virtually all alternative energy sources have three practical shortcomings: they are not continuously available, or if they are they do not supply a constant amount of power, and the available power is often too low for direct use. The engineering discipline that deals with these problems (and finds solutions for them) is called energy harvesting, which is the art of collecting energy whenever a source provides some energy and storing the collected energy until enough is available to be used for a practical purpose. Energy harvesting is receiving more and more attention in recent years, and rightly so.

The block diagram of an energy harvesting system is shown in **Figure 1**. A transducer is necessary to convert a particular form of energy into electricity. The voltage must be raised to a usable level, and the energy must be stored in a buffer. The energy level in the buffer must be monitored to determine when enough is available. At this point, it can be provided to the load – a circuit that does something with the energy. This continues until the stored energy is used up, after which the cycle begins again.

If you want to put this idea into practice immediately, a ready-to-use kit is available from Texas Instruments (EZ-2500-SEH [1]). It is based on the Cymbet EnerChip EH solar energy harvesting module [2] and provides a complete platform for an autonomous domestic wireless sensor system. This kit is primarily intended for rapid prototyping. If you'd rather put something together yourself, read on...

significant results with a modest investment

Eternal energy

As already mentioned, we focus on solar energy here, so the transducer is a solar cell. We looked for solar cells available in the price range of 30 pounds/euros. All manufacturers specify the dimensions and the maximum voltage and current. If you calculate the corresponding power figures (voltage times current divided by the area in square centimetres), you will see that there is a large spread — from slightly more than 2 W/cm² for a cell with an area of just under 25 cm² to a hefty 12 W/cm² for a cell with nearly the same size. If you also check the prices, you can see that the higher-priced models are by no means always better. Accordingly, it's certainly worthwhile to shop around on the Web and do a bit of maths.

The yield per unit of incident light (watt/lux) is only rarely specified, which is a pity because this is an important parameter. From measurements on a cell with a price of 4 euros we saw that the figure of 200 mA at 1 V promised on the package was achieved only with perpendicular illumination on a cloudless day. With subdued artificial light or rainy weather, it amounted to no more than around 0.02 mA at 0.2 V.

Mind the gap

Most electronic components need at least 3 V to do anything useful, and small motors typically need at least 5 V. The gap between what a solar cell can deliver and what we need for practical use is thus approximately 3 V or more. Of course, you can bridge this gap by using a relatively large solar panel or connecting several cells in series or parallel, which amounts to the same thing. However, other solutions are also possible, which brings us to the second block in the block diagram. Two options are described below.

The first is based on the Maxim MAX1044 switched-capacitor voltage converter IC [3]. As illustrated in **Figure 2a** and **2b**, it connects an external capacitor C_e alternately in parallel with the input voltage V_{in} and in reverse series with storage capacitor C_s. The operating current of the IC is approximately 30 µA, which is 50 µA less than its predecessor, the ICL7660, with which it is fully pin compatible. The circuit shown in **Figure 3** doubles the voltage from the solar cell, and with several MAX1055s operating in cascade you can multiply the input voltage even more (**Figure 4**). Here C_e has a value of 10 µF and C_s is the storage device in the block diagram, which can be as large as you wish. We have more to say about this shortly.

Retro technology

We weren't satisfied with a minimum input voltage level of 1.5 V. It should actually be possible to harvest voltages lower than 1 V, and preferably even lower than the transistor base-emitter threshold voltage of 0.6 V. After a bit of detective work, we found the solution shown in **Figure 5**. The principle is not new. It's based on the work of Cockroft and Walton in the 1930s, with further refinements by Dickson in the 1970s, after whom this technique is named. The Dickson charge pump is enjoying renewed interested in recent years because it can be used (in a further improved form) as a separate unit in an IC to boost the supply voltage for the rest of the IC to the desired level [4]. However, it can also be implemented quite well with discrete components.

Briefly, it works as follows (see **Figure 4**): X and $\overline{X}$ are anti-phase clock signals. When X is low, the voltage at the first node is $V_{in} - V_d$, where V_d is the forward voltage drop over the diode. When X goes high, the voltage rises to $V_x + (V_{in} - V_d)$, where V_x is the amplitude of the clock signal. This causes D2 to conduct until the voltage at node 2 is $V_{in} + (V_x - V_d) - V_d$. If you connect enough of these stages in series, you can raise a low input voltage to any desired level. We used an astable multivibrator (AMV) built from bipolar transistors as the clock source. The result is shown in **Figure 5**. The necessary component values can be calculated from the formula for the output voltage:

$$V_{out} = V_{in} + N \cdot \left(V_x \cdot \frac{C}{C + C_p} - V_d - \frac{I_{out}}{(C + C_s) \cdot f_{osc}} \right) - V_d$$

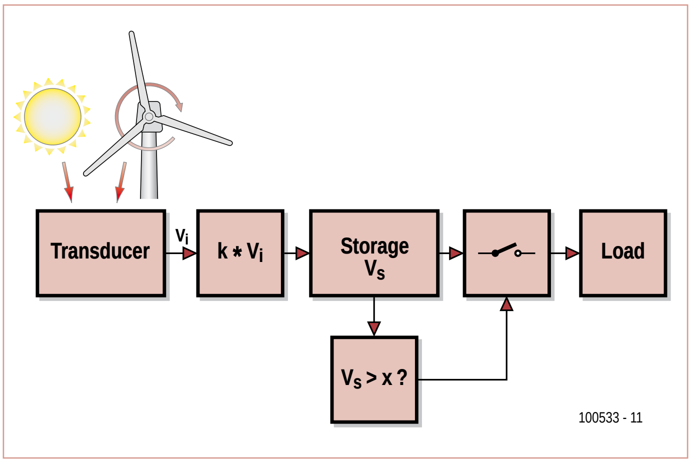


Figure 1. Basic block diagram of an energy harvesting system.

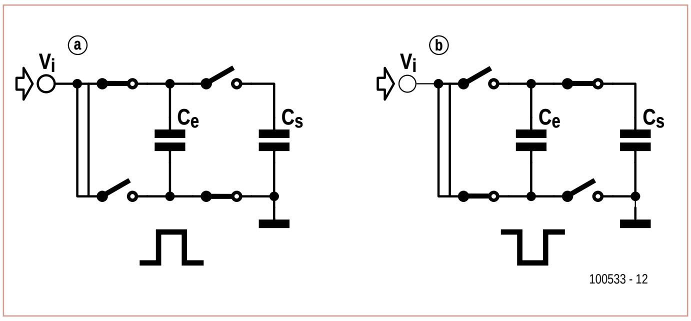


Figure 2. Operating principle of voltage multiplication with a switched capacitor. C_e is connected to the supply voltage in phase 'a' and in series with C_s in phase 'b'. The resulting output voltage is $-V_i$, so the total voltage between the input and the output is doubled.

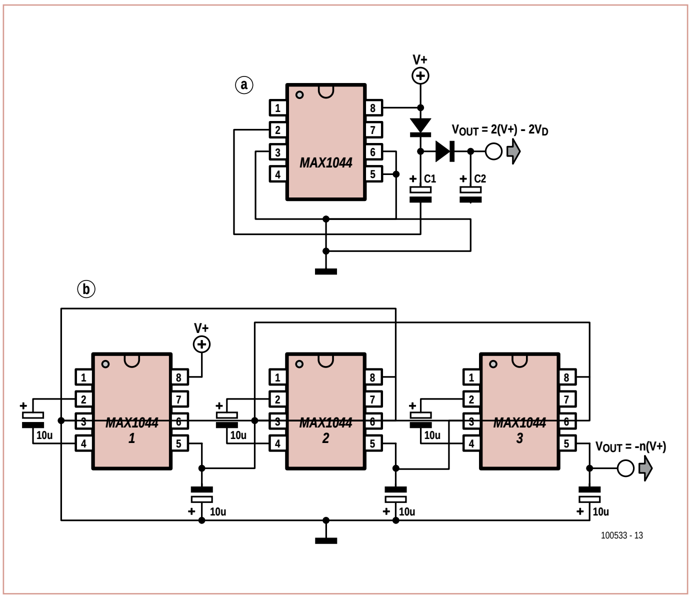


Figure 3. A MAX1044 configured as a voltage doubler (a) and as a voltage

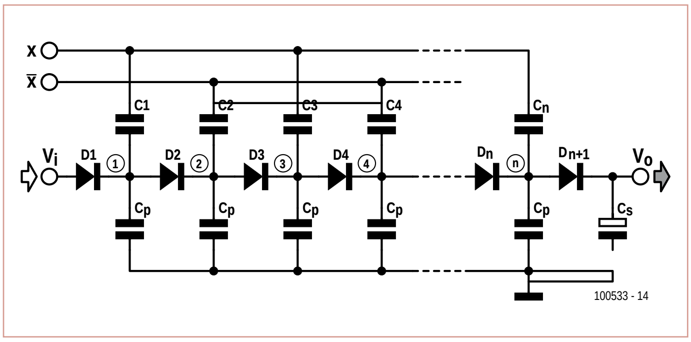


Figure 4. Basic diagram of a Dickson charge pump.

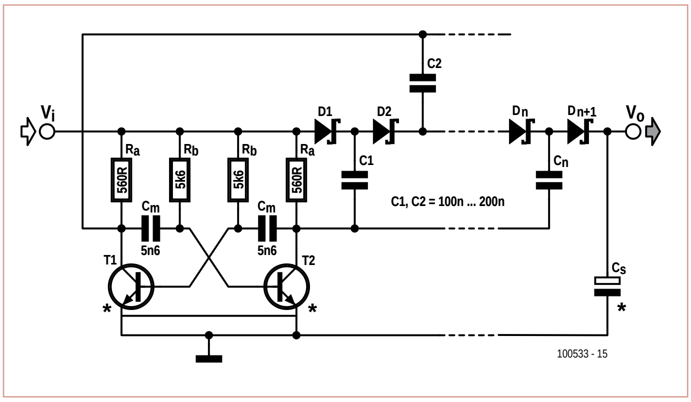


Figure 5. Voltage multiplication with an AMV and a Dickson charge pump. Voltages as low as 200 mV can be harvested if the AMV is built with germanium transistors.

In addition to V_x, V_d and V_{in}, the terms of this formula are *N* (the number of stages), *C* (the value of capacitors C1, C2, etc.), C_p (the parasitic capacitance), I_{out} (the output current), and f_{osc} (the clock frequency). For the enthusiasts, the derivation of this formula can be found in reference [4] with a bit of searching.

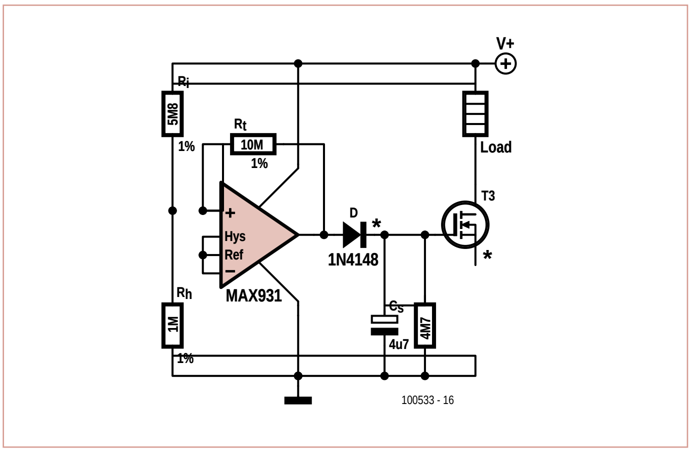


Figure 6. This circuit monitors the voltage of the storage buffer (*V*+) and switches on the MOSFET when enough stored energy is available.

Applied math

The formula clearly shows several things. Firstly, normal diodes with a forward voltage drop (V_d) of 0.6 V have a highly detrimental effect on the result, but this problem can mitigated by using Schottky diodes, which have a forward voltage drop of only 0.2 V (or as little as 75 mV at low current levels). Secondly, the parasitic capacitance (C_p) of several dozen picofarads is hardly negligible. If the value of *C* is kept small, it takes less time for the pump to start filling up the storage capacitor, but this also reduces the contribution of V_x. As V_x is equal to the input voltage, it must be used economically. It is therefore better to make *C* much larger than C_p (for example, 100 pF or 220 pF), so the ratio of C to $C + C_p$ is nearly 1. Thirdly, the effect of the load current I_{out} can be minimised by choosing a clock frequency that is as high as possible.

With an AMV constructed using BC550C transistors, useful energy can be harvested at voltages of around 0.6 V or more. Can we do even better? On eBay we found type AC175 germanium transistors, and with them the circuit starts working at around 200 mV (with thanks to an idea from Vladimir Mitrovic published in the December 2009 edition of Elektor). And once the AMV starts working, it continues to operate until the input voltage drops to approximately 80% of the level necessary to start working.

Storage space wanted

Encouraged by this result, we encountered the next challenge: energy storage. To but it briefly, electrolytic capacitors need several hours to charge, batteries need several days, and both lose most of their charge overnight. An electrolytic capacitor is therefore better, and the question is how big it should be.

The answer may be calculated from:

$I = C \times dV/dt$

$C = I \times dt/dV$

For example, if C_s must supply a current of 1 mA and the voltage on C_s may drop from 5 V to 2.5 V in the process, we need an electrolytic capacitor with a value of 0.8 mF (1 mA × 2 s × 2.5 V), so two 4700 µF capacitors connected in parallel are more than enough. Two seconds may seem like a short time, but bear in mind that an ATtiny (for example) can operate with as little as 200 µA and can certainly do something useful in two seconds, such as reporting a reading in a ZigBee network. Supercaps and other heavy-duty devices can be used for more demanding tasks. Expensive? Not at all. We picked up a 0.15-F device for about 6 pounds, at a recent electronics car boot sale.

Economical watchdog

The final stages of the block diagram are the voltage monitor and the switch that supplies power to the load. The difficulty here is that C_s must be monitored constantly to see whether it has accumulated enough energy, but at the same time no current should be drawn from it. We regarded a separate battery supply for the monitor as unacceptable. Once again we found the solution in a Maxim device: the MAX931 is an ultra low power, low cost comparator with 2%

reference, and it draws almost no current as long as V_{cc} is less than 2.5 V. Above that point this user-friendly IC draws only 2.5 µA. Furthermore, the input leakage current is only around 0.03 nA. This means that high-value resistors can be used to set the trigger thresholds, so the current consumption remains in the microampere range. **Figure 6** shows the schematic diagram. The selected resistor values yield an upper trigger threshold of approximately 5 V and a lower trigger threshold of approximately 2 V. This broad hysteresis is necessary to ensure that the comparator output level is always either high or low. The calculation of the resistor values is explained in the data sheet [5]. The resistor and capacitor at the output are optional; they keep the MOSFET in the on state as long as possible. The MOSFET must have a low gate–source on voltage ($V_{G\text{-}Son}$) and the lowest possible on resistance ($R_{D\text{-}Son}$). We found the ZVN4424A suitable for currents up to 260 mA, and the IRF3708 can be used for higher-current tasks. Both devices are readily available (from Farnell and other sources).

Figure 7. The circuit of Figure 6 implemented with an IRF3708 and a 0.15-MF electrolytic capacitor drives the small pump at the rear. The connector is for the solar panel.

Conclusion

In this article we have examined several ideas that you can use according to your own wishes. Germanium transistors are still available in relatively small quantities as 'new old stock', but they are no longer being made (unless someone rediscovers this market niche). All of the circuits can easily be built on prototyping board, so there are no PCB layouts in this article.

Figure 8. The arrangement of Figure 7 in an experimental waterproof setup.

Of course, you are probably wondering what these circuits can actually do in practice. The answer depends largely on the position of the solar cell relative to the sun, the weather, and the required voltage. With a panel costing around 10 pounds, we were able to charge our 0.15 F capacitor to approximately 9 V and use it to power a small 12-V pump. The cycle time for this was 5 minutes in full sun and approximately 30 minutes in rainy weather, which is not a problem for a small pump that supplies water to a few garden plants. We also placed a chime arrangement with a small 5-V motor on the window sill. On very cloudy days it played a couple of times a day, but in sunny weather we heard it every hour. Solar energy is free, but especially in the winter it's scarce. Bear in mind that large organisms, such as broad-leafed trees, spend the entire winter waiting for better times. In a certain sense, these circuits are comparable to such organisms.

(100533)

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3. www.maxim-ic.com/datasheet/index.mvp/id/1017
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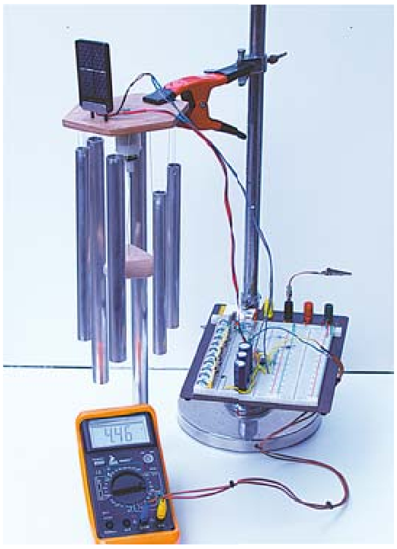


Figure 9. A solar cell supplies 0.2 to 1 V to a Dickson charge pump with 17 stages constructed on a piece of prototyping board. The motor starts running at approximately 5 V.

Thin FAT

Open source FAT file system libraries for embedded applications

By Stephen Bernhoeft (UK)

The FAT file system has become the de facto universally readable file system. A number of architecture-neutral, open-source implementations exist. Before using a solution, it behoves the developer to understand something about how the File Allocation Table system actually works. Before choosing a solution, read this!

The core idea

A File Allocation Table (FAT) holds a collection of linked lists. There is one list associated with each file and each successive list element describes where to find the next part of a file and where to find the next list element.

The lists are the simplest conceivable. Each element consists only of a pointer to the next element — there is no explicit data in the FAT. Given that there is no explicit data in the FAT then how can it be useful? The answer is that the data is implicit. Each non-reserved value in a FAT chain has two meanings: one is that of pointer to next list element, the other is pointer to file data.

A FAT can be considered as an array (**Figure 1**). Given the value of FAT[x] we can find the next item. For example, if the FAT chain for a given file begins at FAT[3] and this holds '14' (0xE), the next item in the list is FAT[14]. Now FAT[14] may hold the value '4' so the next item is FAT[4]. If FAT[x] holds the reserved value 'EOC' (End Of Cluster) then that is the end of that chain.

The first two FAT entries (FAT[0], FAT[1]) are reserved. No FAT entry can ever point to these first two entries. The first, FAT[0] holds a legacy field, the 'media byte'. The second, FAT[1], is used by the operating system to record a 'clean' or 'dirty' shutdown. An important corollary is this: when interpreted as a cluster number, a FAT entry must first have 2 subtracted from it. If a FAT entry is 14, then the cluster number is (14–2) = 12 (0xC). So in figure 1 FAT[14] also points at cluster 14 – 2 = 12 which holds the first part of the actual file data, and FAT[11] points at cluster 11 – 2 = 9 which holds the final part of the actual file data.

This can be considered the basis of the FAT system, however much extra detail must be added to describe a real implementation.

FAT uses little endian format

FAT entry point

How is FAT navigated? The idea is that we begin at the root directory. A directory is a single file, which holds a series of 32-byte entries (this is true for FAT16 as well as FAT32). Each 32-byte entry holds a structure describing another file or directory. The entry includes create time, file attributes and a 'pointer into the FAT'. The way we initially locate the root directory differs from FAT16 to FAT32. With FAT16 we calculate the location and size of the root directory using the Volume Boot Record (VBR). In FAT32, the VBR gives the FAT chain start-index of the root directory file — a FAT32 root directory file can grow without bound. In both cases we can also work out where the FAT itself begins using information in the VBR.

The first FAT element in a FAT chain is not found in the FAT itself, it is found in a directory entry. The single exception to this rule is the FAT32 VBR field BPB_RootClus, which contains the first FAT element in the FAT chain for the root directory.

Disk space is allocated in clusters of contiguous hardware sectors. Because the cluster size is known and clusters are composed of contiguous sectors, FAT needs only the starting sector of a given cluster. Sector size is usually 512 bytes although FAT supports sector sizes of 512, 1024, 2048 and 4096 bytes.

What is the purpose of clusters? It is to keep the number of FAT-

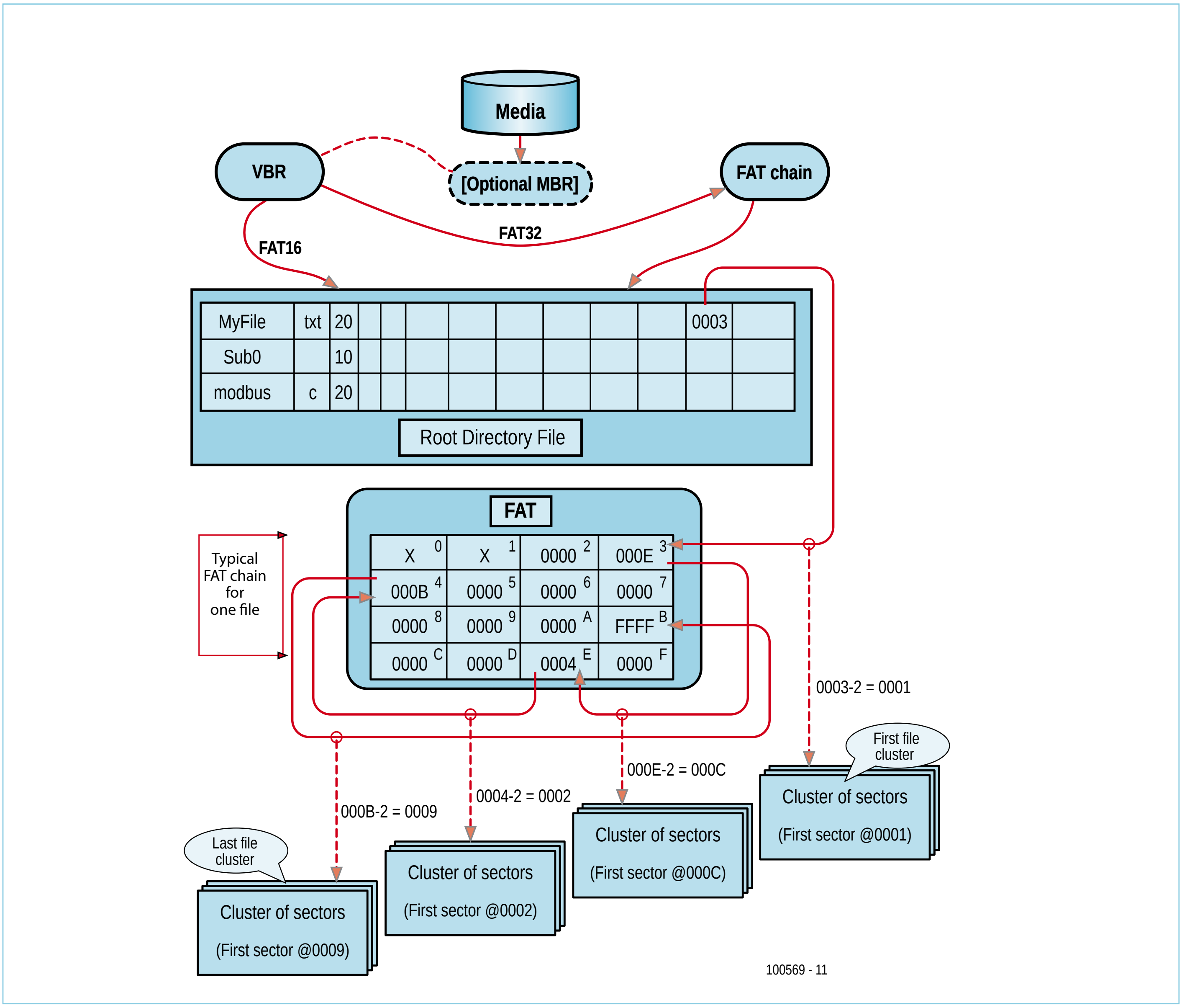


Figure 1. Overview of FAT file system and media organisation. (0xFFFF is the end of the example FAT chain). Partitioned media hold a Master Boot Record (MBR), not located in a partition, which contains the primary partition table. Each entry in this table tells us the partition type (FAT, OS/2, Linux, etc.), starting sector and count of sectors in the partition.

addressable regions at a sensible value: with a cluster size of 1, a large file would have a very long FAT chain; one element for each logical sector occupied by the file. With a cluster size of 64, we only need a single FAT entry for every 64 logical sectors, with the disadvantage that a file using 65 logical sectors (blocks) wastes 63 logical sectors.

Open source FAT libraries

Many FAT implementations are available on the net, commercial and free, and sometimes they are part of a larger project. It was decided to concentrate on open-source, platform-independent FAT libraries. The minimum requirements for the tests were:

- Access to root directory files;
- Create/Open/Read/Write/Truncate;
- FAT32 support (for maximum media compatibility);
- ANSI C (C90 preferred).

We also have an additional preference:

- There is no obligation to publish user code.

In other words, ideally we should be free to use the code as we like. Is this inconsistent with the spirit of open source? Not necessarily: I may be happy to share the source to a module (such as a FAT library), but it may be commercially suicidal to share the code to a complete application, such as a novel piece of test gear.
To aid testing, a 'library test suite' was developed. This is a DOS-like interface (**Figure 2**) allowing the user to interactively test the library

Formatting

As embedded programmers we typically do not require a format function. If you do need to format flash media, be aware that it is usually a mistake to use one of the standard PC utilities. The reason is that the various file system structures (partitions, clusters, etc.) should be aligned to so-called erase blocks. It is not possible to erase one byte. Instead, an entire erase block (perhaps 64 sectors) must be erased. Careful positioning of FAT structures done by the SD card manufacturer assists the card's internal logic in performing its main tasks:

- Wear levelling — ensuring long life of the card.
- Fast read and write access

If the format program is not 'SD-Card aware', performance and card life will suffer.

Only two of the surveyed libraries actually support a format function:

- EFSL – Maybe! The function mkfs_makevfat is undocumented by the authors, and the few references found on the web are not encouraging. Perhaps the default volume label, 'DISCOSMASH!' is a warning...
- FatFs – Flash media aware.

using DOS-like commands via a terminal emulator such as Realterm. The test suite is available on the web page for this article [1].

When customising a generic library one typically has to define:

- A media-initialise function;
- A sector write function;
- A sector read function.

There will usually be a library configuration file where the amount of file buffering can be adjusted (more RAM means faster file I/O) and the types of file operation required can be specified (more ROM means greater functionality).

The example target was Microchip's PIC18F Starter Kit 1 (DM180021), running code generated by the C18 compiler, with all optimisations enabled. Compilation was also done for the PIC24FJ256GB110 using the C30 compiler. This compiler allows a code size/speed trade-off: the smallest possible code size option was chosen. No hardware was available to test the results, however.

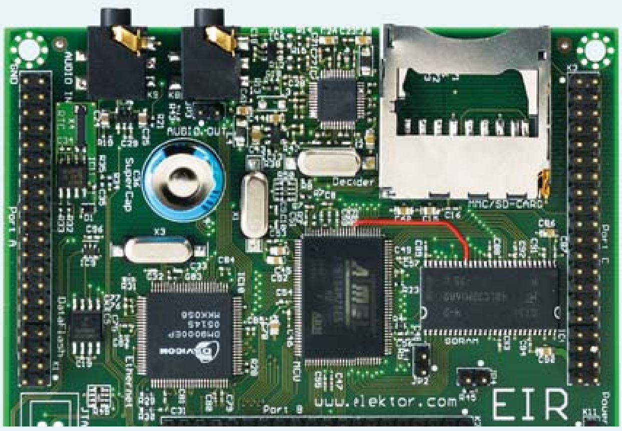
EFSL

The 'state of play' with EFSL is a little hard to judge. The obvious download at sourceforge.net/projects/efsl/ is efsl-0.3.6. The

SD cards and licensing

Many microcontroller development boards nowadays have an SD card connector. In most of these systems the SD card connector is simply hooked up to the SPI bus of the microcontroller, without the use of a dedicated host controller. The SD card standard is controlled by the SD Card Association, "an industry-wide organization setting industry standards to promote SD product acceptance in a variety of applications". The SD Card Association requires that all companies planning to or manufacturing SD host products (e.g. cell phones, cameras or computers) or SD ancillary products (e.g. adapters or SD I/O cards) join the SD Card Association and enter into a Host/Ancillary Product License Agreement (HALA) with the SD Card Association and the SD-3C, LLC. This is regardless of how the card may be used, in SPI mode only or not.

So, if you design or build such a board, do you need to pay a license fee? Even if the SD Card Association would like you to, the answer is probably *No*. According to the document *SD Host Controller Simplified Specification Version 2.00 February 8, 2007* an SD host product is a system containing a host controller that complies with this specification. According to the SD Card Association the host controller is situated between the SD host connector and the SD bus driver.



It will be very likely that your system will not comply with the host controller specification and so your board can not qualify as an SD host product. But please don't take our word for it; this is what we make of it. If in doubt, ask the SD Card Association. Elektor cannot accept any responsibility for any loss or problems caused by improper interpretation of the SD Card Association's rules.

www.sdcard.org/developers

accompanying manual warns “This version is currently not really usable”. The current stable version is 0.2.8. The source tree comes with some example targets and good documentation.
To use EFSL first modify the example header files to suit your target. For the PIC, the following files/modifications apply:

config-sample-avr.h
```
//#define HW_ENDPOINT_ATMEGA128_SD
#define HW_ENDPOINT_PIC_SD
//#define DEBUG
```

interface.h
```
#elif defined(HW_ENDPOINT_PIC_SD)
#include “pic_efsl.h”
```

types.h
Confirm euint16 etc are correct.

Configuration options exist to trade-off performance for RAM usage. However, there are no configuration options available to trade functionality off against code-size. For example, file write is always available.
The core user contribution is to define one structure and four functions (see examples atmega128.h, atmega128.c). Equivalent PIC files (pic_efsl.h, sd.c) were written for this article.

In config.h, we chose “`#define IOMAN_NUMBUFFER 1`”. The manual recommends one buffer per File-System object, two buffers per file, an extra buffer for seek/rewrite operations, and an extra three buffers to “smoothen” file list operations.
For our test program (one file open with seek and list), this is already 7 x 512 = 3584 bytes. We could not afford that on the example target, and so we used just one buffer.

Licence
“*…you are allowed to statically link against the library without having to license your own code as GPL as well.*”

Conclusion

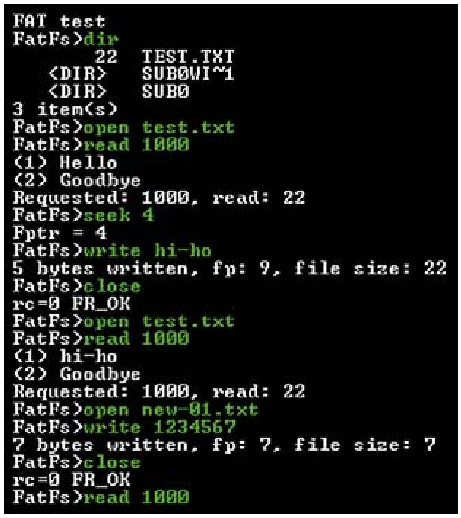


Figure 2. Screenshot of a library test session.

EFSL is quite widely used — for example NXP’s AN10916 and ST’s AN3102. It does not appear to be as widely used as FatFs however. It is worrying that the new version, 0.3.6, seems to have been abandoned.
On the other hand, the actual source code and documentation are of a high standard, and the fact that major chip vendors have used in their application notes is reassuring.

Internet
sourceforge.net/projects/efsl/files/

FatFs

FatFs has an impressive collection of sample projects. Along with code, there are schematics showing interfaces to MMC/SD, IDE Hard Disk and Compact Flash media. Platforms covered are ATMega, H8, LPC2368, PIC24, µPD70F3706, and win32 (PC-based). There are extensive statistics showing code footprints and performance benchmarks for these platforms with various library configurations on the FatFs website. There is fair scope for trading code size against functionality, although some functions are grouped. Thus (f_truncate, f_stat, f_getfree, f_unlink, f_mkdir, f_chmod, and f_rename) cannot be individually enabled.
Adapting FatFs to your needs is similar to the EFSL process. The core user contribution is to define six functions — declared in diskio.h.

FAT licensing

Microsoft applied for, and was granted, a series of patents for key parts of the FAT file system in the mid-1990s. On December 3, 2003 Microsoft announced that it would be offering licenses for use of its FAT specification and "associated intellectual property" at the cost of a $ 0.25 royalty per unit sold, with a $250,000 maximum royalty per license agreement. To this end, Microsoft cited four patents on the FAT file system as the basis of its intellectual property claims. All four pertain to long-filename extensions to FAT first seen in Windows 95. Many technical commentators have concluded that these patents only cover FAT implementations that include support for long filenames, and that removable solid state media and consumer devices only using short names would be unaffected. *(source: Wikipedia)*

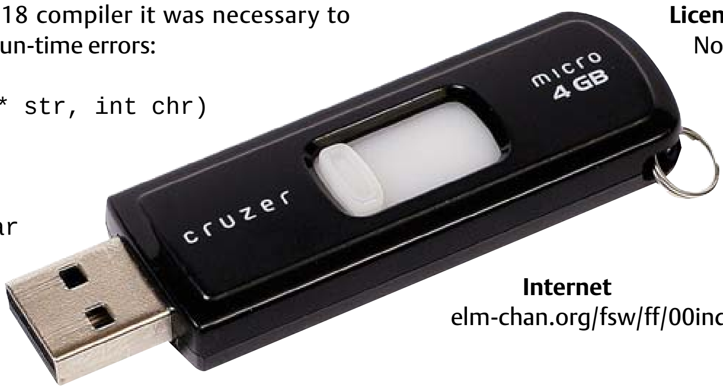
Four of these functions are essentially identical to those needed by EFSL.
When testing FatFs with the C18 compiler it was necessary to amend the code in ff.c to avoid run-time errors:

```
int chk_chr (const char* str, int chr)
```

must be re-declared as

```
int chk_chr (static char
rom *str, int chr)
```

This is a compiler-specific issue.



Licence
No restriction on use.

Conclusion
FatFs is very widely used, and is being actively maintained. It appears to be the most popular library, and thus should be relatively bug-free. The range of sample targets and statistics makes this library stand out. The source code is not easy to follow, and is very cramped in style. Documentation is reasonable, but not as clear as it could be. The user forum is useful but primitive.

Internet
elm-chan.org/fsw/ff/00index_e.html

Petit FatFs

This is a minimal version of FatFs targeted at 8-bit microcontrollers. It offers very limited write functionality:
1. You may only overwrite an existing file;
2. You cannot create a file;
3. You cannot extend the file.

In short, it does not satisfy our minimum requirements.

Licence
No restriction on use.

Conclusion
Petit FatFs is useful on (small) systems that only need read capability like MP3 players and digital picture frames.

Internet
elm-chan.org/fsw/ff/00index_p.html

SD-Reader

The web site gives a good impression. This library differs from others in at least three important ways:
1. Source requires C99 compiler. Thus, for example, the C18 compiler is unsuitable.
2. It is specifically targeted at SD cards.
3. The user interface is very different from the other FAT libraries. It is not sector-based; rather it is byte-offset based, where the byte offset is not aligned to a 512-byte boundary. However, the supplied file, sd_raw.c, provides most of the code required to use the library.

One issue is that there seems to be no way for user code to access the file position, because the 'field pos' is defined in a C file rather than an H file. (There is no ftell function either).

Another aspect is that file open does not use the familiar 'a+' etc file mode parameters. In the tests, custom code had to be written to replicate the 'a+' mode

Table 1. A comparison of several open source FAT libraries

Library	Compiler	Target	Code	Data	Comments
EFSL0.2.8	C18 v3.35	PIC46J50	34292	1258	
	C30 v3.23	PIC24FJ256GB110	15516	1266	
	ARMCC	STM32F107xx	8338	–	
FatFs R0.08	C18 v3.35	PIC46J50	21572	658	Read & Write, _FS_MINIMIZE = 1.
	C30 v3.23	PIC24FJ256GB110	9099	826	
	WinAVR	AVR	8386 / 12700	~600	Read & Write, _FS_MINIMIZE = 3/0
	CH38	H8	6980 / 10686		
	C30	PIC24	7395 / 11376		
	V850ES	CA850	4930 / 7730		
	SHC	SH-2A	5600 / 8592		
	WinARM	ARM7TDMI	6636 / 10520		
	VC6	x86	4923 / 7545		
sd-reader	C30 v3.23	PIC24FJ256GB110	5616	204	The code footprint appears remarkably small. However, this is probably because a lot of the work is done in the interface code which does the media-specific access. File sd_raw.c uses 4341 bytes. For comparison, EFSL's interface code was 2649 bytes, and that for FatFs was 1071 bytes.
File i/o library	C18 v3.35	PIC46J50	24648	2256	Large data space footprint
	C30 v3.23	PIC24FJ256GB110	35958	2258	

(append if file exists, else create).

Licence
GPLv2 or LGPLv2.1.

Conclusion
An interesting project, but currently lacks the functionality of the other examples and is sd/mmc specific, rather than media-generic. Data/variable requirements are the smallest of all the reviewed solutions.

Internet
www.roland-riegel.de/sd-reader/index.html

FAT File IO Library

As happens too often with open source projects, this library has gone missing since the article was written. We decided to publish our findings anyway in case it pops up again. The version we used is included in the download on the web page for this article [1].

Using and configuring this library is particularly straightforward. The only user-code demands made by this library are sector read/write routines (it is up to you to call your own initialisation code).

In fat_opts.h, one may choose whether to support long file names, the number of buffers, and number of simultaneously open files. It was not possible to test the code on the sample PIC18 target due to lack of RAM (PIC variable space). The library required 2256 bytes of RAM out of a total on-chip of 3.8 KB. By 'inventing' extra RAM via the C18 linker script however, some C18 estimated statistics were derived.

Licence
GPL. If you include GPL software in your project, you must release the source code of that project too. If you would like a version with a more permissive license for use in closed source commercial applications please contact the author for details.

Conclusion
An easy-to-use library, but fairly high code space and data space requirements.

Internet
The FAT File I/O library used to be here: www.robs-projects.com/filelib.html

(100569)

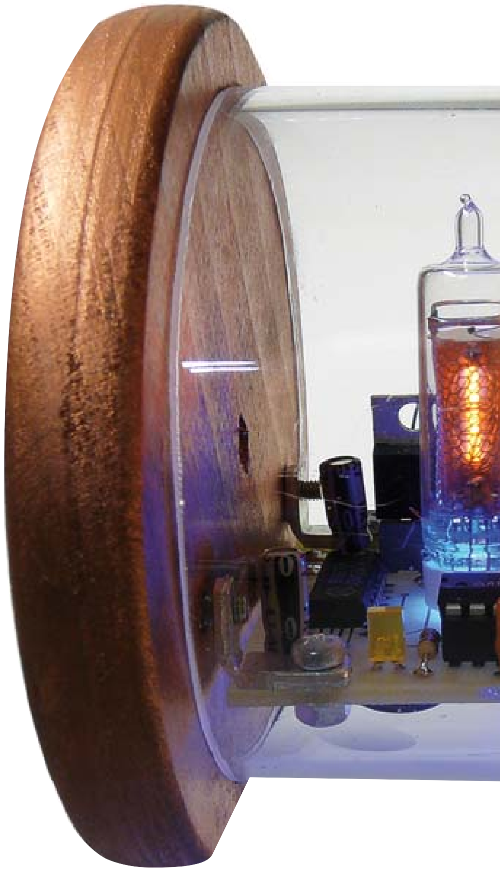
Internet Links

[1] www.elektor.com/100569

Nixie Tube Thermometer

Retro temperature display

By Dieter Laues (Germany)



In this article we describe the union of a modern microcontroller with a classic display technology to create a novel temperature indicator. In its transparent enclosure the device will set off any mantelpiece to advantage and what's more, the unit even doubles up as a night light. An external sensor allows the temperature at any desired location to be displayed.

Nixie tubes have a special charm all of their own. The author's Sputnik-style digital clock using the tubes appeared in *Elektor* in January 2007, and many variations on the theme have appeared on the internet. This digital thermometer, which uses just two tubes, is a little bit different. The temperature measurement itself is done by a DS1820 one-wire sensor, while an AT89C2051 microcontroller processes the temperature information and drives the Nixie tubes.

Hardware

Special attention was paid when designing this circuit to make construction as straightforward as possible. There are only a few components, no SMDs, and no adjustments to be made. The circuit is shown in **Figure 1** and is arranged as follows.
An external mains power supply provides between 12 V and 15 V DC to the circuit. From this voltage IC6 generates the 5 V operating voltage for microcontroller IC1 and nixie drivers IC2 and IC3.
The high voltage supply required for the tubes is generated using a step-up converter based around IC5. The MC34063 device used is a tried-and-tested PWM controller that is easy to find, inexpensive, and available in a leaded package. External MOSFET switching transistor T1, coil L1 and Schottky diode D6 generate and smooth the high-voltage output. The output voltage of the regulator is given by

$V_o = V_{ref} \times R9 / R10$

and with the values given in the circuit diagram, we have

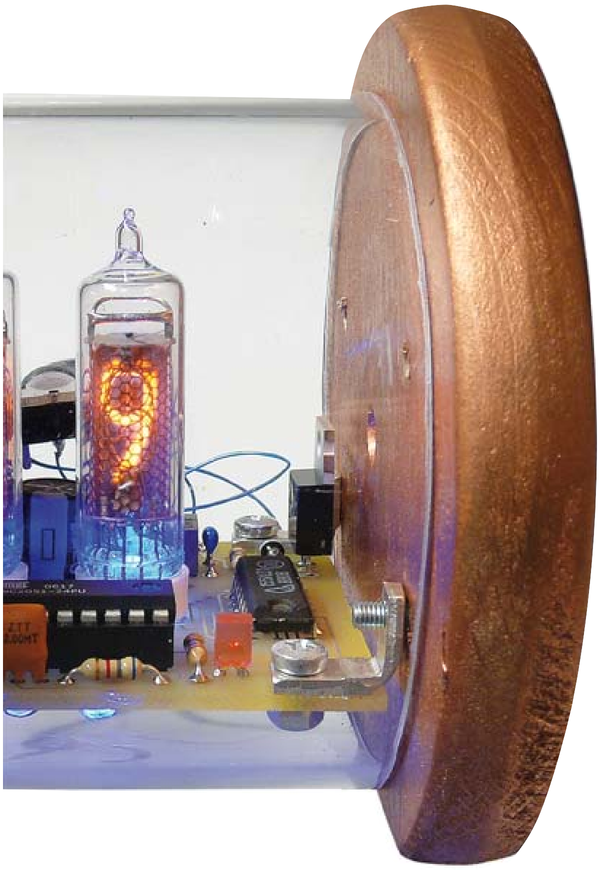
$V_0 = 1.25\ V \times 820k / 5.6k = 183\ V.$

This relatively high voltage has the advantage that the display will be bright. In his prototype the author used a value of 680 kΩ for R9 in the interests of reducing power dissipation: in this case the voltage across C4 is about 152 V. Using values between 680 kΩ and 820 kΩ for R9 you can adjust the voltage and hence the display brightness to taste.
R4 and R5 take the high voltage supply to the anodes of the IN-16 tubes, giving an operating voltage of around 143 V (with 180 V across C4), and an anode current of about 1.72 mA. This is a suitable operating point for Nixie tubes of Russian manufacture, which are inexpensive and easy to obtain. Also, the Russian Nixie driver IC type K155ID1 can be substituted for the 74141, which is now hard to obtain.
In the interests of maximising brightness, it was decided not to multiplex the displays.
The tiny MCS-51-compatible microcontroller fits all the software required to read temperature values and convert them to BCD format for output in its 2 KB of program memory. The 12 MHz clock is produced using X1, which is a resonator with built-in load capacitors. The RC network comprising R6 and C1 provides a power-on reset function, and IC4 (a Maxim-Dallas DS1820) is the temperature sensor itself. The device comes factory-calibrated and delivers temperature readings serially over its one-wire bus to pin P1.3 on the microcontroller. If jumper JP1 (on P3.4) is fitted, the temperature is shown in Fahrenheit.

Options

LEDs D1 to D4 and their series resistors R2, R3 and R7 are optional and can be dispensed with if desired. D1 and D2 show the temperature trend, while D3 and D4 provide a little additional effect lighting to the tubes.
D1 and D2 indicate whether it is getting warmer or colder. Red LED D2 lights when the temperature is rising, while blue LED D1 lights when the temperature is falling. If the temperature is steady from one reading to the next, neither LED lights.

A temperature reading is taken more than once a second, and so it can happen that the display alternates fairly rapidly between two adjacent values. To make the display less distracting it would be possible to average readings over a longer period: readers are welcome to experiment in this direction as there are a few bytes of program memory to spare, and commented source code can be downloaded at [1] free of charge.
LEDs D3 and D4 illuminate the Nixie tubes from below, one LED for each tube. Holes are provided at suitable points on the printed circuit board to allow the light through, with the LEDs soldered to the underside of the board, pointing upwards.
The brightness of the LEDs can be adjusted by changing the value of R7, and of course



Features

Display range:	0 to 99 (Celsius or Fahrenheit)
Temperature sensor:	Maxim-Dallas DS1820, accuracy 0.5 K
Power supply:	AC power adaptor, 12 V to 15 V DC
Current consumption:	170 mA at 12 V
Tubes:	Russian IN-16, 13-way solder connections
Microcontroller:	Atmel AT89C2051 (available ready-programmed)
Firmware:	BASCOM (source and hex files available for free download)
Options:	Choice of Celsius or Fahrenheit display Tube illumination LED trend (warmer/colder) indicators

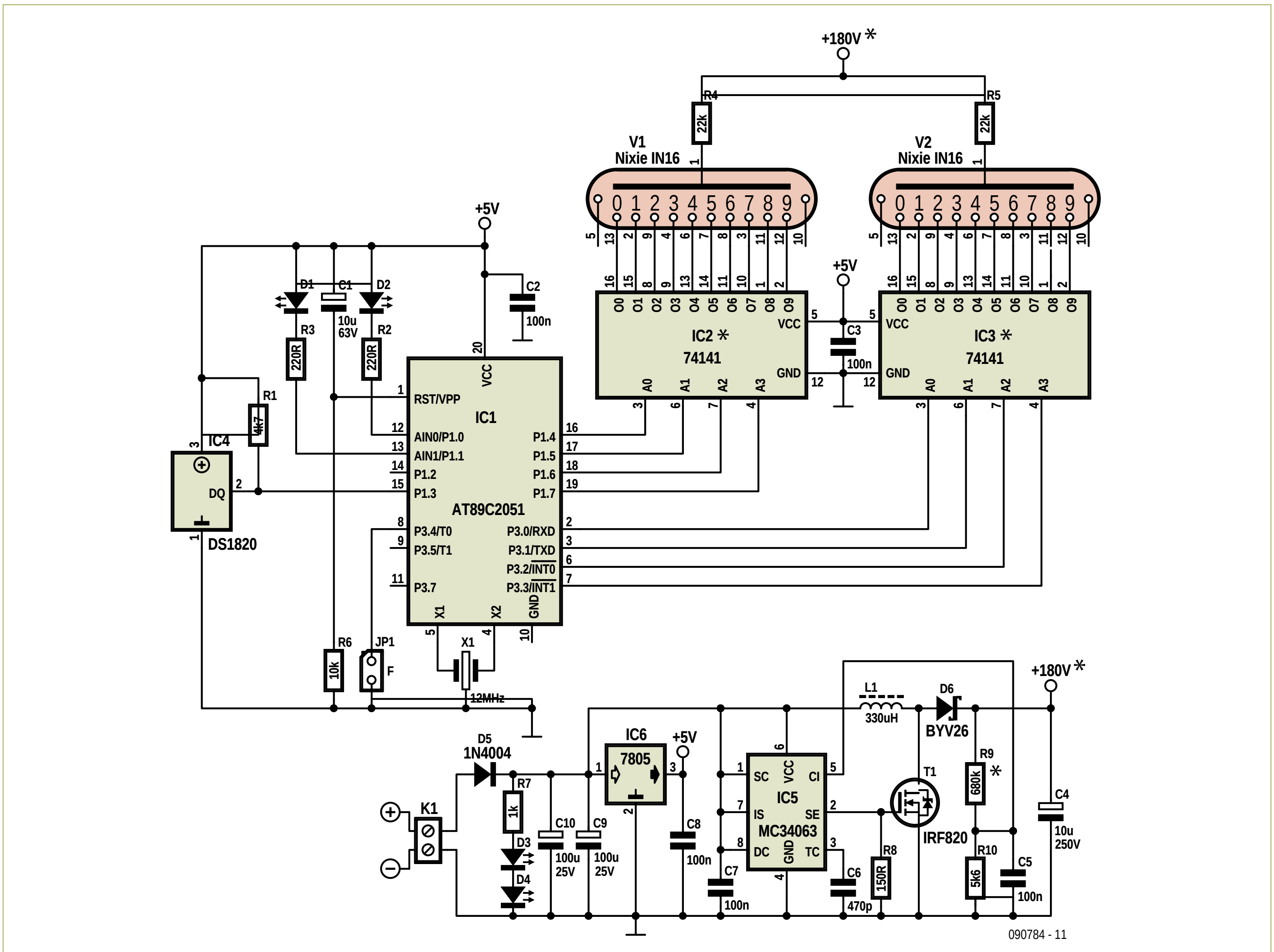


Figure 1. Simplicity is the watchword: only a few components, no SMDs, and no adjustments.

COMPONENT LIST

Resistors
R1 = 4.7kΩ
R2,R3 = 220Ω
R4,R5 = 22kΩ
R6 = 10kΩ
R7 = 1kΩ
R8 = 150Ω
R9 = 820kΩ
R10 = 5.6kΩ

Capacitors
C1 = 10µF 63V, radial, 0.1 in. lead pitch
C2,C3,C5,C7,C8 = 100nF ceramic, 0.2.in. lead pitch
C4 = 10µF 250V, radial, 0.2 in. lead pitch
C6 = 470pF, 0.2 in. lead pitch
C9,C10 = 100µF 25V, radial, 0.1 in. lead pitch

Inductor
L1 = 330µH, 1A, axial, DxL = 11x32.5 mm max., e.g. Epcos B82500CA8 or Fastron 77 A-331 M-00

Semiconductors
D1,D3,D4 = LED, 3mm, blue
D2 = LED, 3 mm, red
D5 = 1N4004

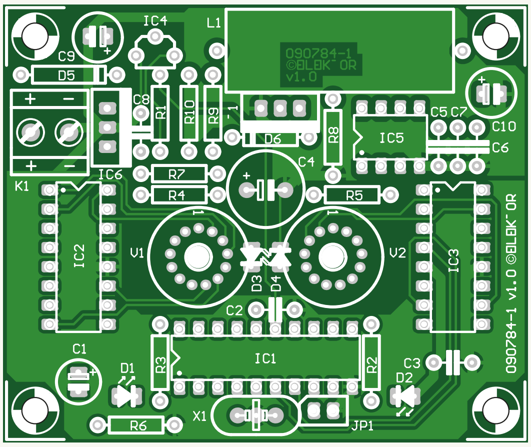


Figure 2. The easy-to-populate printed circuit board is available from the *Elektor* Shop.

D6 = BYV26 (e.g. Vishay)
T1 = IRF820 (Vishay, International Rectifier IRF820PBF)
IC1 = AT89C2051-24PU, programmed, Elektor # 090784-41 *
IC2,IC3 = 74141 or K155ID1 (Russian: К155ИД1)
IC4 = DS18S20 (Maxim/Dallas)
IC5 = MC34063
IC6 = 7805 (TO220)

Miscellaneous
X1 = 12MHz resonator, 3-pin, e.g. AEL Crystals type C12M000000L003
JP1 = 2-pin pinheader, 0.1 in. lead pitch (optional jumper, see text)
K1 = 2-way PCB screw terminal, lead pitch 5mm
V1,V2 = Nixie tube type IN-16 (e.g. Sovtek ИН-16)
PCB # 090784-1 * (artwork free download at [1])

* see www.elektor.com/090784 or Elektor Shop page.

you can select the size and colour of the LEDs as you wish. In the author's prototype he used blue LEDs, which were particularly effective in the dark in conjunction with the orange glow of the tubes. Unfortunately, the IN-16 tubes bought for the Elektor lab prototype came with an opaque grey plastic base, and so it was not possible to recreate the LED illumination effect.

Software

The software running in the microcontroller was written using the BASCOM 8051 compiler from MCS Electronics, which includes commands to support the one-wire bus interface.

After initialisation of all variables and of the sensor the software runs in an infinite loop fetching a new temperature reading roughly every 750 ms. The value is converted to Fahrenheit if required, the fractional part is discarded, and the result converted to tens and units digits in BCD format to be passed to the Nixie drivers. The reading is also stored and used in the next iteration of the loop to drive the trend indicators D1 and D2.

Despite the simplicity of the software structure, it turned out to be harder than expected to get the timing of communications with the DS1820 right. The bus must be reset between requests, and the chip must not be disturbed by a request while it is carrying out a measurement. Sometimes a mistimed request can make the chip get into a state where it stops responding altogether and must be reset. However, none of this need concern the constructor, who can just use the software downloaded from [1] or a ready-programmed microcontroller from the *Elektor* Shop.

If the temperature should go negative the display will simply show '00' (the minimum reading) and temperatures above 100 °C are displayed as '99' (the maximum reading). The display also flashes '99' if the temperature sensor is not connected or is faulty.

Construction and operation

All components apart from the Nixie tubes are fitted to the printed circuit board **(Figure 2)**, which is available from the Elektor Shop. At first, just solder in sockets for IC1, IC2 and IC3. Take care to check the polarity of the electrolytic capacitors, and in particular of C4, before applying power! Now plug in the mains adaptor, and check that a voltage of approximately 180 V appears across C4 (if R9 is 820 kΩ). Take care here with the high voltages, and do not touch the printed circuit board while power is applied.

Now allow C4 to discharge and fit the tubes. On the back of each tube, exactly in the centre behind the glass there is a light stripe that indicates pin 1 (see also the datasheet). It can be quite fiddly to thread thirteen wires of identical length through the holes in the board, so it is a good idea to trim the wires to different lengths so that each one is a little shorter than the next, like organ pipes. It is then easy to thread the wires one at a time, starting with the longest. Finally make sure the tube is vertical and solder the connections.

Now fit the Nixie driver ICs and the programmed microcontroller in their sockets. When power is reapplied the temperature should appear on the displays.

Enclosure

The prototype was mounted in a clear acrylic pipe of diameter 80 mm cut to 75 mm in length. This type of pipe is hard to come by in the DIY sheds, but a wide selection of sizes and wall thicknesses is available from online emporia. It is important to cut the pipe exactly perpendicular to its axis as any unevenness in the end faces will look unsightly, although it is relatively easy to work acrylic by hand using a file or sandpaper. A circular saw is the best way to cut the pipe, but if necessary it can be done by hand, for example using a hacksaw with a fine-toothed metal blade. A U-shaped mitre block of the type intended to help with cutting skirting boards makes a good guide for a clean square cut. The side cheeks were made from solid wooden wheels bought from a DIY shop with a diameter of 100 mm. A single cut created a flat on the wheel on which the unit stands. It would be possible to paint the side cheeks, or to make them from acrylic sheet with a thickness of around 4 mm. Two holes were made in the pipe, one for a jack socket for the temperature sensor and the other for the power socket. The side cheeks were each drilled for two M3 screws at exactly the right height for the fixing bracket, which must be threaded on at least one side.

Next the sockets were wired to the appropriate points on the printed circuit board for the sensor and power supply, and the assembly slid into the pipe. The side cheeks were screwed to the interior brackets from outside using M3 screws. The board is now suspended between the two side cheeks, which in turn are fixed to the acrylic pipe. With a little judicious twisting of the assembly things can be arranged so that the board is inclined upwards, making it easier to see the Nixie tubes from slightly above.

Because of the heat generated by the tubes and the voltage regulator it is not practical to mount the temperature sensor on the board or inside the enclosure. To measure the ambient temperature, place the sensor away from the device on the end of a cable.

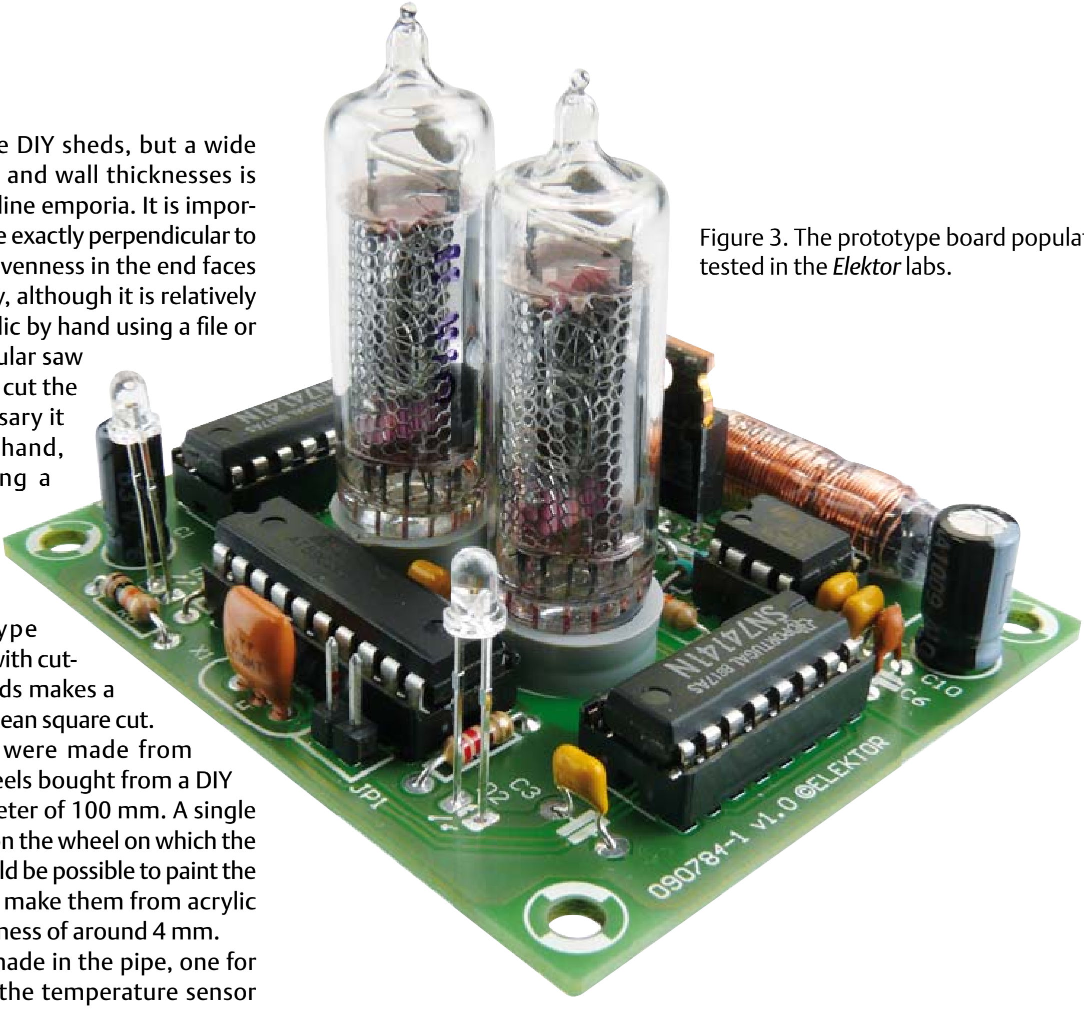


Figure 3. The prototype board populated and tested in the *Elektor* labs.

Of course, the thermometer can be used for other purposes too, such as measuring the temperature inside another device (perhaps that tube amplifier you have alongside it?).

Conclusion

The circuit generates high voltages internally, and so it is important to use an insulating enclosure with no exposed metal parts. Nylon screws and insulating sockets should also be used, or alternatively the mains adaptor and the temperature sensor can be connected permanently using well-insulated wires with suitable strain relief and grommets for the holes in the enclosure. The connections to the DS1820 should also be insulated, or the whole sensor assembly can be enclosed in heatshrink tubing. The reward for all this effort is the pleasure of seeing warm orange, occasionally flickering digits lighting up your living room!

(090784)

Internet Link

[1] www.elektor.com/090784 (web pages for this project)

Design Resources

www.atmel.com/atmel/acrobat/doc0368.pdf (AT89C2051 datasheet)

http://datasheets.maxim-ic.com/en/ds/DS18S20.pdf (DS1820 datasheet)

http://www.tube-tester.com/sites/nixie/data/in16.htm (information on the IN-16 tube)

http://gadget.mda.or.jp/pdf/K155ID1 (K155ID1 datasheet)

www.onsemi.com/pub_link/Collateral/MC34063A-D.PDF (MC34063 datasheet)

www.die-wuestens.de/ (Nixie tubes and drivers)

Flight Data Recorder

For hikes and rides too

Your Captain: Grégory Ester (France)

No need for a piggy-back board any more — the ATM18 module takes to the air to give you a whole heap of very useful information recorded during your flight in a radio-controlled plane. Are you ready? Well, fasten your seatbelts, we're about to take off. Welcome aboard flight ATM18 in the company of Elektor!

So you haven't actually got your pilot's licence yet, even though you know how to fly a Cessna or a Big Lama? When a curious passer-by shyly enquired: "What speed does your little plane fly at?" my off-the-top-of-my-head answer was received with a certain degree of scepticism. In this sort of situation, the project described here may be of interest to you.

Measuring the speed

The MPR-AIR-V3 detector consists of a Pitot-static tube and allows us to measure the speed of any craft moving in the air, as long as the plane doesn't go over 563 km/h... Version 3 of this module also lets us display the result directly on the PCB via a 7-segment display.

The electronics PCB weighs 4 g and the Pitot tube 3 g, and the resolution (step size) is 1.6 km/h (1 mph). The supply voltage must be at least 3 V and must not exceed 16 V. The whole thing is factory-calibrated and temperature-compensated.

The two silicone tubes connect the probe to the electronics board, as is clearly shown in **Figure 1**. The holes on the Pitot probe must be positioned at least 13 mm clear of the leading edge of the wing, so as to avoid any disturbance to the measurement. Of course, the nose of the aircraft would be the ideal place for the probe, but as you'll already have realized, it's not a jet we're flying here, and so we need a propeller to push the air behind our nice plane.

Once all the elements have been positioned, it's a very good idea to glue or firmly fix the silicone tubes and the probe in place in order to immunize them against any vibration.

Measuring the altitude

The MPR-ALT-V3 detector is an altimeter (weighing in at just 4 g!) that uses atmospheric pressure to measure the altitude. It too is factory-calibrated and temperature-compensated. The maximum altitude reached can be directly read on the PCB via a 7-segment display. That's certainly handy, but it's not what we're really interested in here.

The maximum altitude that can be measured is 10,000 ft... No, you're not dreaming: there really are four noughts after the '1' — equivalent to 3,048 m! So which of us is going to fly their plane the highest in the sky? The competition is open!

The PCB can be installed wherever you like in the plane. The hole for detecting the air pressure must be perpendicular to the direction of flight. If the detector is enclosed, a small silicone tube can be used, brought out flush with the fuselage.

The resolution (step size) is 4 ft (1.2 m), and the supply voltage must be a minimum of 3 V but must not exceed 16 V.

Just a word about the single-digit display when used stand-alone (i.e. without the project described here); an example may help. The circuit is powered up, and the plane flies off. Our Wizz plane (**Figure 4**) has reached an altitude of 328 ft (around 100 m). When it returns to the ground, all you have to do is look at the lone digit, which will display, for example (in feet) 3 then 2 then 8 then blank, then once again 3-2-8, and so on. The maximum value reached and stored will be reset when the module is powered down. In this mode, you can select either the imperial system (feet) or the metric system (metres) by wire-strapping or jumpering the brown and yellow pins. At start-up, if the figure that blinks is a '0', the reading will be in imperial units;

if it's a '1', in metric.

It's worth pointing out that the Eagle Tree data sheets are extremely clearly and thoroughly written. This is an important factor, as the technical documentation, closely followed by the application notes, is the sole link between the product and the end user! What's more, it's best to go directly to the manufacturer's website [1] so you can download the latest version.

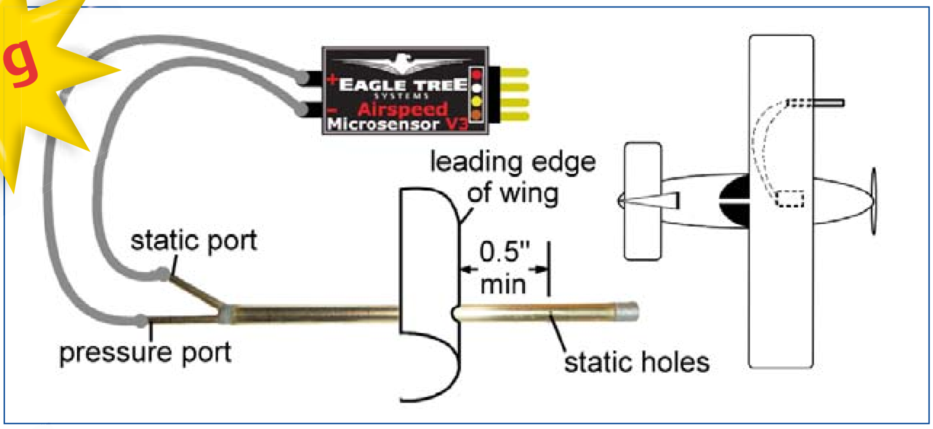


Figure 1. The MPR-AIR-V3 module with its Pitot-static tube.

Watch out: there's an I²C about!

We're going to be using both Eagle Tree modules in I²C mode, but to do this we need to 'unblock' them using the eLogger 8.63 application in association with the eLogger V3 module. But don't worry, you won't have to fork out for this module, all you need do is to state clearly in a note with your order that you want the "I²C mode unblocked detector" and Alexandre at Studiosport, France [2] will prepare your order accordingly.

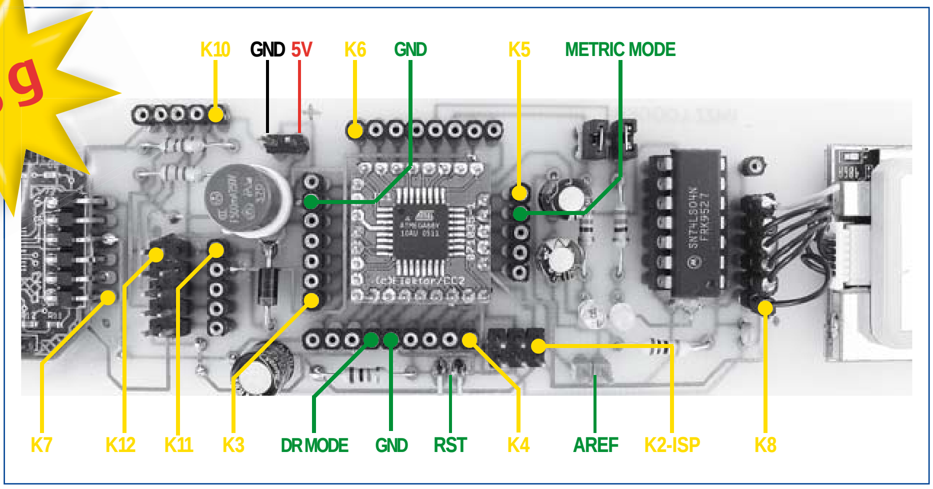


Figure 2. The flight data recorder PCB with connector references.

The flight data recorder board...

...is based on the use of the EM-406A GPS receiver, the VDRIVE1 or 2 from Vinculum, and our two Eagle Tree detectors (**Figure 2**). In the centre is the ATM18 module without its mother board. The data recorder circuit diagram (**Figure 3**) comprises above all connectors, so you'll need to identify these before you can make the interconnections with the peripherals:

- K1: 5 V_{DC} V_{IN}. F1 and D1 together protect our recorder against power-supply reversal. The ratings for the diode and the fast-blow fuse should be chosen according to the power supply being used.
- K2: ISP connector.
- All the pins of the ATM18 module are brought out to K3, K4, K5, and K6. So this featherweight board (just 53 grams) can also be used as a universal development board!
- K7: VDRIVE module.
- K8: EM-406A GPS module. Pin 6 is brought out to K9.
- K12: 1 (GND-Eagle), 2 (VCC-Eagle), 3 (PB1-SDA_Eagle), 4 (PC2-SCL_Eagle). Pins 5–10 are not used. All K12's contacts are brought out on K10 and K11.

Jumpers JP3 and JP4 enable use of the LEDs D2 (orange, O) driven from PC4 and D3 (yellow, Y) driven from PC5, respectively. These are useful for displaying information about our system; the orange LED indicates power-on reset (file set-up and marker writing) and the yellow LED lights during recording. So it's best not to remove the USB key while these LEDs are lit. Note too that it's best to plug in the key before powering up the circuit.

Jumper JP2 offers an optional reference voltage for the ADC and JP1 allows the microcontroller to be restarted (reset).

The microcontroller's PB2 port lets us choose the mode for the data recorder. If the port is left floating, the circuit operates as a flight data recorder. If PB2 is connected to 0 V, it goes into RDR mode (see below).

For flight data recorder mode operation:

1. Connect up the four wires from our two Eagle detectors: ground to K12(1), 5 V to K12(2), SDA to K12(3) and SCL to K12(4)
2. Apply power
3. Program the microcontroller using the 70_WIZZ_RIDE_DATA_RECORDER software [5]

Recording format

The "WDR.TXT" file created at start-up is going to contain all the data collected from the detectors. Below is an example of the file contents:

```
WDR-->
***********************
UTC:15h16m04.000s
LAT:46Deg21’39.4’’N
LON:006Deg28’45.5’’E
SAT:06 SIGNAL:1
ALT:495.5M
0.kmh 0.m
***********************
UTC:15h16m20.000s
LAT:46Deg21’39.6’’N
LON:006Deg28’45.4’’E
SAT:09 SIGNAL:1
ALT:476.5M
0.kmh 0.m
```

The first line tells us that the system is configured in flight recorder mode (WDR = Wizz Data Recorder), the marker "WDR-->" is written into the file each time the system is powered up afresh.

The universal time (UTC), the latitude, longitude, and the number of satellites used to calculate the values are collected, along with the altitude, by means of the EM-406A GPS receiver.

The last line corresponds to the plane's speed and altitude. At power-up, these values are 0.

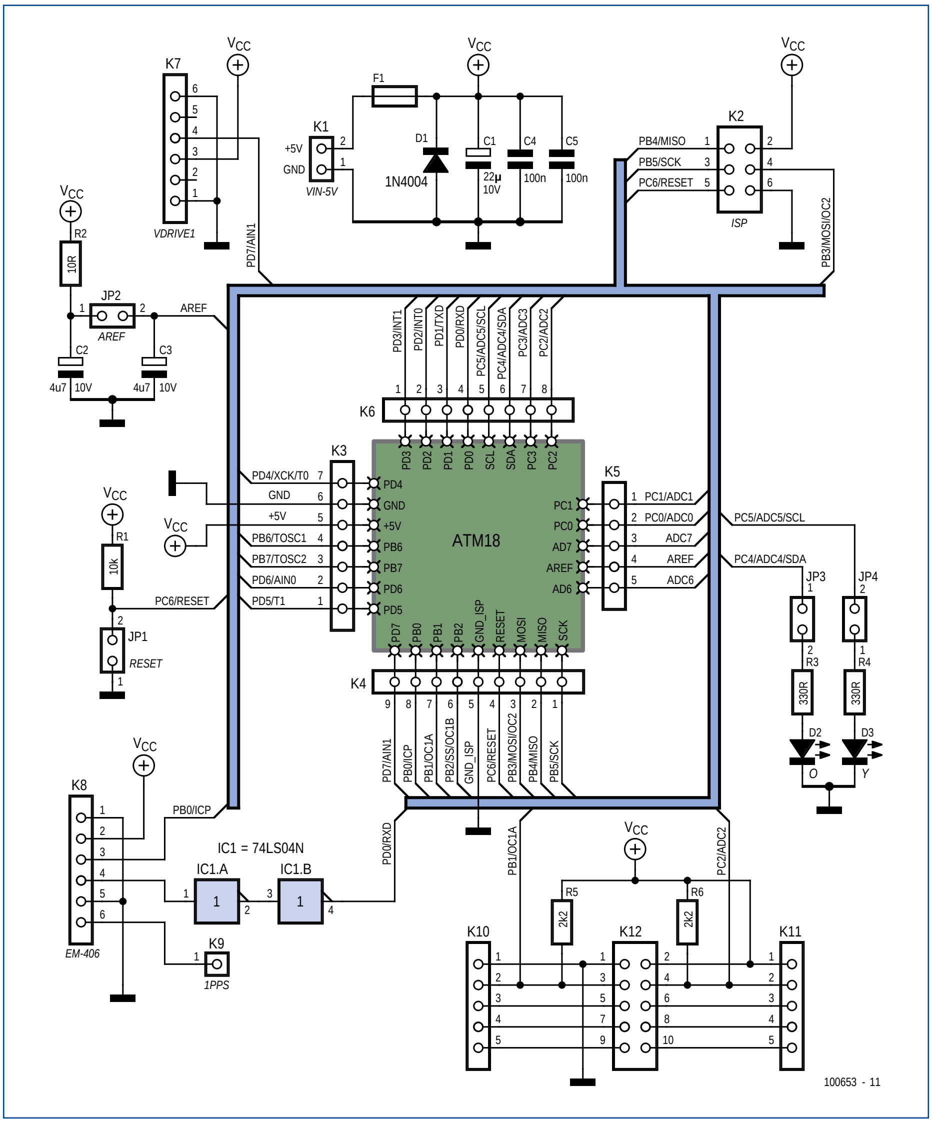


Figure 3. The circuit diagram consists almost entirely of connectors.

4. Power down
5. Plug in the USB key, then power the whole thing up again.

The microcontroller's PC0 port lets you select the units. If the port is left floating, the speed will be in km/h and the altitude in metres, while if PC0 is connected to 0 V, the speed will be in mph and the altitude in feet.

GPS

The GPS module incorporates GlobalSat's EM406-A device with built-in antenna. Of course, there's nothing to stop you using another GPS receiver, or even your own GPS/EIA-232 module using bipolar NRZ (non return to zero) coding, interfaced using the well-known MAX232 device or an equivalent.

Pins 1 and 5 of our EM406-A module are connected to ground, while pin 2 is connected to the 5 V rail. Pin 4 is connected to the input of an inverter, which is in turn connected to another inverter and thence to PD0. This is necessary, as the high level output from the EM406 (2.85 V) is lower than the minimum high threshold of the PD0 input (V_{IH} = 0.6 × V_{CC} with V_{CC} = 5 V, i.e. 3 V minimum for the PD0 input to be regarded as 'High'). So without the presence of 74LS04, the UART would never receive anything at all.

The use of six satellites for the data calculation ensures very acceptable accuracy. Recording of this data will only begin once this condition has been verified; the data from the Eagle detectors, on the other hand, are recorded continuously. The GGA frame is what if used to recover the data during flight. Consequently, we need to send the receiver a command so as to enable this to be sent. This is achieved via pin 3, connected to PB0.

```
Print #1 ,
"$PSRF103,00,00,01,01*25" (Ena-
ble GGA message for a 1Hz con-
stant output with checksum
enabled)
```

If you want to send other instructions to the receiver, it may then be necessary to recalculate the checksum, and a little program has been provided to do just this [5].
The GPS's 1PPS (Pulse Per Second, a signal @ 1 Hz) pin is brought out on K9.

VDRIVE1 or 2

The Vinculum chip has been developed by the company FTDI. It makes it possible to provide a USB host function for any onboard application. The modules using this chip are available in several versions. We're not about to discuss here all the ins and outs of the very many possibilities offered by this innovative product, but simply to suggest an application example that is going to enable us to add a mass storage memory to our system.
The Vinculum chip used manages the file system; the interface is a serial type. Below is an example of a command (in BASIC) to let us create the file called WDR.txt, which contains the start marker 'WDR-->'.

```
Print #2 , "OPW WDR.txt" +
Chr(13);
Print #2 , "WRF " ; "8" + Chr(13);
Print #2 , "WDR-->";
Print #2 , Chr(13) ; Chr(10);
Print #2 , "CLF" + Chr(13);
```

To be able to control our module by sending it ASCII commands, the first operation involves modifying the file named "firmware" — and I did say just "the file". To do this, we're going to use the *Vinculum Firmware Customiser V1.1b* software plus the file *VNC1L firmware V3.68* [3]. In the options, you'll need to be careful to select *IPA Mode ASCII* and *Ext Command Set Mode* and check

Carry out testing before gong airborne!

In order to test the modules before making the final connections to the flight data recorder, we're going to use the Minimod18. Minimod18 is the big sister of ATM18, let's recall its specifications:

Do not take photos while flying!

- Ideal size, at 80 × 25 mm, and weighing 27 g.
- A good brain with its ATmega328P-AU controller.
- An elephant's memory: 32 kB Flash, 1 kB EEPROM, 2 kB RAM
- Easy communications: I2C, SPI, USART, etc.
- Not difficult: bootloader or ISP
- Backlit LCD 2 × 8 in 4-bit mode (HD44780)
- Powering: USB port or K3(2) or 5 V mains PSU with USB connector
- On-board EEPROM: an extra 64 kB!
- Runs at 16 MHz

The "68_EAGLE_TREE_ET_MINIMOD18" software [5] is loaded into the flash memory by means of the universal AVR programmer, connected from a free USB port on your PC to the ISP connector K3 on the Minimod18 board.

The I^2C bus enables communication with our two detectors, and their supplies are derived directly from the Minimod18 board: K1(2)= 5V, K1(10) = GND, K1(5) = SCL, K1(6) = SDA.

At power-on, the addresses of the peripherals present on the bus are displayed, $EA for the speed detector and $E8 for the altimeter.

The measurement result is recovered in two bytes (LSB then MSB) via the I^2C bus and displayed on our tiny 2 × 8 LCD, which is more than adequate for our application. By default, the speed is displayed on the first line in km/h and the altitude in metres on the second line (see photo). Keep S1 pressed for conversion into imperial units (mph and feet).

LEDs Flash at Power-on. After giving the file containing the new configuration a new, customized name, click *Write* then *Finish* to conclude the procedure. You will be asked for a firmware code (you can just enter "123", for example).
At this stage, all you now need to do is load the file containing the new configuration, i.e. your new firmware that you have just customized. For this action, we've connected the VDRIVE module directly to a USB on the PC using FTDI's USB/TTL-223R serial converter, having first fitted the jumper CN4 or J4 as shown in **Figure 5**. Once the firmware has been loaded using the *VPROG VNC1L-1A Flash Programmer* software and the jumpers have been put back into their original positions, the VDRIVE [7] module is ready to be incorporated into our project.

Ride/ hike data recorder

By now you might be wondering about the purpose of the RDR mode. If you like hiking, and like the author never quite know which way to fold your map up, the following may be useful.

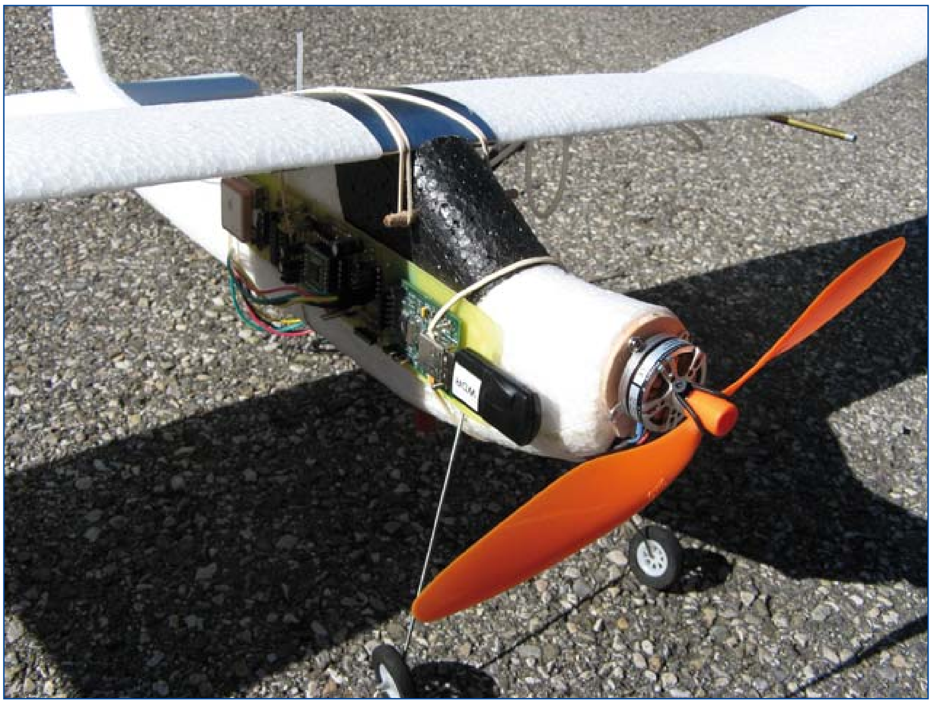


Figure 4. The flight data recorder has been tailor-made for the Wizz [4].

After each hike, you carefully note down your impressions of the walk on a note that you put away more or less carefully in the right drawer with the reference of the correct large-scale map, onto which you have more or less approximately pencilled the route taken. Ideally, of course. Now, the Ride Data Recorder (RDR) is the state of the art, paperless equivalent of it all.

A battery + a 5 V switch-mode Battery Eliminator weighing 12 g + the RDR + some chocolate or a few muesli bars + a bottle of water in the backpack and we're off! Don't forget your walking shoes!

Given that the circuit in this configuration draws an average current of around 200 mA, you'll be able to do a quick calculation to choose a battery capacity to suit the duration of your hike.

All you have to do to enable the RDR mode is connect the DR_MODE pin (PB2) to ground. For as long as the USB key is plugged into the VDRIVE, a RDR.TXT file receives only the RMC frames sent from the GPS module.

In order to be able to plot the route corresponding to these frames, all you have to do is unplug the USB key and convert the RDR.TXT file into the KML format using the NMEA2KML software [6]. With Google Earth already installed, you can then run the file in KML format. The result is then displayed graphically (**Figure 6**).

Create a folder bearing the name of your hike, for example "Mont Blanc 2010", and copy/paste the KML file there. All that then remains is to use a word-processor to write down your impressions. All stored in the same place, in the same directory. You're now a thoroughly modern hiker! And it works for railroad journeys too!

(100653)

Internet Links

[1] www.eagletreesystems.com

[2] www.studiosport.fr
(Eagle Tree modules, contact Alexandre)

[3] www.ftdichip.com/Firmware/Precompiled.htm

[4] www.model2a.com

[5] www.elektor.com/100653

[6] thomaspfeifer.net/gps_route_converter.htm

[7] www.ebconnections.com
(supplier for VDRIVE)

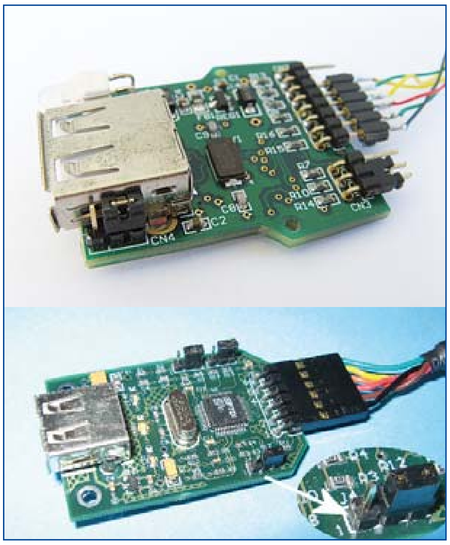
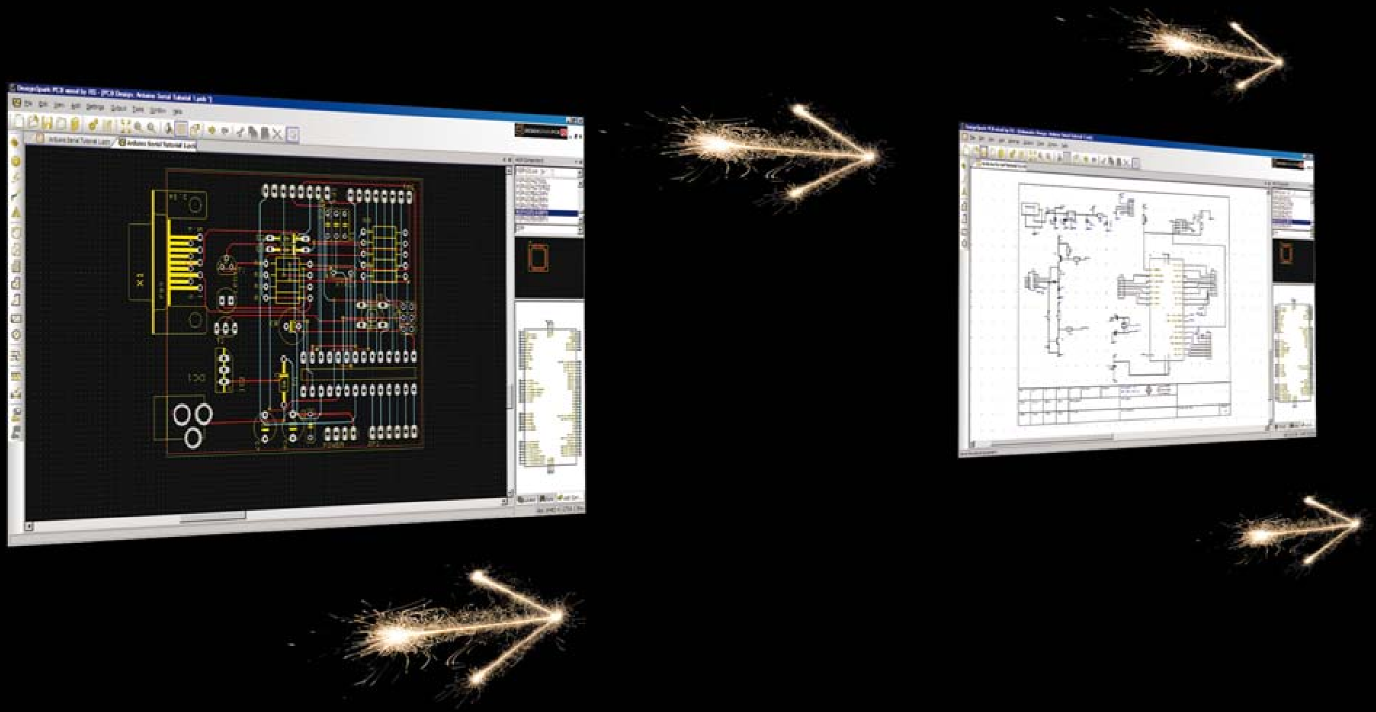


Figure 5. VDRIVE2 & VDRIVE1.

Figure 6. A nice little walk.



Energy Saving Tips (some less serious)

Wind it up

The best energy saving device I can think of has been on the window sill in our kitchen for many years now: the Freeplay radio. It has a large, transparent blue enclosure with a crank on the back (twenty turns of the crank gives it enough energy for a cooking session) and a solar cell. This device is based on an original design by Trevor Baylis, which is now available in many different forms. He intended it to be used in regions and countries where electrical power and information are scarce. Sadly enough, the situation has not changed significantly since then.

The nicest thing about this radio is the surprises. It always stops by itself when the energy from the winding crank is exhausted or there isn't any sunlight, and of course it also starts playing by itself, often when you least expect it. For many years this radio was the first herald of spring; it spontaneously started playing a cheerful tune when the sun rose higher and peeked around the corner of the window. My tip: instead of using batteries, try using a wind-up or motion-powered device.

Act locally

As most people know, a significant amount of power is lost in electricity distribution networks. Big generators in power stations spew out electrons with lot of power, but there are so many obstacles in the form of cables and transformers that only a fraction of this power is left when we want to use it for lighting or heating our homes, companies and schools. 'Act green' means 'act locally'. This applies to food and travel, and it applies equally well to the distribution of electricity. Many of our computers and lighting systems could be powered or charged directly from voltages in the range of 5 to 24 V. My tip: connect two 12-volt car batteries in series, charge them from solar panels or an intelligent charger connected to the AC mains, and install a low voltage network in your home for your computers, mobile devices, lighting, and what have you. Act green – act locally!

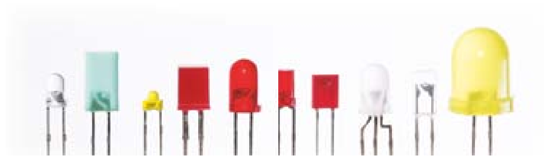
The 'assembly' tip

When you are really serious about energy saving you should give up your electronics hobby and get rid of the soldering iron. If this is too hard for you, then try to use it less often. How? By using SMD parts only. SMD components are smaller and need less energy for soldering because they heat up quicker. They also need less solder, which is another energy saver. But there is more. Because SMD parts are smaller, they need less board space. Smaller boards need less heated etching liquid. Because SMD parts are smaller than through-hole parts, they need less material to manufacture them. Ten times smaller housings for SMD parts are no exception and they have no leads. No leads means no holes to drill! You save electricity, drill bits and time. No leads also means that there will be no clipped of leads to throw in the bin after mounting a board. Think of all the metal you save! So just by using SMD parts you save lots of resources and by saving resources you save energy.

The 'LED OFF' tip

Almost every circuit has a power-on LED. This LED is always on, even if we don't care. The charger of my electric toothbrush for instance has such an LED; it is always on, but I only look at it when I replace my toothbrush (three times a day of course). My router/modem and Wi-Fi access point both have several LEDs shining brightly 24 hours a day without anyone around to look at them. Each of these LEDs consumes probably 10 mA, the default current that most designers force out of habit through an LED.

There are two ways to save energy here. First of all, stop passing 10 mA through an LED, often 2 mA or even less is more than enough. How often do you need to look at it in bright sunlight? That's right, hardly ever.



The second way to save energy is simply to stop using LEDs everywhere. Or, if you really want one, put a pushbutton in series with it so that it will only light up when you press the button. Another way would be to use LEDs to indicate fault conditions only. Indicator on demand, that's all you need.

Energy awareness

How about marking each switch with a sticker showing the estimated annual electricity consumption and cost? And of course, this sort of sticker should be mandatory for all AC power adapters.

Wake and sleep with your television set

Why don't television sets have a sleep mode like notebook computers? Considering that so many viewers are themselves in a kind of sleep mode in front of their television sets, it would be logical for the television set to slowly fade out in order to save energy. If the remote control is fitted with an accelerometer, you only have to tap it to restore the television set to normal operation. Waking up the erstwhile viewer is more difficult. Maybe it would help to make the programmes more interesting.

Intelligent AC outlet design

It shouldn't be that difficult to make AC power sockets a bit more intelligent. With a bit of electronics, they could be made to change colour. For example, they could turn red when a device that draws a lot of power is plugged in, as a warning to the user. If a small current is drawn for an extended period, the socket-outlet could turn orange. And of course, the socket itself shouldn't draw any current when nothing is plugged in – that's the real challenge for the designer.

Just do it

The laws of physics tell us that every action causes an immediate reaction. This also applies to energy costs: it's easy to start reducing your electricity consumption.

For example, systematically de-energising (unplugging) all devices with a standby operating mode can save the average household more than 50 pounds per year.

Kill standby power consumption

Make a list of all the devices powered from the various distribution circuits in your house. When you leave home for an extended period, use this list to switch off the circuits that power devices that don't need to be left on. Naturally, you should leave the alarm system, the refrigerator and the freezer on, but you can prevent 'hidden' energy consumption for standby power by simply flipping the switch for the other devices. This can yield significant savings, especially with long journeys.

Convert your car to run on hydrogen

A conversion kit for cars so they can run on hydrogen generated in an environmentally friendly manner (such as from solar energy or wind energy). If you think this is all wishful thinking, you should have a look at the website listed below (using your energy-efficient computer, of course). http://www.switch2hydrogen.com/

Digital photo frame with motion sensor

Digital photo frames are becoming more and more popular. Prices have dropped dramatically in the last while; now you can pick up a nice digital photo frame now for just a few dozen pounds. It also looks quite attractive in your living room or bedroom. The photo frame displays the pictures you have stored in its memory, periodically changing to a new picture. That's a lot nicer than an old-fashioned photo frame with an unchanging paper print.

However, a digital photo frame requires a constant source of electricity – usually from the AC power grid. A relatively large model consumes a good deal of power, mainly for the background light. Who switches it off when nobody is in the room? Most likely nobody; you might think to do this before going to bed. Accordingly, it wouldn't be a bad idea to link a motion sensor to a digital photo frame so it doesn't go on unless someone comes near it. An ordinary motion detector, such as the types sold by electrical shops or DIY home improvement centres, could be used for this. Plug the AC adapter of the photo frame into the motion detector and you're all set. You should adjust the sensor time setting so the photo frame does not constantly go on and off, and you need a photo frame that can be configured to start showing photos right after it is switched on, instead of ending up in some menu state.

There is also a manufacturer that recently introduced a digital photo frame with a built-in motion sensor: http://www.nix-digital.com/

Mind your maintenance

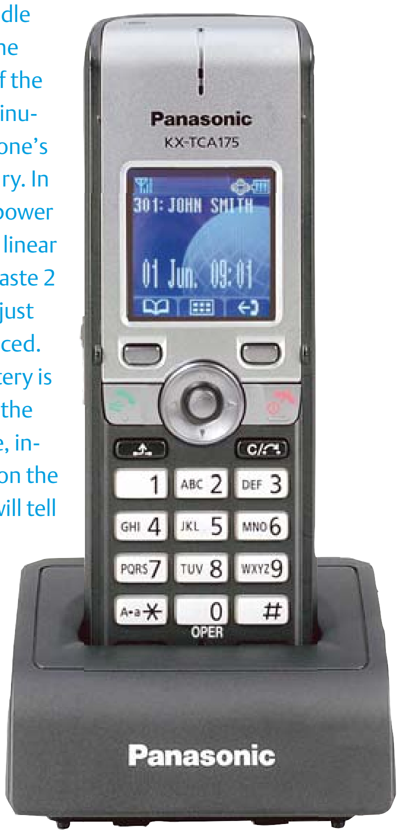
Postponed maintenance (or worse yet, no maintenance) of equipment causes lower efficiency or degraded performance. This leads to higher electricity consumption, and therefore to higher energy expenses. For this reason, you should defrost your freezer periodically. When you buy a new freezer, select a model with automatic defrosting. Even coffee machines, electric kettles and washing machines need maintenance when the heating element becomes covered with lime or scale deposits. This significantly increases how long it takes to heat the water, so the devices use much more energy. This can easily be corrected with a simple descaling product.

The 'Steal power from the mobile phone mast' tip

Mobile phone operators use your money to make big transformers hum and massive transmitters operate 24/7/356 to carry phone calls and Text traffic that — sociologists say — are 95% waffle of the type "howz the weather out there" / "I'm doing like so-so / awesome / chill / xyz / what r u doing" "yeah" "yeah yeah", uh-huh" and generally without any serious purpose except socializing, acting busy or gathering status. Now is the time to reclaim some of that energy and save on your own. The method is well established – in the old days people stole (reclaimed?) energy from nearby AM transmitters by winding lots of metal wire to form a coil an connect it up to a lamp or even a small fluorescent tube. Loud mouthed radio presenters gave the highest brightness. The 2011 equivalent is called the rectenna. Essentially it converts the electromagnetic energy from 800/900/2400 MHz cellphone masts into a tiny charge current you can employ to power a (tiny) electronic device. These masts are now all around us and unexpectedly those who hate or fear them most for being so nearby can benefit. Make a resonant antenna, preferably directional, paint it green and connect an SHF Schottky diode across its terminals. This will feed rectified RF current into a Goldcap. The more smalltalk, CEO bark and Text gibberish on the mast, the more power you're getting for free, for example, to power a medium-wave receiver based on the ZN414 AM radio chip. Reportedly 24 hours of charging yields a whopping two minutes of free AM radio listening — just enough to hear Paint it Black or catch the headlines on energy wasted elsewhere in the world.

The 'Pull the plug on DECT phone' tip

The AC power plug, that is. Most DECT phones, both base and extension, are in their charger cradle which is wasting energy big time through the standby current of the wallwart adapter and the continuous trickle charging of the phone's batteries. Both are unnecessary. In especially bad cases, the AC power adapter block is a traditional linear power supply that'll easily waste 2 watts of power all the time, just touch it if you're not convinced. Make sure the phone's battery is fully charged, then unplug the adapter. From time to time, inspect the battery symbol on the phone, if it's any good it will tell you when charging is due again. My own Philips Kala DECT base phone easily lasts four days on a single charge and an average of two 10-minute calls a day and one short battery test by briefly ringing an extension and watching the BATT symbol. It's got two dead standard 650-mAh NiCd batteries fitted. Work out your personal average for the week and allow headroom to make sure there's always enough battery capacity when the CEO phones late at night with good news. Apply stochastically distributed charging between DECT stations, that way a phone will always ring and the worst that can happen really is a short climb up the stairs to answer a call. Your health as well as that of the batteries will benefit, not forgetting the advantage of having an AC outlet free for, say, an electric kettle.



The 'Make your cellphone charge last longer' tip

It's a little known fact that the transmitter in your mobile phone employs stepped RF output power to save battery energy. In essence, the stronger the signal received from the cellphone mast, the lower the radiated energy required on the phone to set up two-way communication. A fine system ignored by but most people who will phone away till the battery goes flat. By contrast, those with the keenest sense of energy savings and wishing to make a call, will first sight the nearest cellphone mast (if necessary, using optics) and walk or drive to it to effectively reduce the distance and so enable the call to be made at the lowest battery load. The savings are enormous, and the reward is increased peace of mind on the environment. I may be overlooking something but just can't put my finger on it, must be I'm not using my mobile too often.

The 'Drive home, work in the garage' tip

A switched off car engine is a free source of heat! During winter, after work (assuming you get home by car), drive your car into the garage, engine towards the work area, and shut the garage door. Open the hood for quick heat radiation. You can even use some areas on or around the engine to pre-heat food or SMD boards. Careful, there are extremely hot surfaces around. Old cars with V8 cast iron engine blocks preferred. This tip is unsuitable EV owners.

The 'Go 800-ohms OTL' tip

For your stereo set, use an OTL (output transformerless) tube amplifier rather than one with an output transformer. At the same output power, energy savings of up to 15% are achieved through higher efficiency of the power output stage. You're also rewarded by crisper, punchier sound all round due to direct energy transmission to the drive units. Great savings on the world's precious copper resources. No more thick loudspeaker cables, plus a smaller carbon footprint for the postage (the OTL amp is much lighter).

All-Soft-555

ATtiny plays 555 MMV and AMV

By Dr. Thomas Scherer (Germany)

The chip with three fives in its type code sure is among the biggest selling ICs of all times but from today's perspective the internal block diagram certainly looks a little dated with its multitude of analogue signal paths. Can you imagine, we're even expected to calculate the value of external components and solder real resistors and capacitors to make the thing work! What's more, it isn't really that flexible. We give the design a 21st Century makeover to produce a much more versatile 'virtual 555' using an 8-pin microcontroller.

While modifying the motor controller of my electric bike I came to the conclusion that the design would benefit from an additional monostable multivibrator (MMV, monoflop). I knew I had a good supply of all the various incarnations of the 555 timer chip in my workshop. The monostable however needed to be retriggerable and the 555 can only manage that with the help of some extra circuitry. One good feature of the 555 is how little board space it occupies.

With space at a premium the extra circuitry was making the 555 solution look a little less appealing. Maybe a CD4098 monostable from the digital CMOS 4000 series would be an alternative but this is a 16-pin device making it twice as big as the 555 even before you start adding the external components. After a fruitless search for a CD4098 and much head scratching I came up with this solution called the All-Soft(ware)-555'. This would be a digital equivalent of the generic 555 timer chip built into an 8-pin microcontroller. All of its operational characteristics are programmed in software and no additional external components are necessary.

Pick a controller

There are now any number of small powerful microcontrollers on the market from several different manufacturers. The author found some ATtiny25 [1], ATtiny45 and ATtiny85 AVR microcontrollers in a drawer and thought they might just be up to the job. In addition to having the correct number of pins (in the DIL versions) they also contain a hardware timer and an A/D converter, what more could he possibly need? The only difference between the three controllers is the 2, 4 or 8 KByte flash (and RAM/EEPROM) capacity.
BASCOM_AVR from MCS-Elektronik is a simple but effective BASIC compiler for software development for these microcontrollers. The author experimented using both machine code and compiled routines to generate the time intervals and found that there was no discernable disadvantage using the compiled code. What's more there is a download link on the page of the Elektor website for this article [2] where the free demo version of BASCOM-AVR can be downloaded. The only restriction on its use is the size of the finished code cannot be greater than 4 KBytes. This is ample for the project's firmware, including any foreseeable system expansion.

Better than the original

The conventional 555 [3] can in principle be configured as either a monostable or astable multivibrator. The pulse timing is both stable and relatively unaffected by changes of the supply voltage. As a monostable it can generate pulses from a few microseconds long up to hundreds of seconds. As an astable it can go from a few hundred kilohertz down to a few millihertz. Any digital implementation of a 555 should also be able to at least match this performance.

Despite its popularity the conventional 555 has always had a number of disadvantages:

- it requires external components.
- the monoflop isn't retriggerable.
- the trigger input only responds to negative-going pulse edges.
- calculating the multivibrator duty cycle is not straightforward.

It isn't necessary of course to incorporate all the 555's shortcomings in our 'microcontroller' 555 variant. The function of the multivibrator is now configurable under software control. The active trigger edge and other finer points of operation can be changed in the firmware (see 'Features'). Memory capacity would be a problem if all the multivibrator functions were incorporated into one program particularly for the smallest variant microcontroller. In any application the All-Soft-555 will be used as either a monostable or astable multivibrator so it is sensible to divide the firmware along these lines also. The two programs are called iMono and iMulti, accepting that the latter name sounds good rather than striving for technical accuracy (both programs emulate a multivibrator).

Physical pin to pin compatibility with the original 555 is however not possible: The ATtiny uses pin 4 as ground while the 555 uses pin 1, and for other reasons we have not kept to the original pinouts.

MMV program iMono

The pinouts for the monoflop shown in **Figure 1** are fairly conventional. When the All-Soft-555 is used in an application requiring precise and/or narrow pulses a crystal can be fitted between pins 2 and 3. Inherent parasitic capacitance of the crystal usually means that the (10 pF to 15 pF) loading capacitors at either end of the crystal to earth can usually be omitted thereby cutting down on the external component count. For the majority of applications the 8 MHz and 128 kHz internal oscillator will suffice. Tests by the author indicate that you can expect the uncalibrated frequency to be within 10 %. Pin 7 is the trigger input while Pins 5 and 6 are the normal and inverted outputs respectively.

Comments in the iMono source code indicate exactly which values need to be changed to tailor the behaviour of the program to your requirements. The firmware will not accept any invalid parameters. The user can choose any one of three operating modes:

- - not retriggerable
- - retriggerable
- - extended

Features

MMV (iMono) features

- Digital, configurable monostable multivibrator
- Three modes: non retriggerable, retriggerable and extended pulse
- Programmable trigger edge: falling or rising
- Non inverting and inverting outputs
- Pulse width from 0.8 µs to 524 s
- Documented source code in BASIC

AMV (iMulti) features

- Digital, configurable astable multivibrator
- Four modes: Fast, Fixed value, VCO and VCDC
- Gate input defined in software either active High or Low
- Waveform true or inverted
- Frequency adjustable by software or control voltage
- Duty-Cycle adjustable by software or control voltage
- Frequency range 10 MHz to 1.91 MHz
- Documented source code in BASIC

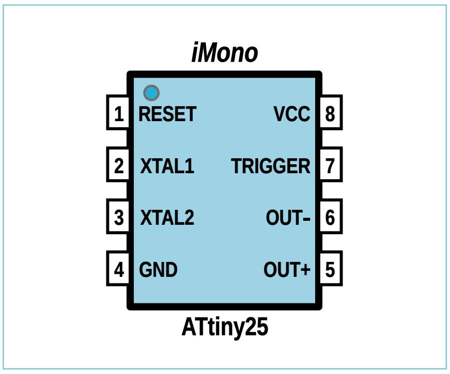


Figure 1. Pin assignments of an ATtiny25 used and programmed as a monostable.

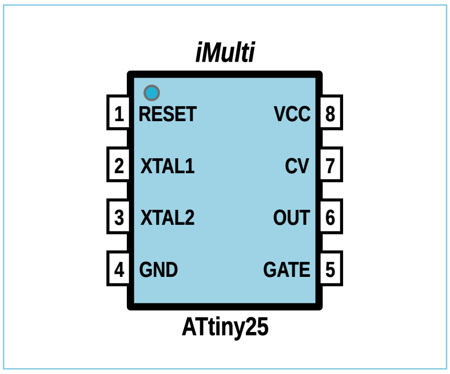


Figure 2. Pin assignments of an ATtiny25 used an programmed as an astable.

In the last mode the trigger input extends the selected monostable pulse width. The following characteristics can be programmed in software:

- trigger edge: rising or falling.
- ticks: 2 to 255 or 1 to 256 timer ticks
- clock prescaler: 1/2/4/8/16/32/64/256
- timer prescaler: 8/64/256/1024
- oscillator type: internal/external

The ATtiny25 has only an 8-bit timer so it can count from 1 to 256 timer ticks. An extra prescaler divides down the oscillator to produce the effective clock frequency (f_{eff}). The timer has a prescaler which in turn is driven by the effective clock. The output pulse length is therefore given by:

Pulse length = ticks × clock prescaler x timer prescaler / clock

Using the 8 MHz oscillator and a clock prescaler of 8 we get an f_{eff} of 1 MHz. The timer prescaler is set to 1024, counting 98 ticks to give a pulse length of:

$t = 98 \times 1024 \times 8$ / 8 MHz = 100.352 ms

This produces a reasonably accurate 100 ms MMV pulse although the accuracy of the internal oscillator cannot be guaranteed. **Table 1** indicates the achievable pulse lengths using combinations of the four parameters. The first column in italics using a timer prescaler of 8 does not produce precise results and because of its limited processing power can only count a minimum of two ticks rather than one as in the other cases.

AMV program iMulti

Pinouts on the iMulti astable mode are shown in **Figure 2.** They are not the same as the monostable version and reflect the different roles the two versions perform. An external crystal can again be connected to pins XTAL1 and XTAL2 when a higher

Table 1. All-Soft-555, MMV mode
Select the desired pulse width for the MMV program. The values in italics with a prescale of 8 have limited accuracy.

20 MHz external		Ticks:	2	256	1	256	1	256	1	256
Clockdiv	f_{eff} (Hz)	Delay	Prescale: 8		Prescale: 64		Prescale: 256		Presc.: 1024	
1	20 M	0.5 µs	0.8 µs	102 µs	3.2 µs	819 µs	12.8 µs	3.28 ms	51.2 µs	13.1 ms
2	10 M	1 µs	1.6 µs	205 µs	6.4 µs	1.64 ms	25.6 µs	6.56 ms	102 µs	26.2 ms
4	5 M	2 µs	3.2 µs	410 µs	12.8 µs	3.28 ms	51.2 µs	13.1 ms	205 µs	52.4 ms
8	2.5 M	4 µs	6.4 µs	819 µs	25.6 µs	6.56 ms	102 µs	26.2 ms	410 µs	105 ms
16	1.25 k	8 µs	12.8 µs	1.64 ms	51.2 µs	13.1 ms	205 µs	52.4 ms	819 µs	210 ms
32	625 k	16 µs	25.6 µs	3.28 ms	102 µs	26.2 ms	410 µs	105 ms	1.64 ms	419 ms
64	312.5 k	32 µs	51.2 µs	6.56 ms	205 µs	52.4 ms	819 µs	210 ms	3.28 ms	839 ms
128	156.25 k	64 µs	102 µs	13.1 ms	410 µs	105 ms	1.64 ms	419 ms	6.56 ms	1.68 s
256	78.125 k	125 µs	205 µs	26.2 ms	819 µs	210 ms	3.28 ms	839 ms	13.1 ms	3.36 s
8 MHz internal		**Ticks:**	**2**	**256**	**1**	**256**	**1**	**256**	**1**	**256**
Clockdiv	f_{eff} (Hz)	Delay	Prescale: 8		Prescale: 64		Prescale: 256		Presc.: 1024	
1	8 M	1.2 µs	2 µs	256 µs	8 µs	2.05 ms	32 µs	8.19 ms	128 µs	32.8 ms
2	4 M	2.3 µs	4 µs	512 µs	16 µs	4.10 ms	64 µs	16.4 ms	256 µs	65.6 ms
4	2 M	4.5 µs	8 µs	1.02 ms	32 µs	8.19 ms	128 µs	32.8 ms	512 µs	131 ms
8	1 M	9 µs	16 µs	2.05 ms	64 µs	16.4 ms	256 µs	65.6 ms	1.02 ms	262 ms
16	500 k	19 µs	32 µs	4.10 ms	128 µs	32.8 ms	512 µs	131 ms	2.05 ms	524 ms
32	250 k	38 µs	64 µs	8.19 ms	256 µs	65.6 ms	1.02 ms	262 ms	4.10 ms	1.05 s
64	125 k	75 µs	128 µs	16.4 ms	512 µs	131 ms	2.05 ms	524 ms	8.19 ms	2.10 s
128	62.5 k	150 µs	256 µs	32.8 ms	1.02 ms	262 ms	4.10 ms	1.05 s	16.4 ms	4.19 s
256	31.25 k	300 µs	512 µs	65.6 ms	2.05 ms	524 ms	8.20 ms	2.10 s	32.8 ms	8.39 s
128 kHz internal		**Ticks:**	**2**	**256**	**1**	**256**	**1**	**256**	**1**	**256**
Clockdiv	f_{eff} (Hz)	Delay	Prescale: 8		Prescale: 64		Prescale: 256		Presc.: 1024	
1	128 k	80 µs	125 µs	16 ms	500 µs	128 ms	2 ms	512 ms	8 ms	2.05 s
2	64 k	160 µs	250 µs	32 ms	1 ms	256 ms	4 ms	1.02 s	16 ms	4.10 s
4	32 k	320 µs	500 µs	64 ms	2 ms	512 ms	8 ms	2.05 s	32 ms	8.19 s
8	16 k	640 µs	1 ms	128 ms	4 ms	1.02 s	16 ms	4.10 s	64 ms	16.4 s
16	8 k	1.25 ms	2 ms	256 ms	8 ms	2.05 s	32 ms	8.19 s	128 ms	32.8 s
32	4 k	2.5 ms	4 ms	512 ms	16 ms	4.10 s	64 ms	16.4 s	256 ms	65.5 s
64	2 k	5 ms	8 ms	1.02 s	32 ms	8.19 s	128 ms	32.8 s	512 ms	131 s
128	1 k	10 ms	16 ms	2.05 s	64 ms	16.4 s	256 ms	65.5 s	1.02 s	262 s
256	500	20 ms	32 ms	4.10 s	128 ms	32.8 s	512 ms	131 s	2.05 s	524 s

or more exact output frequency is called for. The two internal oscillators producing 8 MHz and 128 kHz should be suitable for the majority of applications.

These alone allow operation up to 4 MHz which a conventional 555 can only dream of. Pin 5 is a gate input, used to turn the output signal on and off. The square wave output signal is produced from pin 6. The CV input on pin 7 should be a DC voltage in the range of 0 V to Vcc. It can be used to either control the output signal frequency by more than one octave or vary the mark/space ratio of the output signal in the range from 1 to 99 % (frequency modulation and PWM).

Altogether the AMV program (iMulti) has four operating modes:

- fast: high frequency with a 50:50 square wave output.
- fix: Frequency and duty cycle adjustable in software.
- VCO: Frequency via CV (1:2.56) with the duty cycle adjustable in software.
- PWM: Duty cycle via CV (1 to 99%) with the frequency adjustable in software.

Table 2. All-Soft-555, AMV mode
Output frequency selection of the AMV program. Ticks of less than 100 can only be used if it is running in fast mode.

20MHz	Ticks:	2	100	256	2	100	256	2	100	256	2	100	256	2	100	256
Cl.div	f_{eff} (Hz)	Prescale: 1 (Hz)			Prescale: 8 (Hz)			Prescale: 64 (Hz)			Prescale: 256 (Hz)			Presc.: 1024 (Hz)		
1	20 M	10 M	200 k	78.1 k	1.25 M	25 k	9.77 k	156 k	3.13 k	1.22 k	39.1 k	781	305	9.77 k	195	76.3
2	10 M	5 M	100 k	39.1 k	625 k	12.5 k	4.88 k	78.1 k	1.56 k	610	19.5 k	391	153	4.88 k	97.7	38.1
4	5 M	2.5 M	50 k	19.5 k	313 k	6.25 k	2.44 k	39.1 k	781	305	9.77 k	195	76.3	2.44 k	48.8	19.1
8	2.5 M	1.25 M	25 k	9.77 k	156 k	3.13 k	1.22 k	19.5 k	391	153	4.88 k	97.7	38.1	1.22 k	24.4	9.54
16	1.25 k	625 k	12.5 k	4.88 k	78.1 k	1.56 k	610	9.77 k	195	76.3	2.44 k	48.8	19.1	610	12.2	4.77
32	625 k	313 k	6.25 k	2.44 k	39.1 k	781	305	4.88 k	97.7	38.1	1.22 k	24.4	9.54	305	6.1	2.38
64	312.5 k	156 k	3.13 k	1.22 k	19.5 k	391	153	2.44 k	48.8	19.1	610	12.2	4.77	153	3.05	1.19
128	156.25 k	78.1 k	1.56 k	610 k	9.77 k	195	76.3	1.22 k	24.4	9.54	305	6.1	2.38	76.3	1.53	596 m
256	78.125 k	39.1 k	781	305 k	4.88 k	97.7	38.1	610	12.2	4.77	153	3.05	1.19	38.1	763 m	298 m
8MHz	**Ticks:**	**2**	**100**	**256**	**2**	**100**	**256**	**2**	**100**	**256**	**2**	**100**	**256**	**2**	**100**	**256**
Cl.div	f_{eff} (Hz)	Prescale: 1 (Hz)			Prescale: 8 (Hz)			Prescale: 64 (Hz)			Prescale: 256 (Hz)			Presc.: 1024 (Hz)		
1	8 M	4 M	80 k	31.3 k	500 k	10 k	3.91 k	62.5 k	1.25 k	488	15.6 k	313	122	3.91 k	78.1	30.5
2	4 M	2 M	40 k	15.6 k	250 k	5 k	1.95 k	31.3 k	625	244	7.81 k	156	61	1.95 k	39.1	15.3
4	2 M	1 M	20 k	7.81 k	125 k	2.5 k	977	15.6 k	313	122	3.91 k	78.1	30.5	977	19.5	7.63
8	1 M	500 k	10 k	3.91 k	62.5 k	1.25 k	488	7.81 k	156	61	1.95 k	39.1	15.3	488	9.77	2.81
16	500 k	250 k	5 k	1.95 k	31.3 k	625	244	3.91 k	78.1	30.5	977	19.5	7.63	244	4.88	1.91
32	250 k	125 k	2.5 k	977	15.6 k	313	122	1.95 k	39.1	15.3	488	9.77	2.81	122	2.44	954 m
64	125 k	62.5 k	1.25 k	488	7.81 k	156	61	977	19.5	7.63	244	4.88	1.91	61	1.22	477 m
128	62.5 k	31.3 k	625	244	3.91 k	78.1	30.5	488	9.77	2.81	122	2.44	954 m	30.5	610 m	238 m
256	31.25 k	15.6 k	313	122	1.95 k	39.1	15.3	244	4.88	1.91	61	1.22	477 m	15.3	305 m	119 m
128kHz	**Ticks:**	**2**	**100**	**256**	**2**	**100**	**256**	**2**	**100**	**256**	**2**	**100**	**256**	**2**	**100**	**256**
Cl.div	f_{eff} (Hz)	Prescale: 1 (Hz)			Prescale: 8 (Hz)			Prescale: 64 (Hz)			Prescale: 256 (Hz)			Presc.: 1024 (Hz)		
1	128 k	64 k	1.28 k	500	8 k	160	62.5	1 k	20	7.81	250	5	1.95	62.5	1.25	488 m
2	64 k	32 k	640	250	4 k	80	31.3	500	10	3.91	125	2.5	977 m	31.3	625 m	244 m
4	32 k	16 k	320	125	2 k	40	15.6	250	5	1.95	62.5	1.25	488 m	15.6	313 m	122 m
8	16 k	8 k	160	62.5	1 k	20	7.81	125	2.5	977 m	31.3	625 m	244 m	7.81	156 m	61 m
16	8 k	4 k	80	31.3	500	10	3.91	62.5	1.25	488 m	15.6	313 m	122 m	3.91	78.1 m	30.5 m
32	4 k	2 k	40	15.6	250	5	1.95	31.3	625 m	244 m	7.81	156 m	61 m	1.95	39.1 m	15.3 m
64	2 k	1 k	20	7.81	125	2.5	977 m	15.6	313 m	122 m	3.91	78.1 m	30.5 m	977 m	19.5 m	7.63 m
128	1 k	500	10	3.91	62.5	1.25	488 m	7.81	156 m	61 m	1.95	39.1 m	15.3 m	488 m	9.77 m	2.81 m
256	500	250	5	1.95	31.3	625 m	244 m	3.91	78.1 m	30.5 m	977 m	19.5 m	7.63 m	244 m	4.88 m	1.91 m

Also:

- gate: gates the o/p signal (High or Low)
- period length: 2 to 256 or 100 to 256 Timer-Ticks
- duty cycle: 1 to 99 %
- clock prescaler: 1/2/4/8/16/32/64/256
- timer prescaler: 1/8/64/256/1024
- oscillator type: internal/external

The full range of ticks from 2 to 256 is only valid for operation in fast-Mode. Modes producing a variable duty cycle must have a minimum number of 100 ticks in a period. The ATtiny's 8-bit timer is used in fast-PWM mode.

The frequency f_{eff} is derived from the oscillator and the clock prescaler from which the timer and timer prescaler are clocked. The output frequency is given by:

Frequency = clock / (ticks x clock-prescaler x timer prescaler)

For example using an 8 MHz clock and a clock prescaler of 8 we get f_{eff} = 1 MHz. Choosing a timer prescaler of 64 and 156

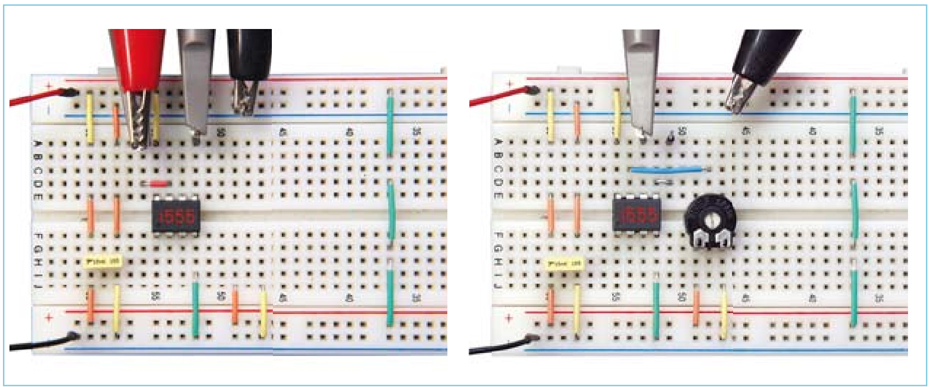


Figure 3. Under test using a prototyping board.

ticks therefore gives an output frequency of:

f = 8 MHz / (8 × 64 × 156) = 100.1602564 Hz

This generates a 100 Hz signal assuming the internal oscillator is reasonably accurate. **Table 2** indicates the frequency range of the AMV firmware based on the selection of four variables.

Code & Chips

The source code of both the iMono (MMV) and iMulti (AMV) firmware together with two hex files implementing a 100 ms monostable and a 100 Hz multivibrator with a 25 % duty cycle are available to download freely from the Elektor webpage for this article [2]. The iMono firmware is 694 bytes. This gives plenty of space even on the ATtiny25 for any additional code you may wish to add to expand the system. The situation is different for the iMulti firmware which takes up 2022 bytes leaving only 24 bytes free in an ATtiny25 memory. The reason for this is largely due to the additional code needed for the A/D converter.

A close look at the iMulti source code reveals that the procedure for configuring the timer0 registers including the start and stop commands are coded 'by hand'. The reason is that fast PWM modes are not directly supported in the current version (1.12.0.0) of BASCOM. The iMono firmware however uses the standard options for Timer0 which are much simpler.

Any pin not defined as an output will by default be an input and (with the exception of the CV input in the iMulti) with an internal pull-up resistor to guard against the possibility of undefined input levels if an input is left floating. This is also the case for the reset input. The definition 'Const Int_osc = False' disconnects internal pull-ups on the crystal connector pins XTAL1 and XTAL2 so that an external crystal can be connected.

Clock selection is made by burning the appropriate fuses. The 8 prescaler which is normally set by a fuse will have no effect because the prescaler is set by the firmware. One point to be aware of is with very low frequency outputs or long pulses it is necessary to use the internal 128 kHz oscillator. The serial ISP programming interface expects a minimal serial frequency of 1.2 kHz and the effective clock speed of the processor must be a minimum of four times the serial clock speed. The practical limit for ISP programming is therefore with the clock prescaler set to 16 which gives an f_{eff} = 8 kHz. With a prescaler setting of 32 and upwards you will find on programming the device you have made a totally different type of 'one shot' i.e. it will only be possible to program the chip once over the ISP interface.
There are tips on the Internet indicating how a chip which has been locked in this way can be recovered. The simplest method is to use so-called 'high voltage serial programming' (e.g. the STK500 programmer from Atmel) which is clock independent.

General points

To get the best from the All-Soft-555 it is worth bearing the following points in mind when selecting a particular pulse width or frequency from the table:

- The higher the value of timer prescaler the more precise the timing will be i.e. with a prescale of 256 the timer is very accurate.
- When the iMono uses a prescale value of 8 and a low value of Ticks (<16) the timing is not particularly precise.
- Current consumption by the ATtiny is proportional to its clock frequency. A controller running at 5 V with an f_{eff} = 8 MHz draws a supply current of approximately 8 mA, but at 3.3 V and 1 MHz it falls to 0.7 mA. At 128 kHz and 2.5 V it is happy with just 0.1 mA which is almost as low as the CMOS version of a real 555.

We hope you find this virtual timer chip useful. If this example has inspired you to try your hand at producing a virtual version of some other standard IC the author and the editors at Elektor would be interested to hear from you.

(100691)

Internet Links

[1] ATtiny25 data sheet: www.atmel.com/dyn/resources/prod_documents/doc2586.pdf

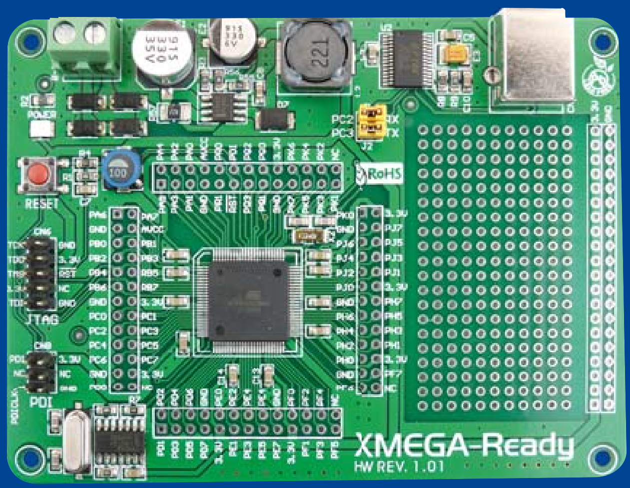
[2] Visit the web site for this article: www.elektor.com/100691

[3] Download the BASCOM-AVR demo version: www.mcselec.com/index.php?option=com_docman&task=cat_view&gid=99&Itemid=54

[4] Wikipedia 555 info: http://en.wikipedia.org/wiki/555_timer_IC

Under Scrutiny: the Xmega Board

by Jens Nickel (Germany)

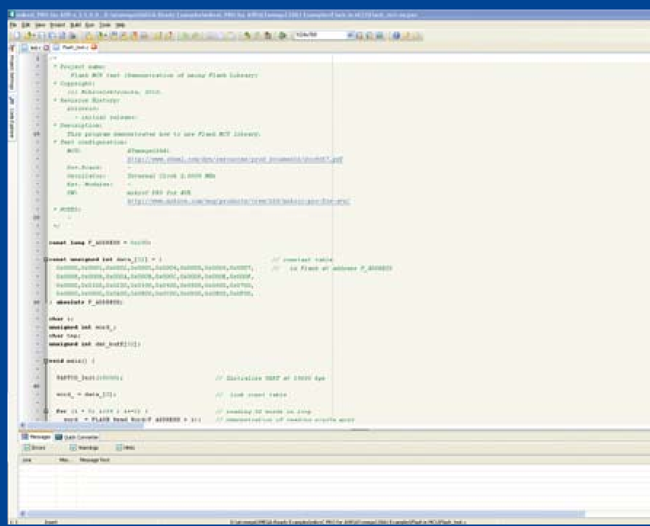


It's not only here at Elektor Labs that the ATtiny and ATmega AVR controllers top the polls for favourite processor. Many of you in Elektor land think the same too, judging by your many e-mails. No wonder then the community reacted with enthusiasm when Atmel announced in spring 2008 that it was planning to expand its 8-bit range with the ATxmega controller. Outstanding new features [1] included significantly improved processing performance of up to 32 MIPS at 32 MHz as well as an Event System (enabling peripheral events to trigger external circuitry functions without involving the CPU).

Now an increasing number of manufacturers are following up this opportunity to produce development boards and tools designed specially for the Xmega. One of these is the Serbian firm Mikroelektronika based in Belgrade, who sent us a sample of their 'Xmega Ready Board' for evaluation in our lab.
The board is pictured here. It's immediately obvious that the PCB (unlike other AVR boards from the same firm) is not over-provided with options. You'll search in vain for any user interface involving LEDs, press-buttons or even any kind of display. The only off-board connectivity is a single USB connector and a pair of screw terminals for the power supply. This minimal interface imposes two restrictions that you'll just have to live with. First, power to the board cannot fed over the USB connection. Second, you cannot install hex files through the bus (at least on an unmodified controller), simply because the board does not include an integrated USB programmer.

Our first investigation into the Xmega Ready Board came to a fairly rapid conclusion, simply because we couldn't lay our hands on either an AVR ISP-compatible or a JTAG programmer (evidently Mikroelektronika could not either!). When we asked them how they managed without these, they told us they were working on a solution. Sure enough, two weeks later they sent us another package containing exactly the same board, only this time the ATxmega128A1 they supplied was now equipped with a bootloader. And this was not a one-off solution for us, as you can read on their website [2]. Click on the Download section of the site and you find not only demo versions of the respected Mikroelektronika compiler but also sample programs (for C, BASIC and Pascal) plus a PC program for transferring hex files over the USB connections to the bootloader.

We immediately tested out the whole package (see screen shot) and it all worked very smoothly. A minor shortcoming is the fact that the corresponding function is not integrated in the IDE. Instead you must first produce a hex file with the compiler (limited to a code length of 4 KB in the free downloadable version) and then use the auxiliary program to transfer it to the Xmega. For our first trial we tested the 'LED Blinking' routine. After flashing this successfully we were puzzled; there was no sign of any LED blinking at us. This was pure and simply because the board is not equipped with any LEDs (other than a green



power-on indicator)! But if you can wield a soldering iron you will not find this a major hurdle, because every pin of the Xmega controller is taken to its own solder terminal on this board. In addition the board contains a special prototyping area where users can install circuitry of their own. A multimeter reassured us that our experiment had been blessed with success and the accessibly written source code explained that the specified port pins should alternate between High and Low level to make an LED flash.

The second sample program we tried out was called 'Flash_Test' (see screen shot) and sent a test sequence of bytes across the USB interface to the PC. We were able to control this process using Hyperterminal. Four other code samples are provided, for working with timers, the internal EEPROM and other functions. According to Mikroelektronika other sample programs are in preparation (for ADC, PWM, UART, LCD/GLCD/TFT controllers and more). These will include demo code that will work with corresponding compiler-specific commands rather than provide fully developed applications. This should not be taken to mean you should not look to other sources for software. Users are free to flash other hex files (developed with WinAVR) into the controller using the bootloader.

A major plus-point of this board is undoubtedly the low price of 29 US dollars (the distributor Tigal is currently offering it for 24 euros [3]). If your development turns out successful you can even build the board permanently into your application without leaving yourself vastly out of pocket. At this stage it's worth mentioning that the manufacturer also offers an even more compact version of the board. This is admittedly somewhat pared-down (as you'll see on the right-hand side of the photo); it lacks the screw terminals for the power supply and the prototyping area for example). But with a price of just $24 the mikroXmega board is even better value for money than the Xmega Ready Board [4].

Shortly before we went to press the news reached us that the guys at Mikroelektronika were working on a lavishly equipped 'Multimedia Xmega Board'. This is planned to include a TFT display, an accelerometer, an MMC/SD-card socket, an audio interface and much more on board. This PCB will also be available in a more compact micro version.

(100716)

[1] www.atmel.com/products/AVR/default_xmega.asp

[2] www.mikroe.com/eng/products/view/579/xmega-ready-board/

[3] www.tigal.com/product.asp?pid=2039&lang=en

[4] www.mikroe.com/eng/products/view/580/mikroxmega-board/

Spotted at electronica 2010

Between the 9th and 12 of November this year we found ourselves at electronica 2010 billed as the world's leading trade fair for electronic components, systems and applications. Held in the massive Munich trade fair centre it was packed to the rafters with so many products and exhibitors that it's impossible to give a fair overview so we just picked a few products here which caught our eye. Elektor were of course also there and this year we were pleased to be sharing a booth with our US sister publication 'Circuit Cellar'. It was a good opportunity for Elektor editors and engineers including Ernst Krempelsauer, Antoine Authier and Jens Nickel to press the flesh and chat with readers about our projects and publications. With so many exhibitors under the same roof it was a good opportunity for them to spot the latest products and trends. With an area this big we couldn't help thinking that visitors would have benefited from their very own Elektor Wheelie!

(100843)

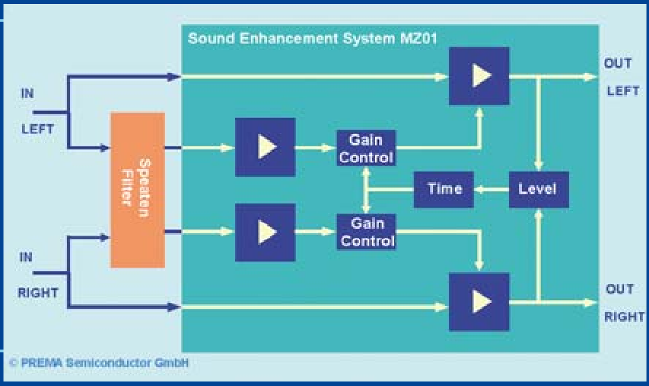
The Stellaris Robotic Evaluation platform (Evalbot) from Texas Instruments is based on a Stellaris LM3S9B92 microcontroller supporting a small real-time kernel. It uses many of the manufacturer's analogue components for motor drive, communications and power supply. The kit is available from a number of distributors and just needs a few minutes assembly time before its ready to go. It retails at $150.00 according to the TI website.

www.ti.com/litv/pdf/spmu166

On the Glyn stand we found this powerful new development board incorporating the FTDI Vinculum II featuring a snap-off debugger and Flash tool. This board is supplied as part of a one-day Vinculum II workshop costing 60 euros. A nice application shows it interfaced to a USB Logitech webcam, displaying the image on a Seiko TFT display. Apart from the Vinculum no other controller is needed.
www.glyn.de

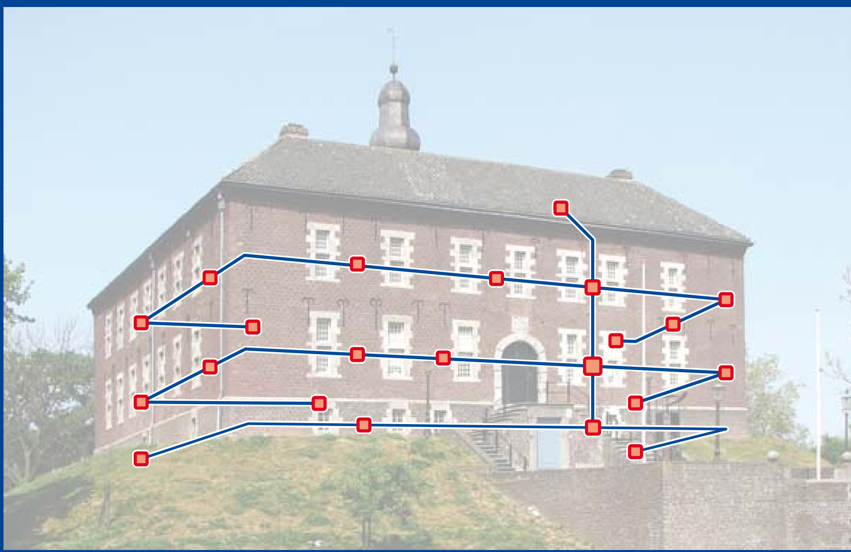
Aaronia were showcasing their impressive range of innovative hand-held spectrum analysers. These devices have excellent sensitivity and are a world first in portable real-time spectrum analysis (real time bandwidth up to 200 MHz). Together with a (powerful) computer they can stream received data to a hard disk. The system can log the entire radio traffic passing through a mobile phone mast. The basic 6 GHz version retails at around 3000 euros and includes the antenna, LiPo battery, mains adapter, carry case, analysis software and accessories.
www.aaronia.co.uk

Prema semiconductors produce analogue and mixed signal ASICs. On show was a 'Speaten Filter' audio chip developed by Dedekind R&D. This filter boosts bass and treble frequencies without affecting the mid range. This produces improved liveliness especially in the reproduction of instrumental sounds. Tiny loudspeakers at their stand were reproducing unbelievably rich sounds, really quite impressive.
www.prema.com
www.dedekind.jp/pdf/mz01_e.pdf



These high-tech, dimmable AC powered LED lamps incorporate a small active heatsink from Nuventix to keep the LED running cool. Power for the LED comes from a highly efficient mains interface designed by Fairchild. The LED modules are from Everlight (10 W) and Huey Jann (20 W).
www.fairchildsemi.com

Here comes the Bus!



By Jens Nickel

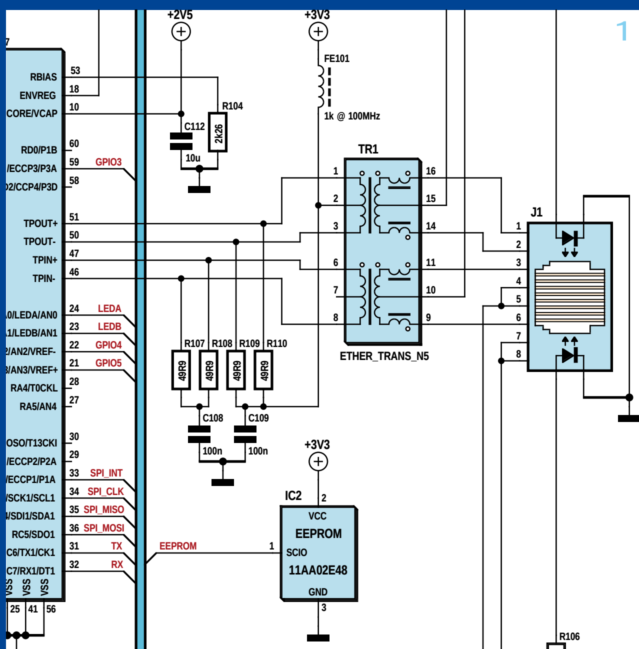
The best things in life may or may not be free (in the *Elektor* labs we know a song about that), but sometimes there just isn't time to get round to them. Lots of good ideas come out of our editorial planning meetings, but many just end up languishing in the bottom of a drawer never to see the light of day.
'E-Labs Inside' to the rescue! As the chief lab correspondent, I often find myself looking around at what my colleagues are doing. Sometimes this can be a source of ideas, and on this occasion I was inspired to dust off an old project that had never come to fruition, and use it as an example to show how a concept is developed from scribbles on the back of an envelope to reality.

After a bit of thinking I narrowed the choice down to two large-scale project ideas, and went to consult a couple of colleagues: Luc and Chris from the lab and Clemens from the international editorial team, who has already seen several large projects through to print début.
The first idea was a general-purpose microcontroller base board, into which a variety of processor boards could be plugged. Perhaps we could include AVRs, PICs and 8051-series processors?
The second idea was to develop our own bus system for interconnecting sensors, actuators, instruments and anything else we could think of.

We soon came to the conclusion that 'ElektorBus' would be the better choice for illustrating the development process in the 'E-Labs Inside' series, and so the 'Elektor Controller Platform' went back in the drawer until next time.
The ElektorBus should, we decided, be able to carry rapidly-sampled sensor measurements as well as control signals, and be suitable for use in a small home automation system. We would be able to add new types of nodes gradually, the whole thing would be easy to build and, of course, the software would be open source down to its last bit.

A few details were nailed down at the first brainstorming session with Clemens and Chris. We wanted to keep things as simple as we could, and so for the lowest protocol layer (the purely electrical specification) we decided to use an established standard and readily-available components. Clemens suggested using Ethernet, and I proposed a bus based on the RS-485 standard. Either would be able to work with cable runs of tens of metres, enough for wiring up the elegant castle that is the *Elektor* nerve centre.

There are fairly cheap microcontrollers available with a built-in 10Base-T Ethernet transceiver, giving a data rate of up to 10 Mbit/s (see for example the 'NetWorker' project in the last edition [1]; circuit diagram snippet in **Figure 1**). RS-485 buses can in principle achieve similar data rates. With a 10 Mbit/s link we have plenty of bandwidth: even enough to send high-quality sampled audio data in real time.
It was clear, however, that not every network node would need to be capable of top-speed performance. To make the project interesting to as many readers as possible, we decided that the components for a minimal node, perhaps for connecting up a simple sensor, shouldn't come to more than fifteen euros. That seemed feasible, as RS-485 transceivers (such as the LTC1535, or the SN65HVD08P, which Clemens had used in the InterSceptre project [2]) are available for about five pounds. And, if we make the simple bus node run at ordinary UART data rates up to say 115.2 kbit/s, we can use an ordinary AVR microcontroller for its brains.



RS-485 thus looked like the ideal option, and, as many readers will know, is the electrical standard on which many diverse bus systems are based. But still Ethernet, with its highly-developed and sophisticated protocol stack and, significantly, enormous open-source code base, seemed too attractive to discard.

Clemens had an idea: why not use both? Previously we described a USB-to-RS-485 adaptor that uses a standard Ethernet cable with four twisted pairs and RJ45 plugs at each end to carry RS-485 signals (**Figure 2**) [3]. RS-485 needs just two data wires, and 10Base-T Ethernet uses just two of the four pairs in the cable. Can we carry RS-485 and Ethernet in the same cable? Could we even use the last remaining pair to supply power to the nodes?

There is always a catch, and in this case it was the fact that modern Ethernet networks are arranged in a star topology. This means that if we want to wire up a few sensors and actuators in a single room, we end up with a spaghetti of cables. Many home automation networks have a hierarchical structure where Ethernet is used between the individual rooms of the house, but the wiring between the nodes within each room uses a two-wire bus.

Furthermore, as Chris pointed out, our combi-cable would be incompatible with existing (mostly 100Base-T) Ethernet equipment. Often in modern devices the spare pairs in the Ethernet cable are grounded (see for example **Figure 3**) [4,5]. Clemens started thinking about how to make best use of ready-made cables in practice. For example, it is not possible to thread them through a cable gland, so it is not easy to see how to make a waterproof node for use outside or in the bathroom. This problem hadn't even occurred to me, so it was a good thing that there were three heads brainstorming rather than one!

We decided to leave out of our first specification any details that we had not settled on. We would definitely use standard Ethernet cable with four twisted pairs, with one pair for our bus and one pair for 12 V and ground. (Clemens thought 12 V was the best choice for most applications, as it gives some headroom when powering 9 V or 5 V equipment.) The remaining pairs we would reserve for future expansion, or perhaps an enterprising reader might come up with a clever use for them. Of course anyone making such 'unauthorised' modifications would have to forfeit the right to use our neat ElektorBus logo on their devices...

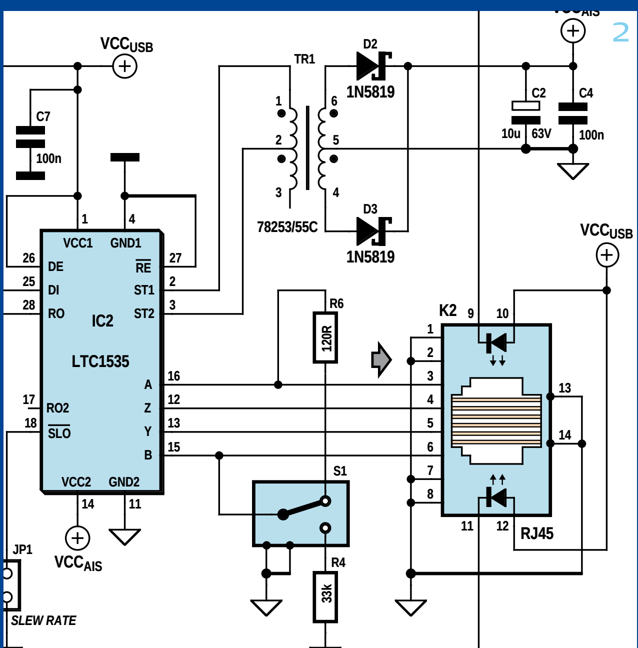
What bit rate should the RS-485 bus operate at? If we are using just one twisted pair then it is simplest if all communications happen at the same speed. We decided to take things gently and first define an 'ElektorBus low speed profile' with a standard bit rate of 9600 bit/s. This will allow us to use standard crystals and probably also experimental hardware and software that we already have. When that is working we will then venture on to define 'standard speed' (115.2 kbit/s) and perhaps also 'high speed' (around 5 Mbit/s) profiles.

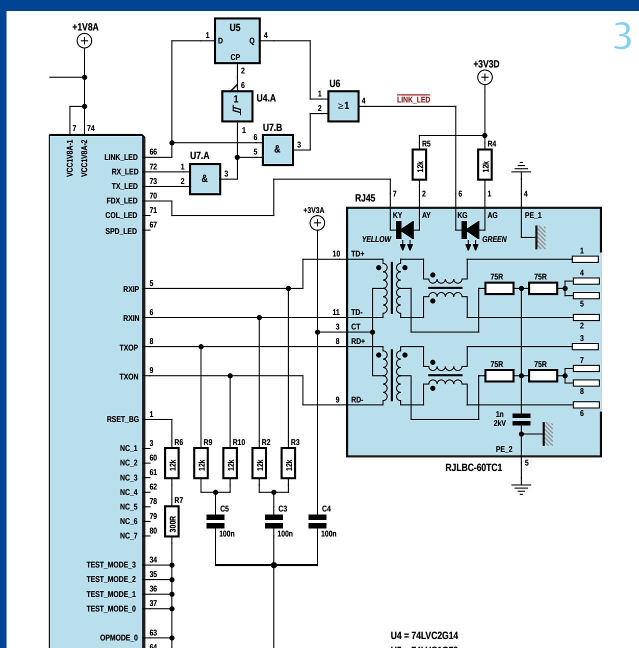
To keep communications at different speeds separate we could later make use of the spare pairs in the cable. Clemens was also considering how he might arrange for different speed communications to run on a single conductor pair. The transmitter could transmit away, and the receiving node would have to determine from a preamble sequence whether the message was being sent at a speed it could read. Would the higher bit rates have to be multiples of the slowest, he wondered? It wasn't long before we were deep in grisly protocol details...

What do you think? You can help inspire the design: the ElektorBus team welcomes your ideas, improvements and thoughts. Send them by email to editor@elektor.com.

(100817)

[1] www.elektor.com/100552
[2] www.elektor.com/100174
[3] www.elektor.com/100372
[4] www.elektor.com/090607
[5] http://en.wikipedia.org/wiki/Ethernet_over_twisted_pair





Low-cost Headphone Amp

Music to your ears

By Stefan Dellemann (Germany)

There have of course been numerous designs for headphone amplifiers before this one, either more or less successful and simpler or more elaborate. The design presented in this article is straightforward, sounds quite good and can be built using well-established components.

Specifications (output load: 33 Ω, supply voltage: ±9 V)

• Input impedance (without P1)	10 kΩ
• Bandwidth	3.4 Hz – 2.4 MHz
• THD + Noise (1 kHz, 1 mW/33 Ω)	0.005 % (B = 22 kHz)
• THD + Noise (20 Hz - 20 kHz, 1 mW/33 Ω)	0.01 % (B = 80 kHz)
• Signal to noise ratio (ref. 1 mW/33 Ω)	89 dB (B = 22 kHz) 92 dBA
• Max. voltage (into 33 Ω)	3.3 V (THD+N = 0.1 %)
• Max. input voltage	0.57 V (with P1 set to maximum volume)
• Current consumption	19 mA

These days it's not that easy to find a separate headphone amplifier in the shops. They do exist, especially in the hi-fi world, but they come with a matching price tag. The design presented here comes in a bit below these high-end circuits, but can be built using easily obtainable components and still manages to have quite a good sound quality.

The circuit

The circuit could be described as a type of power-amp, built with discrete components (see **Figure 1**). At the input we find a volume control (P1, which is connected via a header) and a coupling capacitor (C1), followed by a differential amplifier (T1, T2) with a constant current source (T3) in the emitter branch. The preset between T1 and T2 (P2) is used to set the symmetry, or in other words, the output voltage is set to 0 volt DC compared to ground. For the best sound quality we should have the same collector current flowing through both transistors. This can be seen from voltages at test points F and G in the circuit diagram, which are nearly equal. The input offset across R1 is caused by the base current flowing into T1. This causes the voltage at point A ($V_{(A)}$) to be slightly negative. A quick measurement of the prototype showed that the base current into T1 was about 3 µA. Without the offset compensation provided by trimpot P2 the output offset voltage V_O would exceed 0.2 V:

$$V_O = (1 + R6/R5) \times V_{(A)}$$
$$V_O = (1 + 10/1.5) \times 0.028 = 0.215\ \text{V}$$

The offset can therefore be removed by setting the differential amplifier to operate slightly asymmetrically. Although this isn't the best method as far as the sound quality is concerned, it does keep the circuit much simpler.

Constant current settings

The current source in the emitter branch (T3) is set to about 3 mA with diodes D1, D2 and resistor R4, which results in T4 being driven as linearly as possible.

The audio signal then makes its way to the driver stage, T4, which drives the more powerful output transistors (T6 and T7). C4 has been added to provide a greater internal gain. The quiescent current in the output stage is set to about 5 mA with T5 and R9. Assuming a gain (h_{FE}) of 50 in the output transistors, this 5 mA could theoretically provide a linear 0.005 A×50×32 Ω = 8 V_{peak} into 32 Ω. However, some limitations are introduced by constant current source T5 and the voltage drop across the base-emitter junction of T7 (about 1.5 V). We should also take account of the voltage divider around R11 and R12 (R10 and R12) in the calculations. The maximum voltage V_{max} across the load (R_L) then becomes

$$V_{max} = R_L / (R_L + R11 + R12) \times (9 - 1.5)$$
$$V_{max} = 4.6\ V_{peak}$$

This corresponds to about 3.26 V_{rms}, which is what we measured, as you can see in the specifications. This means that the circuit can deliver ($3.26^2/32$) = 330 mW into 32 Ω, which should be enough to keep most pop and rock fans happy.

Resistor R12, which follows the output stage, limits the output current and keeps the circuit stable when a capacitive load is connected, such as a long shielded cable to the headphones. This prevents the output transistors from overheating when there is a short circuit. R10 and R11 keep things symmetric. Despite the value of C2 in the feedback circuit, the bandwidth is still much greater than the audio bandwidth (see the specifications). To obtain a low corner frequency at the input we used 4.7 µF for C1. A capacitor of 2.2 µF (which is easier to obtain) still results in an acceptable corner frequency of 7 Hz (–0.6 dB at 20 Hz).

The measurements from one of our prototypes are shown in the circuit diagram. These should be seen as guideline values

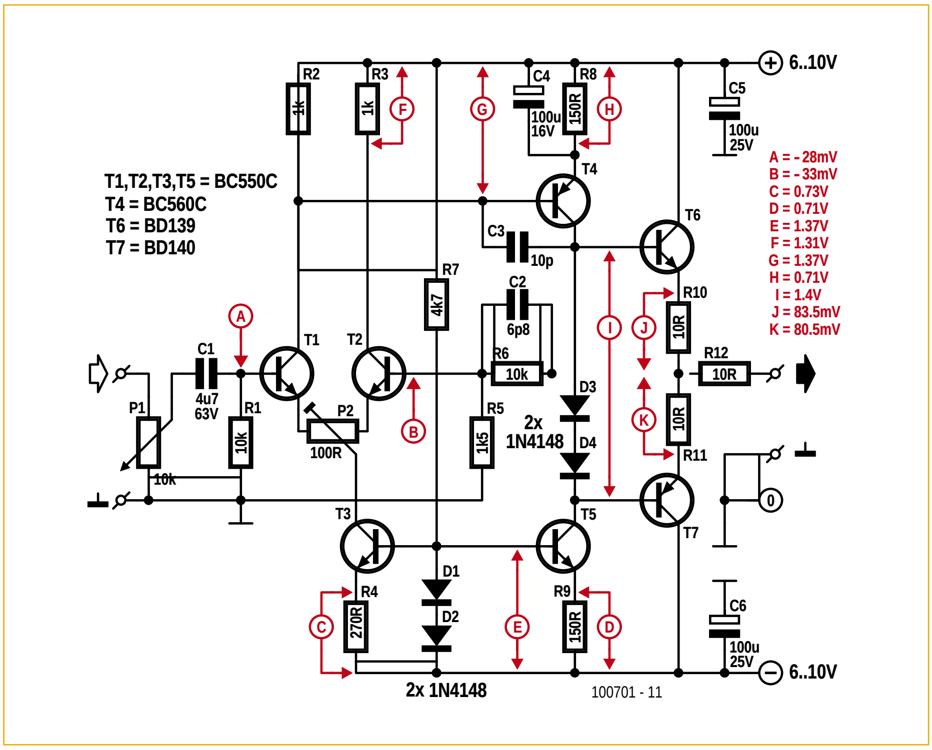


Figure 1. The circuit for the simple headphone amplifier uses easy to get components (one channel shown).

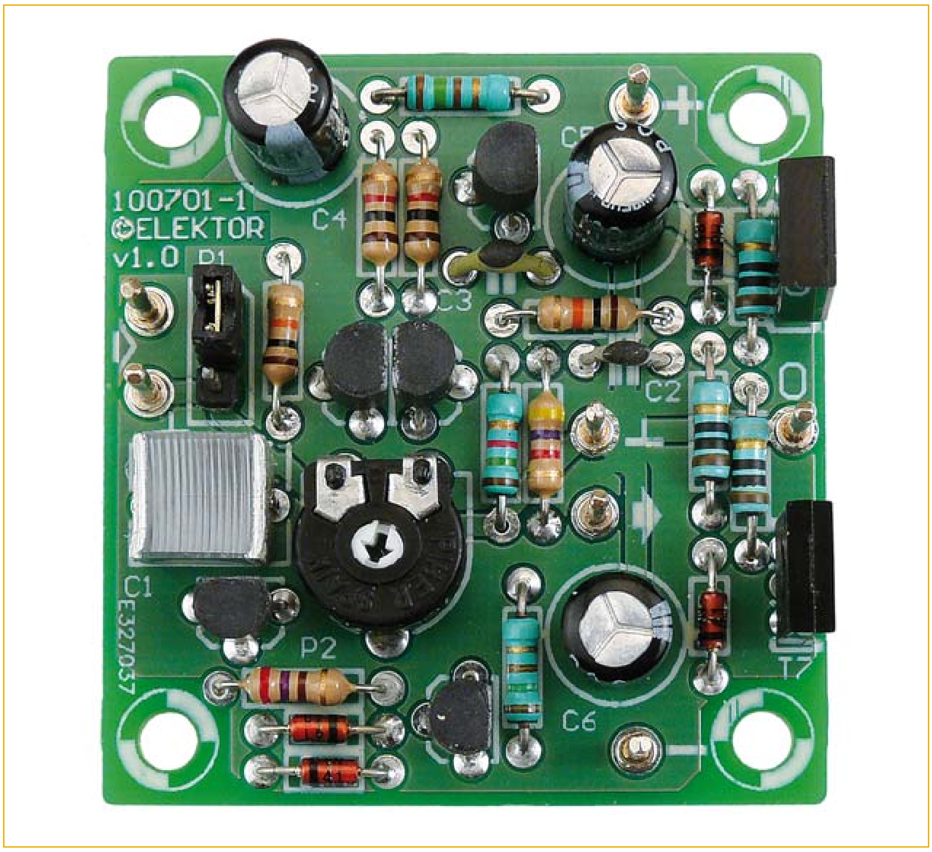


Figure 2. The completed circuit is still compact despite the lack of SMDs.

COMPONENT LIST

Resistors
R1,R6 = 10kΩ
R2,R3 = 1kΩ
R4 = 270Ω
R5 = 1.5kΩ
R7 = 4.7kΩ
R8,R9 = 150Ω
R10,R11,R12 = 10Ω
P1 = 10kΩ
P2 = 100Ω trimpot

Capacitors
C1 = 4.7µF, lead pitch 5mm or 7.5mm
C2 = 6.8pF, lead pitch 5mm
C3 = 10pF, lead pitch 5mm
C4,C5,C6 = 100µF 16V radial

Semiconductors
D1,D2,D3,D4 = 1N4148
T1,T2,T3,T5 = BC550C
T4 = BC560C
T6 = BD139
T7 = BD140

Miscellaneous
Connection for P1 = 3-pin pinheader, lead pitch 0.1''
Connection for P1 = 3-way socket strip, lead pitch 0.1''
7 pcs 1.3mm diam. solder pin
PCB # 100701, see [1].

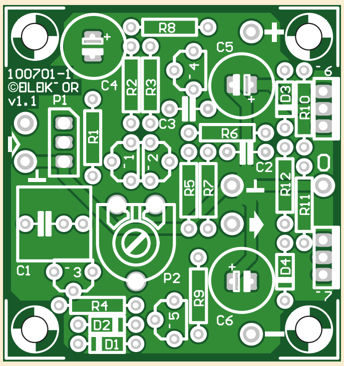


Figure 3. The component layout for the no-frills headphone amplifier.

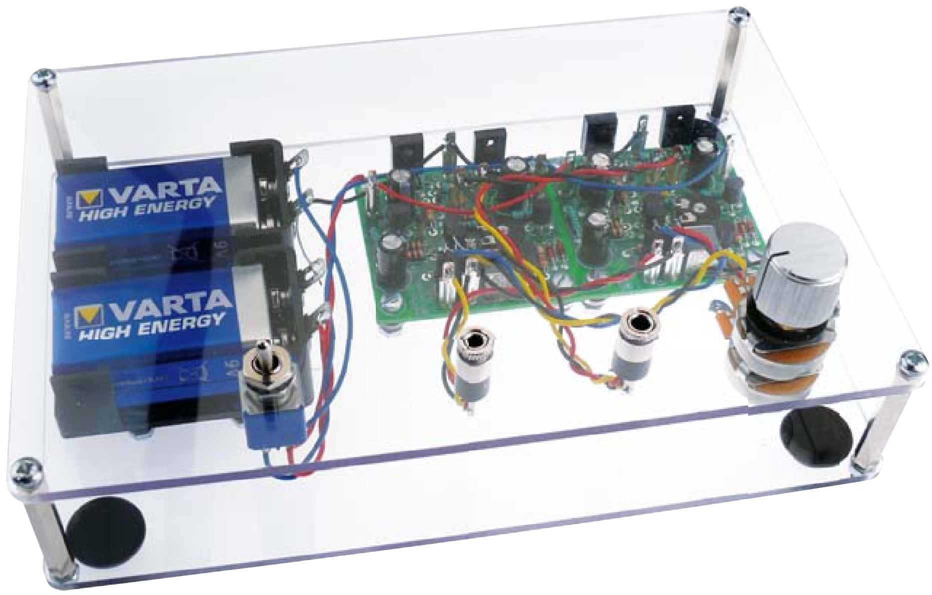


Figure 4. The circuit has a distinctive appearance when it's built into a ProjectCase.

rather than as exact requirements. The PN junctions and the gain of the transistors can of course vary depending on the manufacturer (this also applies to the current consumption given in the specifications).

Experimenting

For those of you who don't mind a little bit more noise (although it will still be inaudible with most headphones), you can increase the impedance of the feedback loop to about 10 kΩ. This can be achieved by increasing R5 and R6 in the parallel circuit to 10 kΩ. In this case the base currents of T1 and T2 will compensate each other. If you like experimenting you can replace R5 with a resistor of 12 kΩ and R6 with a resistor of 68 kΩ (perfectionists should use 11.5 kΩ and 76.8 kΩ from the E96 series). It is unlikely that this offers an audible improvement, but there may be a smaller offset this way.

Construction

A small printed circuit board has been designed for this circuit (see **Figure 2**), which can be ordered via [1]. From here you can also download the board layout in PDF format. The component layout is shown in **Figure 3**. As usual, construction is easiest if you start soldering the lowest components (resistors, diodes) and then continue mounting increasingly higher components (capacitors, transistors, connection pins).

You will need two boards for a stereo version, in which case P1 has to be replaced with a stereo potentiometer, so that the volume can be controlled on both channels simultaneously. If your audio source already includes a volume control, you can leave out P1 (put a jumper on the header or solder a wire link on the board from pin 1 and pin 2 of the header instead of the actual header). The input impedance of our suggested circuit (which includes P1) has a minimum of 5 kΩ (P1 set to maximum volume). This shouldn't be a problem for most modern audio sources. Take note of the pin spacing of decoupling capacitor C1; the board accommodates 5 mm and 7.5 mm versions.

For the power supply you could use two 9V batteries. Alternatively, a 2x6 V, 5 VA transformer with a 1.5 A bridge rectifier and 8200 µF/16 V per supply rail is another option. This could optionally be supplemented with a pair of voltage regulators.

The output transistors (T6 en T7) probably don't need heatsinks in practice, although a small heatsink will make sure that they will be short circuit proof.

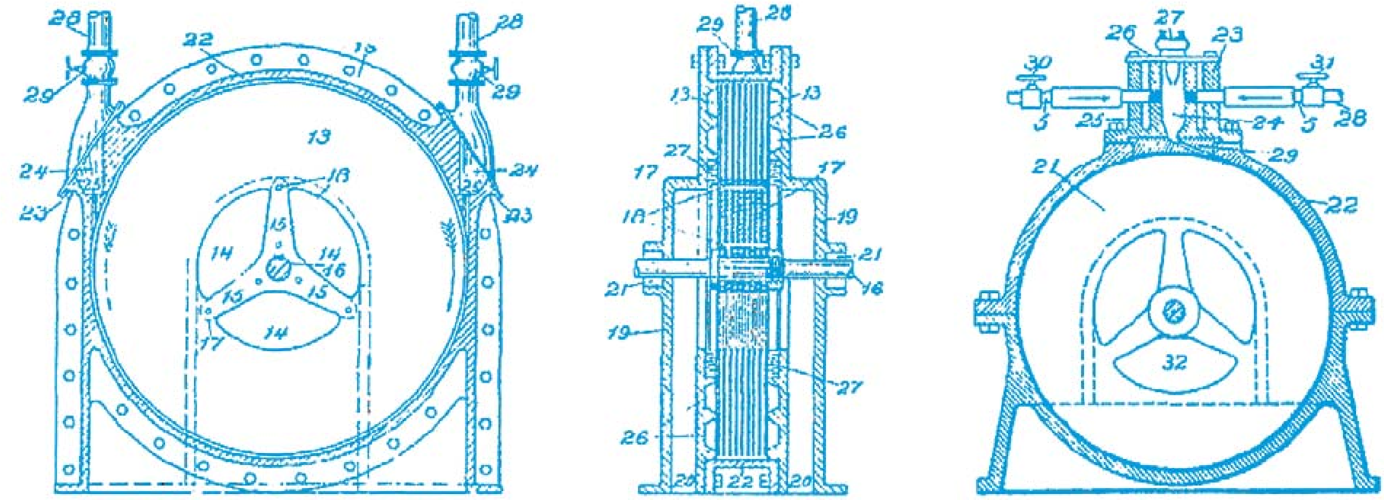
We decided to build this circuit into an Elektor ProjectCase [2]. This is very easy to do and it gives it a distinctive look and a good view of the electronics (see **Figure 4**).

(100701)

Internet Links

[1] www.elektor.com/100701
[2] www.elektor.com/100500

Free Energy
Energy for free from known and unknown sources



By Harry Baggen (Elektor Netherlands Editorial)

For centuries, savants have searched for ways to make devices move perpetually or to generate energy from nothing. These pursuits still occupy the attention of many people, as can be seen from the massive interest in this topic on the Web, along with innumerable projects. Is it truly possible to generate free energy, or are we simply deceiving ourselves and others? Here we describe a selection of interesting ideas and projects.

In the past, before the discovery of electricity, many savants spent their time trying to develop a perpetual motion machine — a device that would keep moving forever after it had been put in motion, effectively drawing energy from the void. In the last two centuries electrical energy has become increasingly important in our society, and during this time the focus of people who invent devices of this sort has shifted towards generating 'free energy', usually in the form of electricity. However, the laws of thermodynamics say that this is not possible. Despite the fact that these laws have been known for more than a century, each year countless patent applications are submitted for devices of this sort. Highly ingenious lines of thought and instructions appear in these patent applications, but detailed examination of these devices ultimately reveals that they do not work or that there is actually some source of energy present, either concealed or perhaps unknown to the inventor.

History

It is known that self-powered machines were developed in ancient India, starting as early as the seventh century. One of the best known designs from that time is a wheel with a number of mercury-filled cylinders attached to it. People in the western world also attempted to develop similar types of self-powered devices. One example is a device that uses falling hammers. Naturally, the free energy devices designed by Leonardo Da Vinci are very well known, but it is questionable whether he expected that they would actually work, since he said that according to his understanding they could not possibly work. Many other inventors of perpetual motion devices appeared after him. The first such device that 'actually' worked is ascribed to the inventor John Joseph Merlin, originally from Belgium, who designed a self-powered clock in 1760. However, its operation was found to be based on natural changes in ambient temperature and air pressure, which means that it cannot be regarded as a true self-powered perpetual motion device.

Despite the progress of scientific knowledge, the dream of a perpetual motion device continued to inspire many people. Especially from the middle of the twentieth century onward, many inventors have concentrated on the concept of 'free energy' (also known as zero point energy), which involves devising a construction that delivers more energy than what is supplied to it. Of course, there are various ways to do this – a device that supplies electricity from sunlight

or water power effectively delivers energy for free without requiring any sort of mysterious events. However, there are people who go much further and try to extract energy from magnetic fields or from an extra spatial dimension that has not yet been discovered by anyone else.
With many of these inventions, it is very difficult to determine whether they actually work. Although the inventors are convinced that they work, in many cases they are unable to provide a reasonable scientific explanation of how they work or demonstrate their inventions.
Overviews of the history of perpetual motion devices, some with background information and names of well-known persons may be found at various websites including [1].

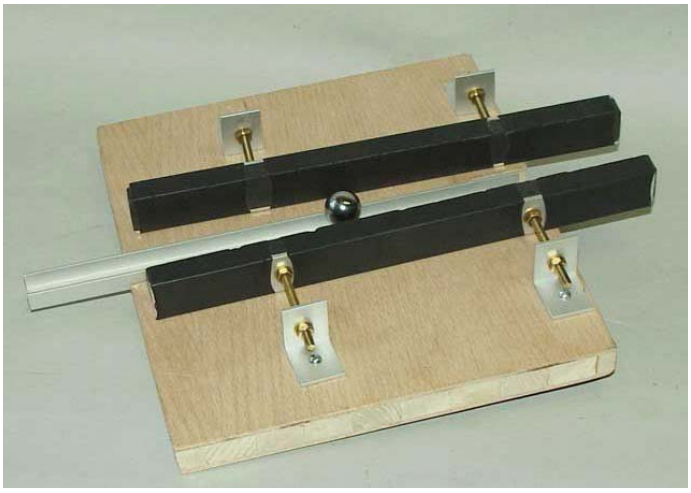


Figure 1. Structure of a 'Simple Magnetic Overunity Toy' (SMOT). (photo source: [11])

Electricity from nothing

In the remainder of this article we focus on electrical free energy devices, whose objective is to generate more electrical energy than they consume. Here we are mainly interested in devices with the least possible number of mechanical parts, and especially in devices employing a lot of electronics.
Most of the devices we found on the Web utilise magnetic fields in some way or the other, primarily with the aid of permanent magnets and coils. The explanations of how these devices operate are highly varied.
To demonstrate that it is possible to use magnets to cause an object to move without supplying external energy, there is a very simple experiment that can be performed using two bar magnets, a length of aluminium U channel and a steel ball. This miniature perpetual motion device (shown in **Figure 1**) is called the 'Simple Magnetic Overunity Toy', or SMOT for short. The magnetic field between the two magnets, which are positioned at a slight angle to each other, causes the ball to roll uphill 'by itself' when it is placed at the low end of the slightly inclined U channel. This idea dates from 1922, and in 1997 Greg Watson produced an updated version. A detailed description of a practical implementation and test results are available on the website of French experimenter J.L. Naudin [2]. It's fun to try this for yourself. Incidentally, a variety of explanations of how the SMOT works can be found [3].
Most energy generators use a rotating wheel fitted with several magnets. The magnets rotate beneath coils that act alternately as drive coils and detection coils with the aid of electronic control circuitry. This objective of this arrangement is to generate more energy than the drive energy supplied to the coils to keep the wheel turning. Many systems of this sort have rather complicated mechanical constructions, but there are a few very simple generator designs that are quite suitable for experimentation by people who are not expert machinists. For instance, at [4] there is a description of how to convert an ordinary PC fan into an energy generator. There is also a YouTube video [5] that shows you how to make the conversion. **Figure 2** shows the simple schematic diagram of the full circuit.
John Bedini has developed several projects that are very popular with everyone interested in free energy generators. He has several decades of experience in this area, and a large number of generators of various types are described on his website [6]. To show

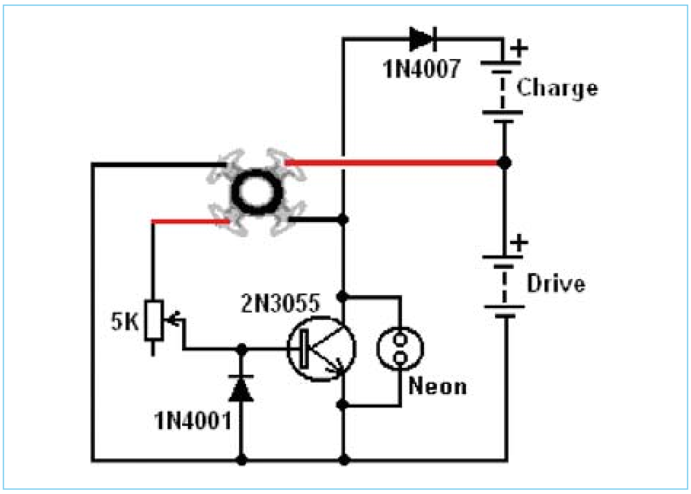


Figure 2. A simple circuit is all you need to convert a PC fan into a free energy generator. (source: [12])

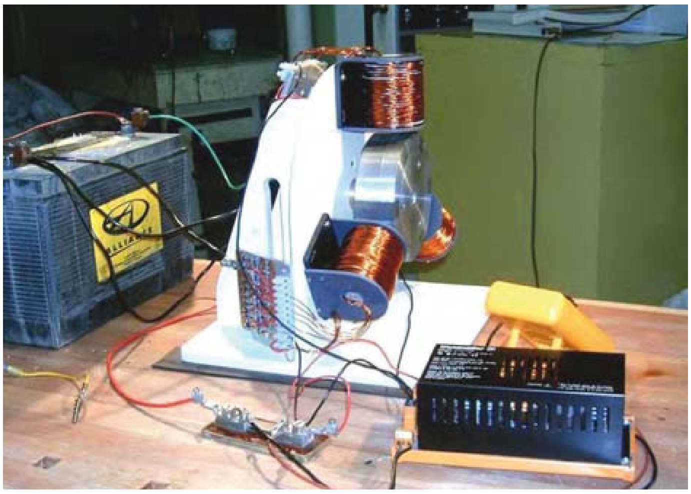


Figure 3. This free energy generator from Ron Pugh has a reasonably simple mechanical design. (source: [12])

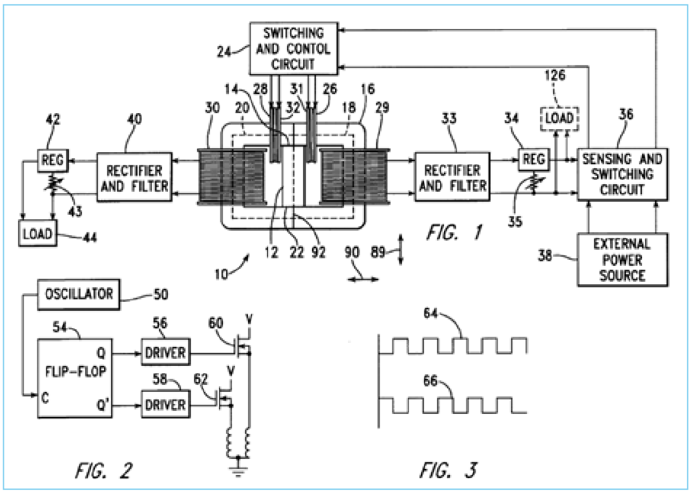


Figure 4. The MEG is a generator with no moving parts. This is the original schematic diagram from US patent 6.363.718 B1. (source: [7])

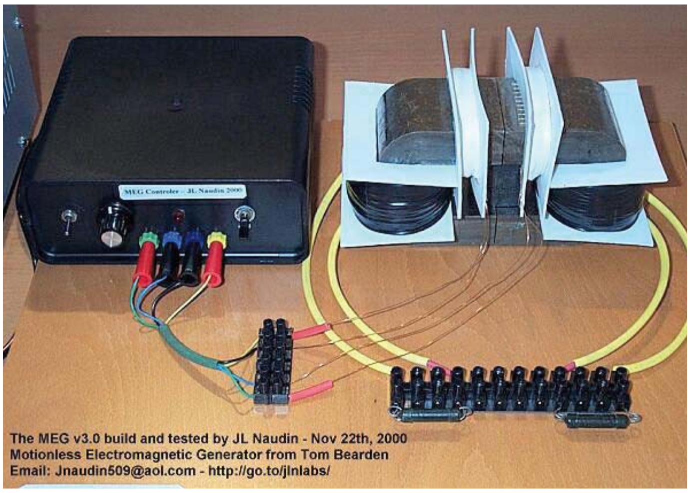


Figure 5. A practical MEG transformer implementation designed by J.L. Naudin. (source: [7])

how easy it is to build your own version of a Bedini generator, he describes a special design that he claims can be built by a ten-year-old schoolgirl.
A design by Ron Pugh based on Bedini's ideas (which is also described clearly and extensively at [4]) is illustrated in **Figure 3**. The mechanical construction of this design is reasonably simple. It has a homemade rotor with six pairs of magnets glued into slots in the rotor. Three coils used to drive the rotor and generate energy are mounted around the perimeter of the rotor. The control electronics essentially consists of a number of power transistors and a few passive components. An experienced electronics enthusiast can probably design a tidier version of the electronics (with a PCB), but what ultimately matters is the overall concept.
The 'Motionless Electromagnetic Generator' (MEG) is an invention of Tom Bearden *et al.* [7] based on a special transformer with a permanent magnet fitted in the middle (see **Figure 4**). Two large windings for energy output are fitted on the outer ends of the transformer core, while two smaller windings for energy input are fitted near the middle. This device is claimed to be able to extract electromagnetic energy from the vacuum, thereby supplying more energy than it consumes. Here again the Frenchman J.L. Naudin has developed a very nice prototype (**Figure 5**) with a number of improvements compared to the original design [8]. He has also generated a simulation of the magnetic field for this design.
Finally, we wish to draw your attention to the 'Tesla Switch' [9], since it can be built using only electronic components with no need for a special transformer. The circuit is based on Tesla's ideas, as implemented by Ronald Brand and John Bedini in the form of a circuit with three rechargeable batteries that are repeatedly connected in series in different configurations in which one of the batteries is charged by the other two. The ultimate result is three fully charged batteries, which means that energy has been extracted from an unknown source in some way or the other. The circuitry of the Tesla Switch is fairly simple. An especially interesting version of this idea can be obtained by replacing two of the batteries with electrolytic capacitors, so that only one battery is necessary (**Figure 6**). Unfortunately, few detailed circuits based on this principle can be found on the Web.

As you can see, the 'free energy' area is a hotbed of experimental activity. The question is whether it ultimately delivers anything useful. In this regard, we wish to conclude this article with the frequently given advice 'don't try this at home', accompanied by a request to subject a number of the designs described to detailed examination and even try to develop your own design for a similar sort of energy generator. We are very interested in hearing about your experience, results and conclusions, both positive and negative.

Internet Links and References

[1] www.theorderoftime.com/ned/wetenschap/nieuweenergie/4.html, www.hp-gramatke.net/perpetuum/index.htm

[2] http://jnaudin.free.fr/html/smotidx.htm

[3] www.mathematik.tu-darmstadt.de/~bruhn/SMOT.HTM www.lhup.edu/~dsimanek/museum/smot.htm

[4] www.free-energy-info.co.uk/Chapt6.html

[5] www.youtube.com/watch?gl=US&feature=related&hl=uk&v=eDS9qk-Nw4M

[6] http://johnbedini.net/

[7] http://cheniere.nii.net/megstatus.htm

[8] http://jnaudin.free.fr/meg/meg.htm

[9] www.icehouse.net/john1/tesla.html

[10] www.lhup.edu/~dsimanek/museum/unwork.htm#top

[11] www.hcrs.at

[12] www.free-energy-info.co.uk

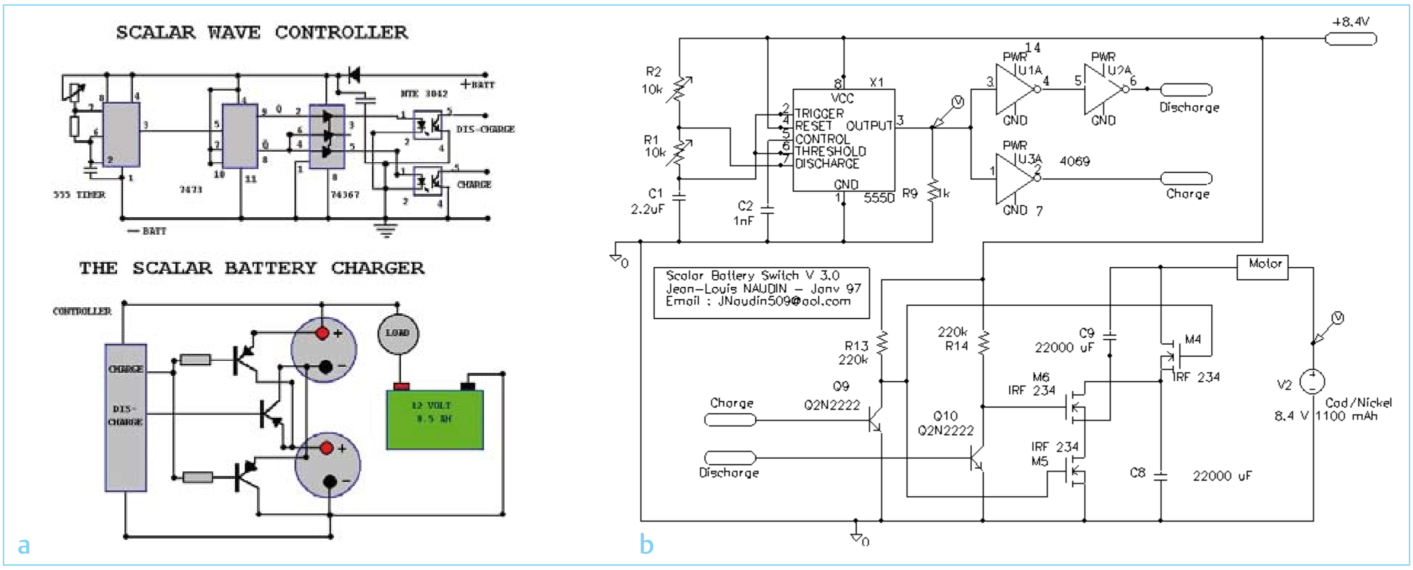


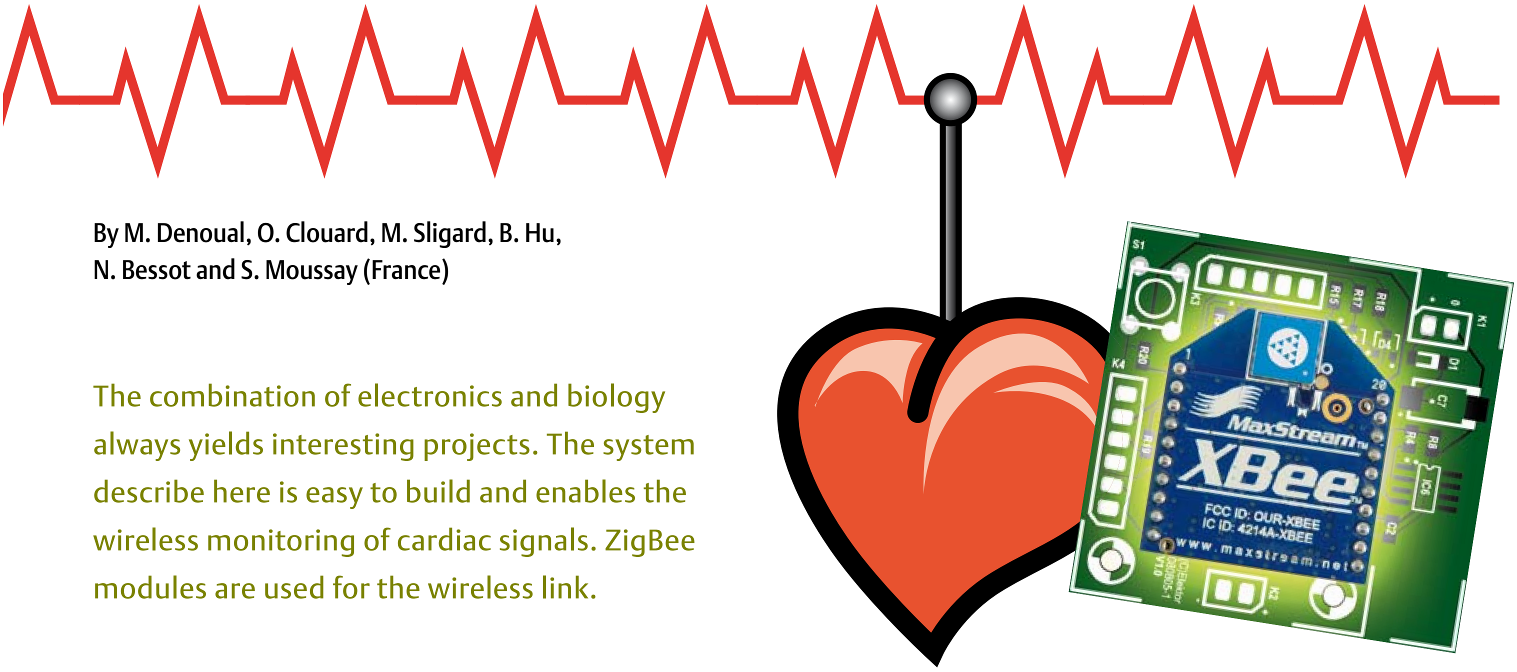
Figure 6. A yield of more than 100% is possible with the 'Tesla Switch', which alternately charges and discharges two electrolytic capacitors. Figure 6a shows the basic concept according to Bedini, while Figure 6b shows a detailed circuit designed by Naudin. (sources: [7] and [9])

If you find the entire subject of free energy preposterous, we suggest you have a look at the 'Museum of Unworkable Devices' [10]. After visiting this website, you will doubtless find yourself reinforced in your convictions.

(100672-I)

Wireless ECG

Monitoring cardiac signals with ZigBee



By M. Denoual, O. Clouard, M. Sligard, B. Hu, N. Bessot and S. Moussay (France)

The combination of electronics and biology always yields interesting projects. The system describe here is easy to build and enables the wireless monitoring of cardiac signals. ZigBee modules are used for the wireless link.

Key features

- ECG resolution 10 bits
- ZigBee wireless data transmission
- Range 100 m (outdoors)
- Based on XBee modules
- No programming necessary
- Serial computer interface
- Identical PCBs for acquisition and receiver boards

Many devices are available for recording or visualising electrocardiogram (ECG) signals. Protection of the subject (patient) is a paramount requirement with all of these devices, which is why circuits of this sort are typically powered by batteries. This circuit is also battery powered, but it uses a wireless link as an elegant solution to the problem of galvanic isolation, completely eliminating any hazard to the subject. The wireless link also gives the subject more freedom of movement.

This special approach forms the basis for this project, which was originally developed for monitoring athletes while they are exercising or performing.

Why ZigBee?

ZigBee technology is an ideal choice for this application in terms of cost, ease of use and low power consumption. The data transmission rate of 250 kbit/s is sufficient for applications such as transmitting ECG signals, which have a narrow bandwidth. The range of 100 m (300 ft.) outdoors or 30 m (100 ft.) indoors with the selected XBee modules [3] is sufficient for monitoring in a gym or stadium, and the range could be extended to 1 km for monitoring outdoor sporting events by using higher-power modules and relay modules. Finally, ZigBee modules (in particular the XBee modules from Digi) have integrated A/D converters, which simplifies overall circuit design and construction.

Hardware

The system consists of two parts: a data acquisition board that senses the ECG signal and a receiver board that is connected to a PC for displaying the ECG signal. In this article we also describe a third module that can be used to adjust the data acquisition board and test the wireless data link. It is a sort of signal generator that produces an artificial ECG signal.

Acquisition and receiver boards

The block diagram and schematic diagram of the acquisition board are shown in **Figure 1** and **Figure 2**, respectively. The board is designed to be used with three electrodes (two sense electrodes and one reference electrode; see the 'ECG Measurement' inset). It has an analogue stage that amplifies and filters the input signal before it goes to the 10-bit A/D converter integrated into the XBee module. The board is designed to allow all components to operate from a single 3.3-V supply voltage, which matches the operating voltage of the XBee module. A compact 3.3-V lithium-ion button cell would be a good choice for powering the board. However, during development it was more convenient to use a regular 9-V bat-

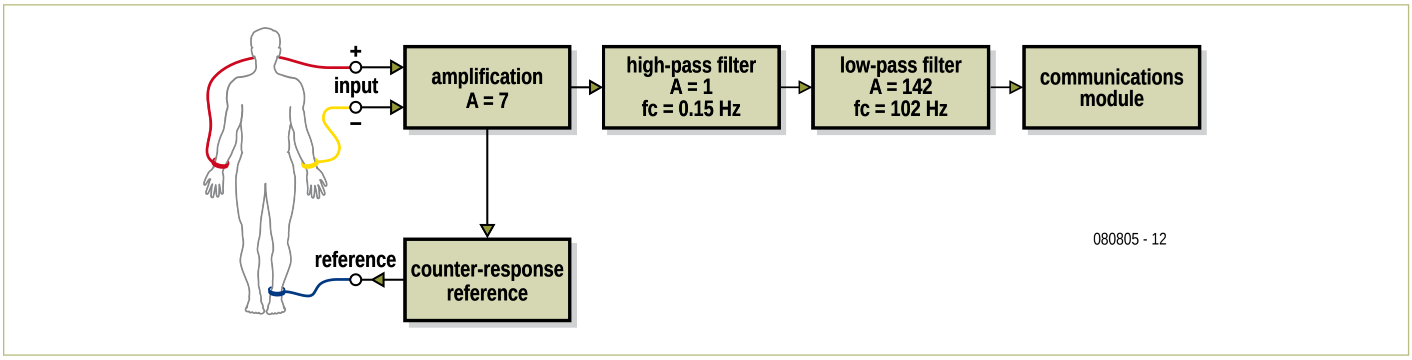


Figure 1. Block diagram of the acquisition circuit.

tery together with a 3.3-V regulator on the board to power the circuit.

The 3.3-V supply voltage restricts the choice of components for the analogue functions. The economical AD623 instrumentation amplifier is able to operate from a single supply voltage, and so are the OPA237 opamps used in the filter stages. The reference level for the circuitry is provided by a 1.2-V potential generated by a MAX6120. This potential is applied to the subject's body by a reference electrode, and it determines the common-mode level of the signals picked up by the sense electrodes. A reference potential of 1.5 V can also be used if a suitable reference voltage IC in an SMD package is available.

The first-order high-pass filter built around IC5 and the low-pass filter built around IC3 limit the effective frequency band of the signal and amplify the signal. The low-pass filter also acts as an anti-aliasing filter for the A/D converter. A passive twin-T filter is placed ahead of the converter input (pin 20 of the XBee module) to suppress any 50-Hz mains hum that may be present. If desired, it can be bypassed when the board is used in an environment free from mains interference. The 3.3-V supply voltage is connected to pin 14 to serve as the reference voltage for the A/D converter.

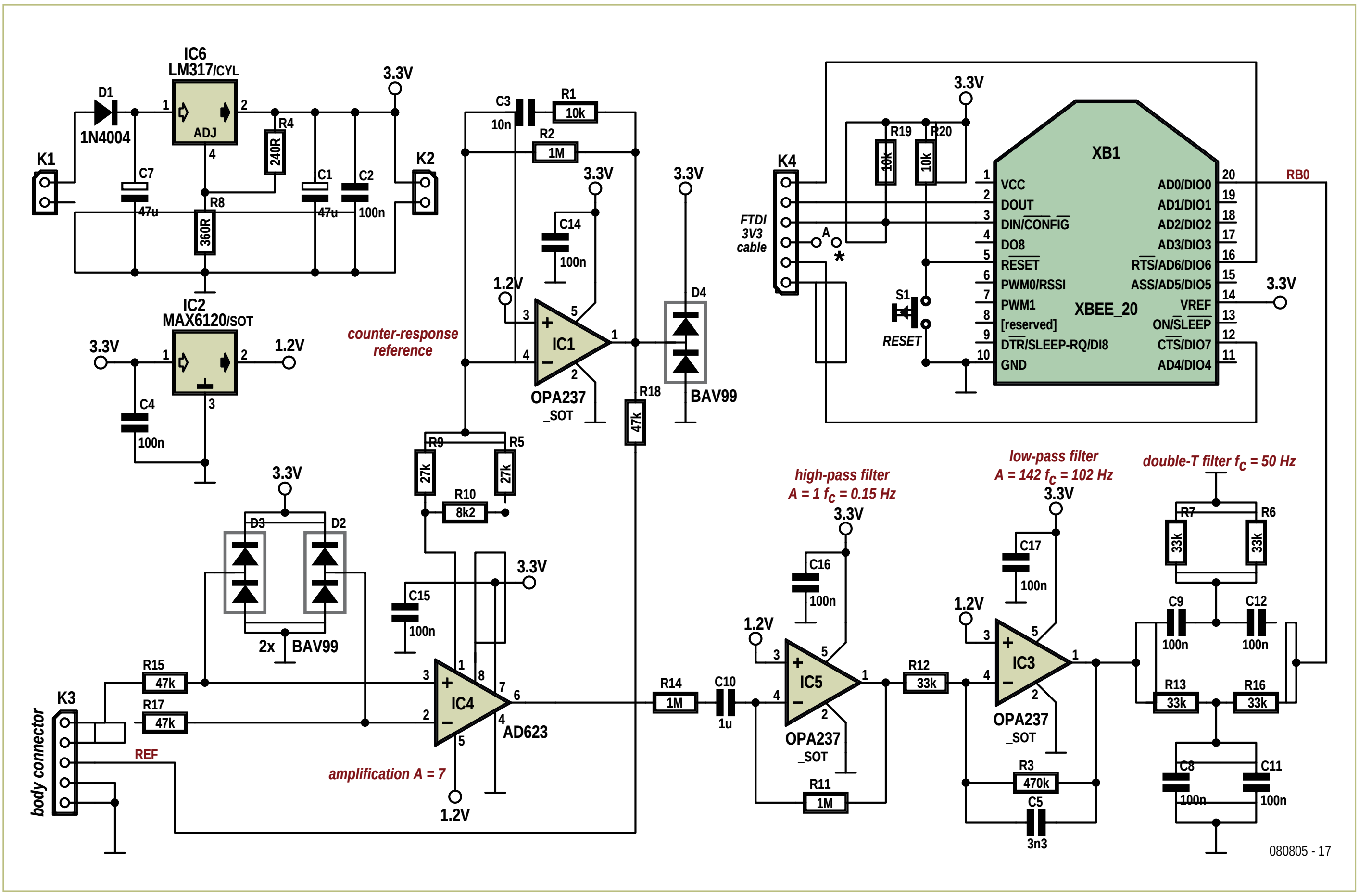


Figure 2. Schematic diagram of the acquisition circuit.

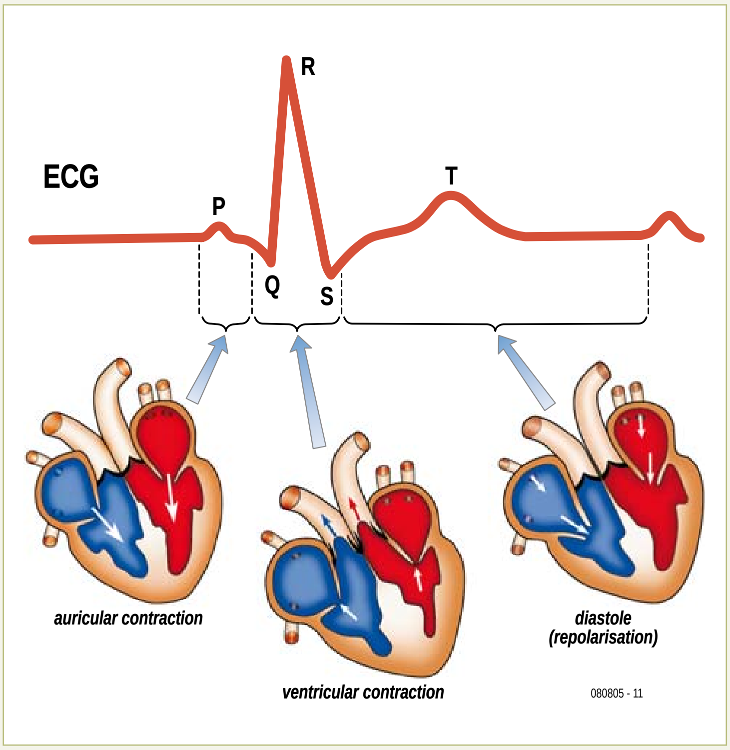
ECG Measurement

This circuit uses three electrodes to sense the electrical activity of the subject's heart. Two of the electrodes are placed on the subject's wrists, and the third is placed on the left leg. The electrodes on the wrists pick up the electrical signal, while the electrode on the leg provides a reference level for the other electrodes.

The adjoining figure shows the electrical signal generated by a beating heart and the phases of the cardiac cycle:

- P wave: contraction of the auricles. Blood from the veins is pumped into the ventricles.
- QRS complex: contraction of the ventricles. Blood flows out of the heart and is pumped into the arteries. The combination of P and QRS waves generates the characteristic 'lub-dub' sound of a heartbeat.
- T wave: repolarisation of the ventricles. The heart muscle returns to the relaxed state.

See reference [2] for more information on ECGs.



Relationship between the electrical activity of the heart and the phases of the heartbeat cycle. Pulse R has an amplitude of only a few millivolts. The bandwidth of the pulses in the ECG signal is 0.1 to 100 Hz.

Electrodes

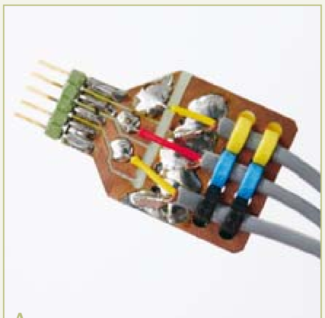
In order to make good ECG measurements, it is essential to use good electrodes and to attach and connect them properly.

We recommend using shielded cables to reduce interference from external sources. In theory, shielded audio cables are quite suitable for this purpose, but the ends of these cables are fairly fragile. We therefore recommend using small connectors in combination with heat-shrink tubing to virtually eliminate the risk of breakage (see **Figures a** and **b**).

You may have already noticed the shields are connected only at the acquisition board end pf the cables and are carefully insulated at the electrode ends to prevent any contact with the skin.

If you terminate the cables in 4-mm plugs, you can use commercial electrodes (**Figure c**), but the prices of these electrodes may put you off (more than 10 pounds each, and you need three of them). However, you can also make your own electrodes from coins containing nickel to make the electrodes (some research required to find suitable coins; "Google is your friend"). Solder a length of 4-mm metal tubing onto each coin to receive a 4-mm plug, and you're ready to go.

Use elastic straps (one for each electrode) to hold the electrodes securely in place on the subject's wrists and lower calf. You can make your own straps by cutting suspenders straps into suitable lengths and sewing or gluing Velcro table to the ends. Straps cut from a bicycle or scooter inner tube are also serviceable.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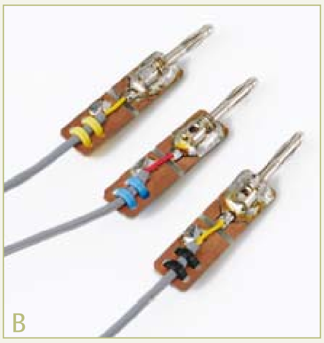
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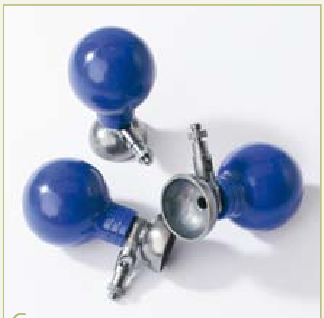

C


D

The wireless signal is received by a board holding only an XBee module only. All you actually need to receive the data and transfer it to your PC is an XBee module and a USB to TTL adapter cable (available from the Elektor Shop; item number 080213-72 for the 3.3-V version). To power the module from the USB bus, install wire link A on the board. Actually, the combination of an XBbee module and a USB-TTL cable (caution: 3.3 V version required, Elektor order code 080213-72,) is sufficient to receive data and convey it to the computer You can also use this cable for configuring the XBee modules. For this purpose, be sure to connect the supply voltage lead of the cable (on the TTL connector) to the XBee module. For data reception, the XBee module only needs to be configured for a serial data interface.

Configuring the XBee modules

The XBee modules can be configured using a 3.3-V USB to TTL adapter cable and the free program X-CTU [4]. The default serial data transmission rate of the XBee module is 9600 baud. To configure a module, connect it to the PC via the serial interface adapter cable, connect a power source to the module, and launch the X-CTU program (**Figure 3**).

You can use the ‘Modem Configuration’ tab to read and modify the configuration registers of the XBee module. After selecting this tab, click ‘Read’ to read the current register settings. You can modify them directly by selecting values from a drop-down menu, or you can enter new values from the keyboard. After changing the settings, select ‘Write’ to save the new register contents. The first time you use X-CTU, you may be asked to download a new version of the modem firmware for the connected XBee module. Click ‘Download new versions...’ to do this automatically, after which you can use the ‘Function Set’ and ‘Version’ menus to select the new modem versions for your modules.

Before you configure the modules, it’s a good idea to assign them ID codes so you can tell them apart. After this you must give

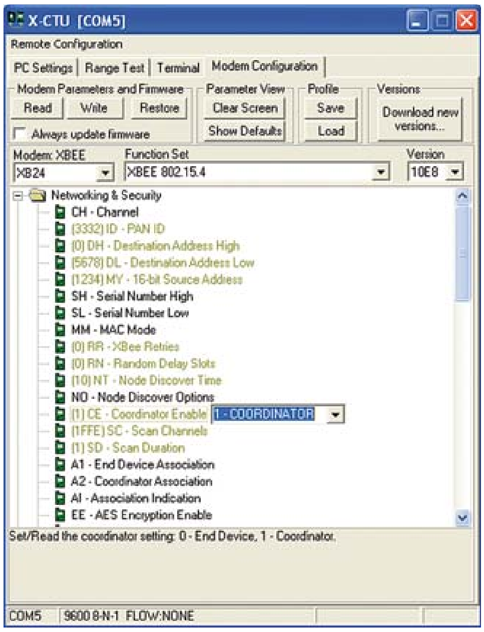


Figure 3. User interface of the X-CTU program for configuring XBee modules.

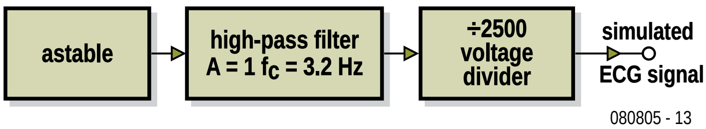


Figure 4. Block diagram of the ECG simulator.

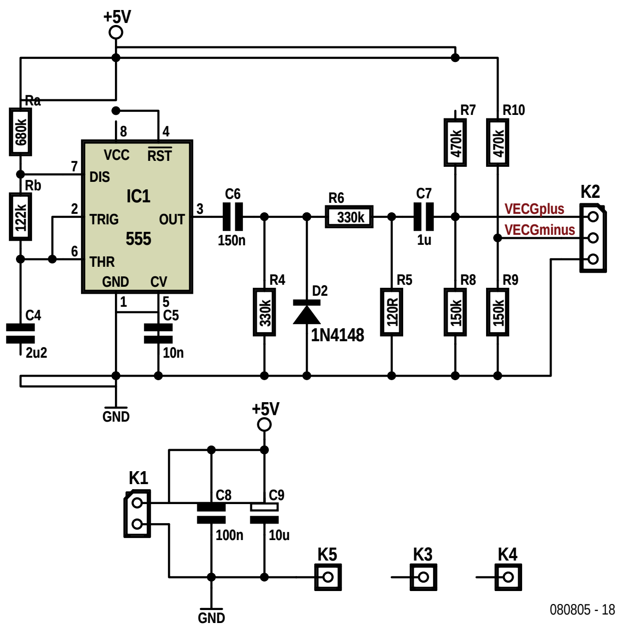


Figure 5. Schematic diagram of the ECG simulator.

COMPONENT LIST

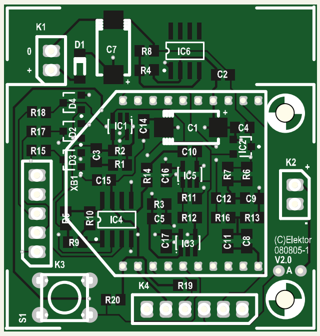
Resistors (SMD 0805)
R1,R19,R20 = 10kΩ
R2,R11,R14 = 1MΩ
R3 = 470kΩ
R4 = 240Ω
R5,R9 = 27kΩ
R6,R7,R12,R13,R16 = 33kΩ
R8 = 360Ω
R10 = 8.2kΩ
R15,R17,R18 = 47kΩ

Capacitors (SMD 0805, ceramic, except C1,C7)
C1,C7 = 47µF 10V, SMD, Kemet B45196E2476K409
C2,C4,C8,C9,C11,C12 = 100nF
C3,C6,C13 = 10nF
C5 = 3,3nF
C10 = 1µF

Semiconductors
D1 = 1N4148 SMD Minimelf
D2,D3,D4 = dual diode BAV99 (SOT23)
IC1,IC3,IC5 = OPA237NA/250 (SOT23-5)
IC2 = MAX6120EUR+T (SOT-23)
IC4 = AD623ARZ (SOIC-8)
IC6 = LM317LM (SOIC-8)

Miscellaneous
K1,K2 = 2-pin pinheader, lead pitch 0.1'' (2.54mm)
K3 = 5-pin pinheader, lead pitch 0.1'' (2.54mm)
K4 = 6-pin pinheader, lead pitch 0.1'' (2.54mm)
S1 = pushbutton, make contact, PCB mount, 6mm, e.g Multicomp type MC32830
XB1 = XBee module, ZB ZigBee with chip antenna, Digi type XB24-Z7CIT-004
A = no wire link
PCB # 080805-1, see [1]

Receiver only
XBee-module, Digi type XB24-Z7CIT-004
USB-to-TTL cable, 3.3V version, Elektor # 080213-72
R19,R20 = 10kΩ
K4 = 6-pin pinheader, lead pitch 0.1'' (2.54mm)
S1 = pushbutton, make contact, PCB mount, 6mm
A = wire link
PCB # 080805-1, see [1]

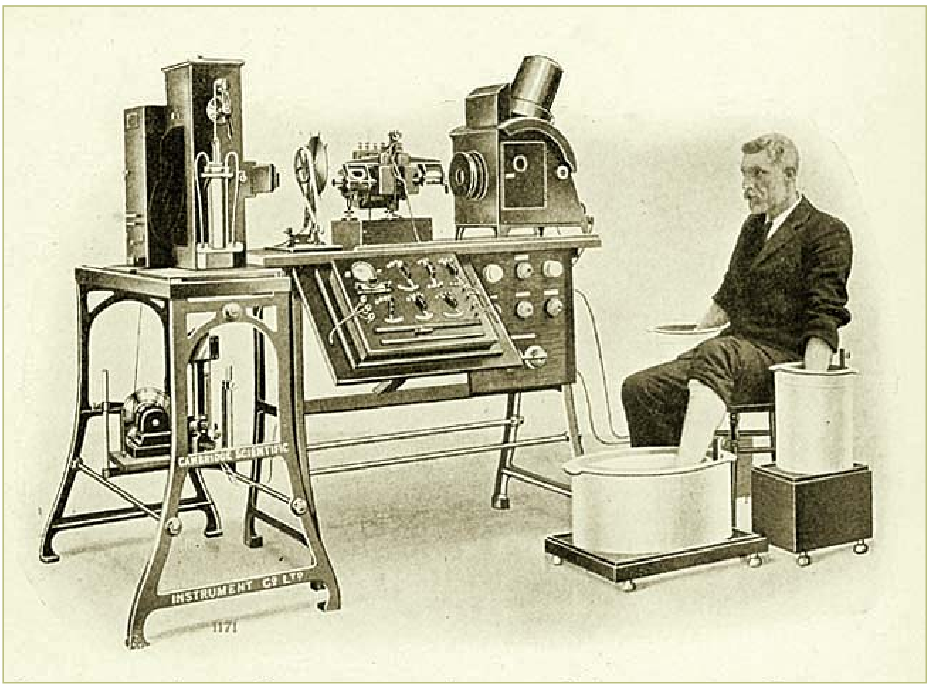


Component layout of the acquisition board.

each module a unique address. Every XBee module actually has two addresses. The first is a long unique address (64 bits) in the form of a serial number assigned by the manufacturer, which is divided into two parts: 'Serial Number High' (SH) and 'Serial Number Low' (SL). The second is a short address (16 bits) assigned by the user. The short address is used in this system. Configure the short addresses of the modules by setting the 'Destination Address High' (DH) register to '0' and the 'Destination Address Low' (DL) to a value less than '0xFFFE'.

Configuring the module on the acquisition board

- 'Networking & Security' menu: Configure the module as an end station by setting 'Coordinator Enable' (CE) to '0'. Then set the destination address (DL) to '0x1234' and the source address (MY) to '0x5678'.
- 'I/O Settings' menu: Set 'D0' to '2' to enable the A/D converter connected to pin 20 (ADC 2). The XBee module has six ADC inputs (AD0 to AD5) on pins 11, 15, and 17–20. Set 'IR' to '3' to configure the sample rate interval to 3 ms. This interval is sufficient for digitising the ECG signal applied to pin 20 of the module after amplification and filtering. IR will subsequently be set to '1' for transmitting the sampled data sequence.



One of the first ECG diagrams taken with the system. The three electrodes are vessels filled with saline water.

Configuring the module on the receiver board

- 'Networking & Security' menu: Set 'CE' to '1', since this module controls the transmission process. Set the addresses to DL= '0x567' and MY = '0x1234'.
- 'I/O Settings' menu: Enable the I/O enable command (I/O Output Enable) by setting IU to '1' (Enabled).
- 'I/O Line Passing' menu: Set 'I/O Input Address' (IA) to '0x5678', which is the same as the address of the module on the acquisition board. If you set 'PWM0 Configuration' (PO) to '2' (PWM Output), you can view the transmitted ECG signal on the receiver board with an oscilloscope after connecting a 200-Hz passive filter to the PWM0 output on pin 6.

ECG signal simulator

We designed this circuit (see **Figures 4** and **5**) to allow tests and measurements

on the entire system to be made safely during the design phase. It generates a signal that resembles a real ECG signal in terms of period, pulse width and amplitude. This artificial ECG signal is generated by an NE555 configured as an astable multivibrator.
The outputs are referenced to a level of approximately 1.2 V by R7/R8 and R9/R10, so they can be connected directly to the inputs of the acquisition card. Capacitor C6 connected to the output of the NE555 shapes the pulse waveform. The diode clamps the negative pulses, and the amplitude of the resulting signal is reduced to a few millivolts by voltage divider R5/R6.

Assembly

Assembling the acquisition and receiver cards is relatively straightforward. Note that the XBee modules have an unusual lead pitch of 2 mm and the leads are square. However, special matching connecters are available. Nine leads of the module on the acquisition card are used, while only five leads of the module on the receiver card are used. Individual socket posts cut from an IC socket can be used for the connections to the module leads.
To allow the modules to be programmed, reprogrammed or used later for other purposes, they should not be soldered directly to the PCB.
You can use stimulation electrodes for the body electrodes, or you can make your own as described in the ‘Electrodes’ inset.

Viewing the ECG signal

For safety reasons, you should never connect an oscilloscope directly to the acquisition board in order to view the ECG signal. However, you can view the signal on the receiver card if you connect a filter to the PWM output. An example is shown in **Figure 6**. Another option is to view the signal on the PC monitor by using a program that displays the data received from the interface cable in graphic form. **Figure 7** shows an example of an ECG plotted with the aid of an interface developed with LabVIEW. It is available as an executable file on the Elektor web page for this article [1] and on the project website [5]. This simple program allows the ECG signal to be visualised quickly.

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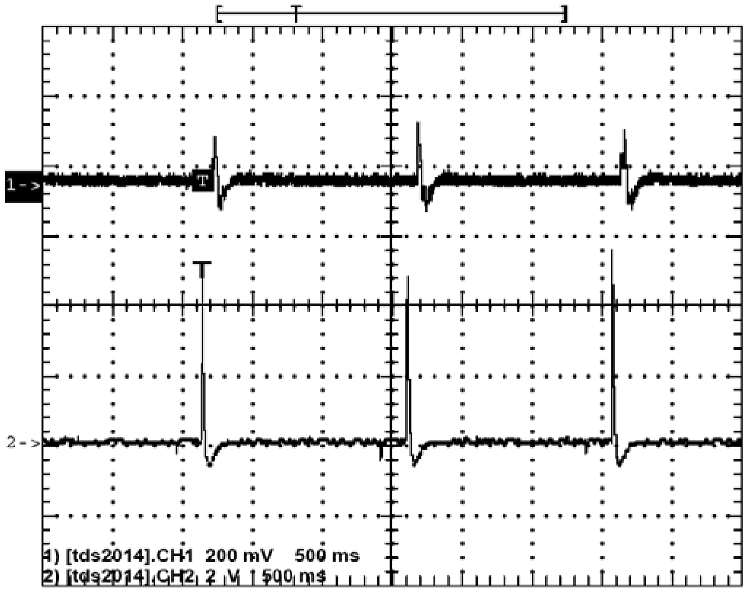

Figure 6. Simulated ECG signal at the output of a low-pass filter connected to the PWM output of the receiver module (trace 1) and the signal from the ECG simulator after attenuation (trace 2).

Internet Links

[1] www.elektor.com/080805

[2] ‘GBECG’, *Elektor* October 2006, www.elektor.com/050280

[3] ‘ZigBee Transceiver’, *Elektor* March 2007, www.elektor.com/060348

[4] www.digi.com/support

[5] www.enseignement.ensicaen.fr/claroline/course/index.php?cid=PRJECGXBEE (in French)

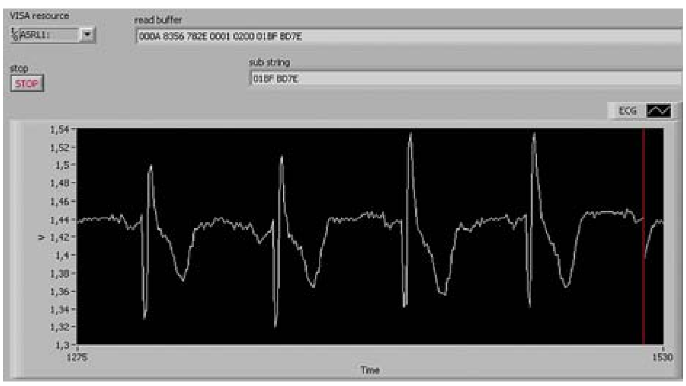

Figure 7. An actual ECG signal on the PC monitor, visualised using a LabVIEW interface.

Groping in the Dark

Webcam conversion to night-vision camera?

By Thijs Beckers (Elektor Netherlands Editorial)

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

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

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

Not too expensive

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

Results before...

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

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

Both drivers are at their default settings.

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

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

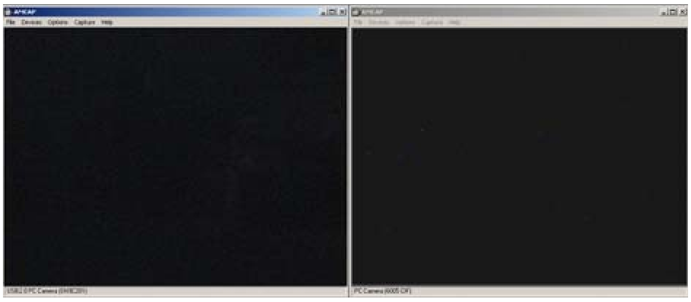

Figure 2. Without lights the image of both cameras remains black.

a few individual IR-LEDs and a — somewhat older, but nevertheless still very well functional — IR-floodlight with 28 IR LEDs from Conrad Electronics.
Neither of these webcams were able to see anything in complete darkness, despite the fact that the infra-red LEDs were turned on (**Figure 2**). Some image noise and the odd lost red, blue or green pixel were the only things visible on the laptop screen. Only when we pointed the IR LEDs directly into the lens could we see that they were actually turned on. It was not possible to recognise any objects at all in the dark.
From this it appears that both cameras have a built-in IR filter. So, open them up, because that has to come out.

...and after modification

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

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

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

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

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

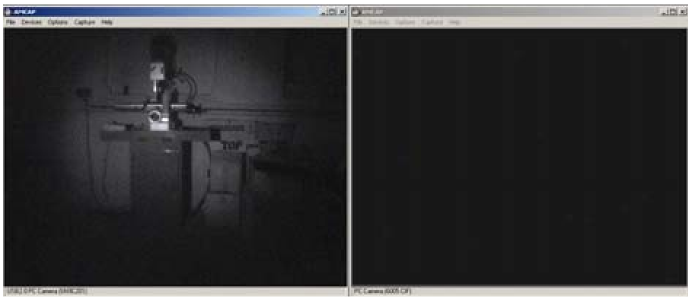


Figure 4. Using only 3 IR-LEDs a nice picture already begins to form with the modified camera. The camera with IR-filter is still groping in the dark.

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

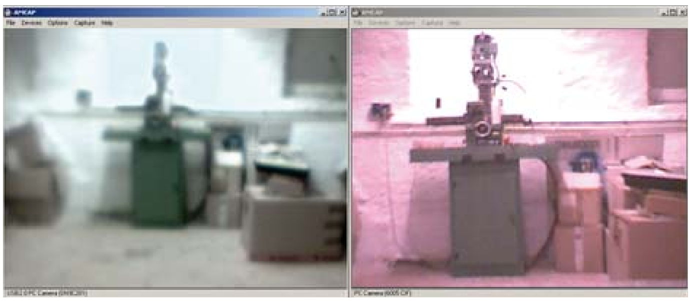


Figure 6. Using the modified camera during both the day and night is unfortunately not very practical: the focussing has to be redone every evening and morning, and by hand.

Opamp versus Comparator

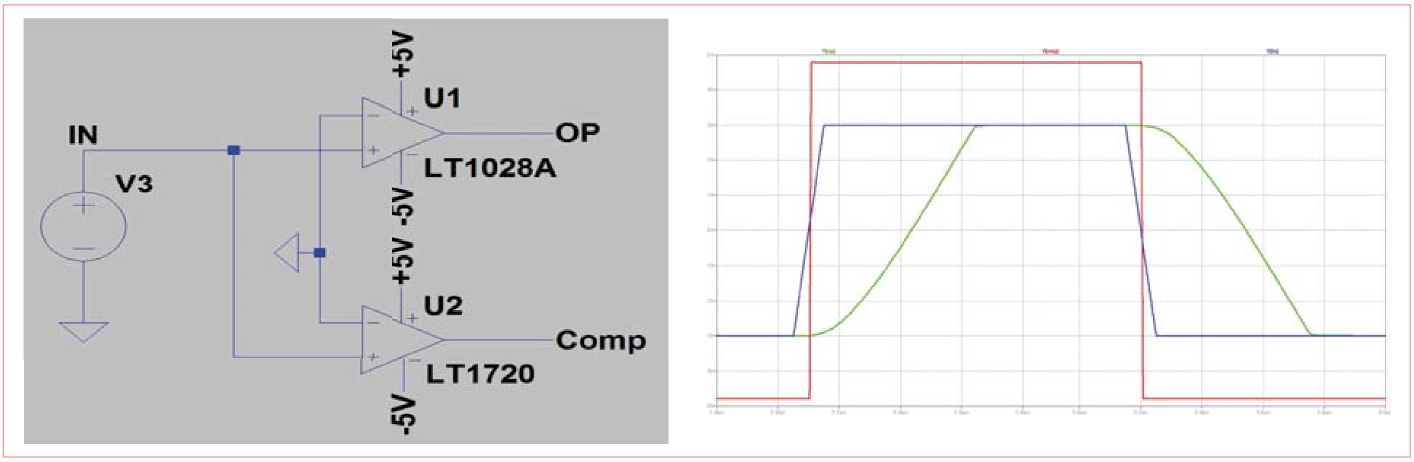
Superficially similar yet decidedly different

By Michael Hölzl (Germany)

Practically every lecture course or textbook on electronics describes how to use an operational amplifier as a comparator. Here we look at the possibility in more detail, and see how it can often be a very poor idea.

The idea behind the comparator configuration is simple. An opamp has a very high open-loop DC gain which means that even a tiny differential input voltage will drive the output to one extreme or the other. If the voltage at the non-inverting ('+') input is greater than that at the inverting ('–') input the output goes high; otherwise the output goes low. In other words the two voltages are compared and the output is a binary indication of which of the two is the greater. So the opamp looks like the perfect device to provide digital logic levels at their outputs while accepting symmetrical analogue input signals.

What do these differences mean in practice? Comparators can react very quickly to changes in their input voltages with short propagation delays and output rise- and fall-times all specified by the manufacturer. In contrast, because opamps are not expected to be used in this mode, manufacturers tend not to give explicit specifications for propagation delay and rise- and fall-times (although they do normally specify slew rate), and these characteristics can be considerably poorer for opamps than for comparators. To take an extreme example, a low-power opamp might have a propagation delay measured in milliseconds, whereas a comparator might react in nanoseconds: a million times faster.



SPICE simulation results: an LT1028 opamp pressed into service as a comparator versus a real comparator type LT1720.

use as a comparator. But why then do there exist special-purpose comparator devices?
Looked at from the outside, opamps and comparators appear indistinguishable. Besides power connections, they both have '+' and '–' inputs and a single output. Taking a look at the internal circuit diagram, again the two devices appear broadly very similar (although a comparator device with an open-collector or open-drain output does look more obviously different from an opamp). The big difference, which is not apparent without looking at the circuit more closely, is that the output stages of operational amplifiers are designed for linear operation, with the general aim of amplifying the input signal with as little distortion as possible (assuming that some negative feedback is provided), but in the case of a comparator the output circuit is designed to operate in saturation, that is, to switch between the upper and lower output voltage limits without the provision of external feedback. Comparators often also offer a ground connection in addition to the usual power connections, and

There is a further problem with opamps. Many devices exhibit significantly increased power consumption when the output is in saturation, the resulting power dissipation on occasion being enough to destroy the device. Also, many opamps (those not advertised as having 'rail-to-rail outputs') are not capable of driving their outputs close to the supply rails, for example having a maximum output voltage of 3 V with a 5 V supply. There can also be restrictions on the inputs. Some opamps are equipped with antiparallel diodes across their input terminals, which prevent differential input voltages of more than about 0.6 V whereas comparators' inputs are often allowed to vary over the whole supply range.

Of course, there are many non-critical applications where an opamp will work perfectly acceptably as a comparator, but it is not a practice to be recommended. The sceptic should lash up a quick test with a comparator and an opamp side-by-side, each fed with a squarewave signal with rapid edges. Some of the potential pitfalls are shown up more easily in simulation, such as the possibility of an opamp being so slow that it entirely misses a narrow pulse. It is hard to guarantee circuit performance, current consumption, and even the survival of the device.

The illustrations show a SPICE simulation of a relatively nimble opamp (an LT1028 with a minimum slew rate of 11 V/µs) and a type LT1720 comparator. It is clear that the comparator responds sooner and with a much shorter rise-time. Its output swings all the way to +5 V rather than the 3 V managed by the opamp. The situation is similar when the output swings low: the opamp is much slower and only reaches an output voltage of –3 V rather than –5 V. The original squarewave is hardly recognisable at the opamp's output. Although the LT1028 cannot achieve its maximum specified gain with a ±5 V supply, it is still a factor of at least 20 faster than an LM324 (with a slew rate of 0.5 V/µs); what the latter would make of our squarewave would not be a pretty sight. The opamp fails to cope at all with shorter pulses, which are then effectively 'swallowed', while the comparator continues to handle them without difficulty.

Worthwhile further reading on this subject is Texas Instruments Application Note SLOA067 by Bruce Carter, entitled *Op Amps and Comparators – Don't Confuse Them!*.

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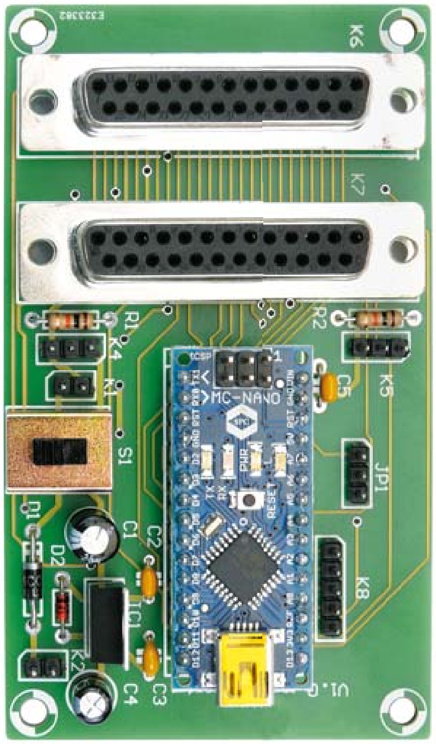
Support Board for Arduino Nano

By Philippe Frétaud & François Auger (Saint-Nazaire Institute of Technology, France)



Arduino boards exist in several formats. The standard board (which itself also exists in several versions like the Diecimila, the Duemilanove, the Uno, etc.) is the one that measures around 5 × 7 cm and to which can be added a 'shield' — an Arduino extension board.

The LilyPad board is a circular Arduino for clothing applications, and the Nano is a small Arduino module (18 × 43 mm) specially designed for use with prototyping boards and breadboards.

In place of the standard Arduino's female connectors, the Nano has two rows of 15 solder pins on a 2.54 mm (0.1") pitch. So it looks quite a bit like the boards for older microcontrollers like the Basic Stamp 2 or the CUBLOC CB320, with an additional USB link that is ideal for current computers.

Unlike a standard Arduino module, the Nano needs a support board if we want to use it in an application. In this article, we're proposing a motherboard that was originally designed for a robotics application, but which can very well be used for other jobs too. The robotic aspect of this board can be seen in the 6 V supply and connectors K4 and K5, to which a servomotor can be connected. If you're not using servos, you can dispense with the 6 V supply.

For the rest, the board is very simple: All the Nano's inputs/outputs are quite simply brought out to two 25-pin sub-D connectors (K6 and K7).

The boards are powered by 9 V. The Nano has an on-board 5 V linear regulator, and also makes available the 3.3 V rail produced by the USB interface chip. By means of JP1, one of these two voltages can be connected to K6 and K7, by fitting a jumper to contacts 1 and 2 (5 V) or 2 and 3 (3.3 V). These rails are also available when the Nano is powered via its USB port.

As these two outputs can't supply much current, an additional 5 V linear regulator has been incorporated into the support board. The 9 V input rail is also wired to K6 and K7.

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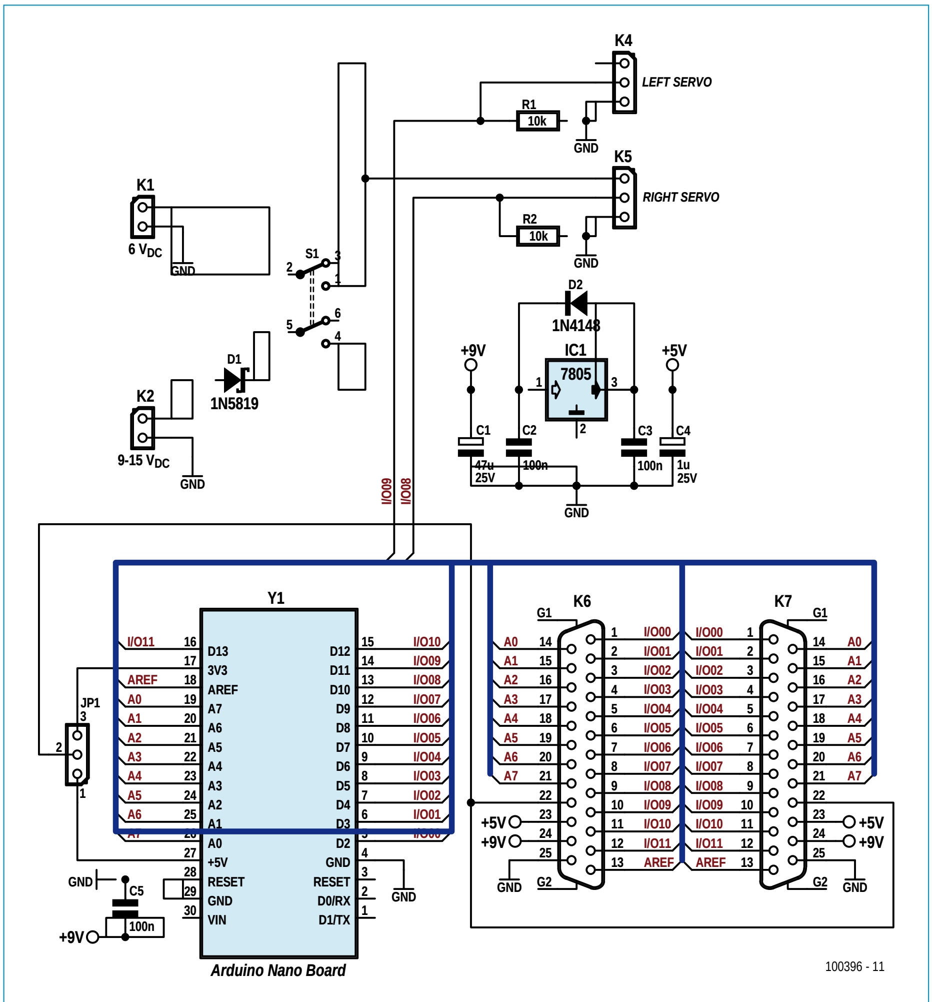
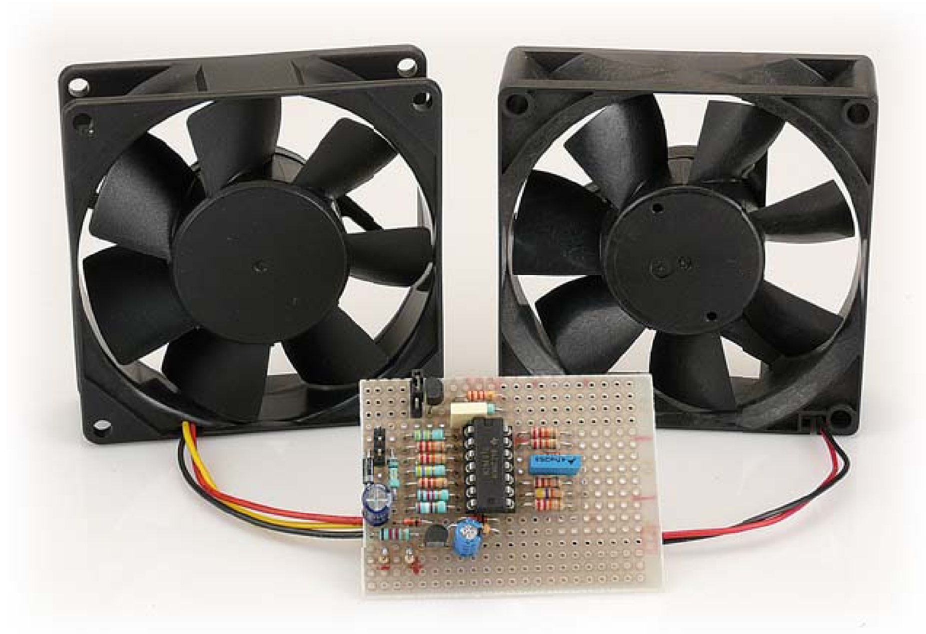


Three Out of Two Ain’t Bad

Add a tachometer output to 2-wire fans

By Volker Schmidt (Germany)

If you replace a broken three-wire fan in a PC or other device with a more readily-available two-wire fan, the missing tachometer (‘tacho’), signal will cause the system to report a fault and possibly even refuse to function at all. The problem is solved with the circuit shown here, which analyses the fan current to generate a signal that corresponds to its rotation speed.



Three-wire fans have an internal tachometer which produces a signal on the third wire (the other two being the supply voltage and ground) whose frequency depends on the rotation speed. This output can be used by the device being cooled by the fan to check that the fan is running.

If such a fan is replaced by one of the two-wire variety, it is possible to simulate the tacho signal with an astable multivibrator circuit, for example using a 555 timer. However, this has the disadvantage that the operation of the fan can no longer be properly monitored by the device. One way to generate a meaningful tacho signal is to analyse the current draw of the fan.
The simple circuit shown here uses a readily-available TL074 quad op-amp and just a handful of other ordinary components.

How it works

The circuit does not look at the absolute level of current draw of the fan: rather, it analyses the regular variations in current which are synchronised with the rotation of the fan. The oscilloscope trace in Figure 1 shows the characteristic regular interruptions to the current flow from which our circuit derives the tacho signal. We use a low-value resistor as a current sensor, coupled to a differential amplifier to extract the signal. The resulting signal is then cleaned up and used to trigger a monostable circuit.

The details

The circuit of the tacho signal generator (Figure 2) is centred around a type TL074 quad op-amp. A few passive components, three diodes, one Zener diode and two transistors complete the circuit.

R1 is the current sensor, with a value of 1 Ω. The low value means that the voltage to the fan will not be reduced to a significant extent. Differential amplifier IC1.A amplifies the voltage drop across R1 by a factor of about 21 and inverts the signal. Interruptions to the fan current therefore appear as positive-going spikes at its output. Capacitor C1 couples these to the input of comparator IC1.B. If the spike peak should exceed the threshold set by the voltage divider comprising R6 and R7 the output of IC1.B will swing high, almost to the positive supply rail. The spikes are thus converted into a rectangular wave signal (see Figure 3).
The third op-amp (IC1.C) forms a monostable triggered by positive-going edges

On the bench

We tested the circuit in the Elektor labs with a two-wire fan made by Canon (type number CF80-T211N1D). We compared the tacho signal output by the circuit with that of a three-wire fan, a Sunon KDE1208PTB1-6A, which provides its tacho signal on a yellow wire.

With a 12 V supply the circuit worked well. The duty cycle is not 50 % and falls at reduced supply voltage and fan rotation rate: the pulse width remains the same, but the interval between pulses increases as rotation slows. Our test fan gave a duty cycle of 50 % with a 12 V supply using a value of 56 nF for C2.

Since the virtual ground generated by Zener diode D4 and T1 is fixed relative to the system ground, the supply becomes asymmetric at of this rectangular wave. The period of the monostable is given by the formula

$t = R9 \times C2 \times \ln(1 + R11/R10)$

and with the suggested component values the output pulses are a little over one millisecond wide. The output stage, consisting of IC1.D and T2, provides this signal as an open-collector output. As T2 inverts the signal, IC1.D is also wired in an inverting buffer configuration (gain of –1). JP1 gives the choice of this open-collector output or a direct output from IC1.C.

The circuit takes its power from the +12 V supply to the fan, which is normally provided by the device being cooled. D3 and C3 smooth the supply and the circuit around T1 provides a virtual ground at around half the supply voltage. In effect this provides a symmetric ±6 V supply to the op-amps in the TL074, referenced to the virtual ground.

In practice

When building the circuit, be aware that the ground symbol that appears at various points in the circuit diagram is not system ground, but the virtual ground at around half the supply voltage. These virtual ground points should be connected to one another, but not, of course, to system ground! System ground is connected only to the GND pin of K1 and thence to other points in the circuit marked in the diagram with an inverted triangle.

The circuit can be built on a piece of prototyping board (Figure 4) with the following external connections:

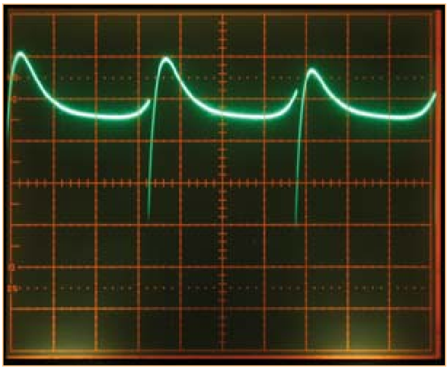


Figure 1. Oscilloscope trace showing regular interruptions in the fan current, from which the tacho signal is derived.

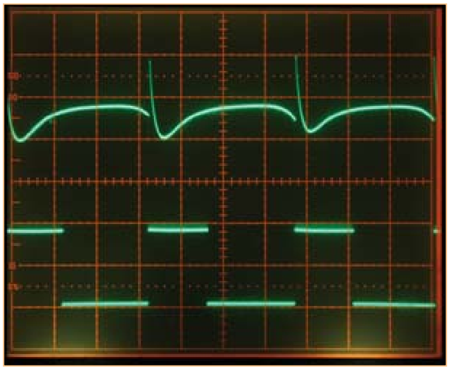


Figure 3. The signal at the output of the differential amplifier (upper trace) and the tacho signal at the output of the circuit (lower trace).

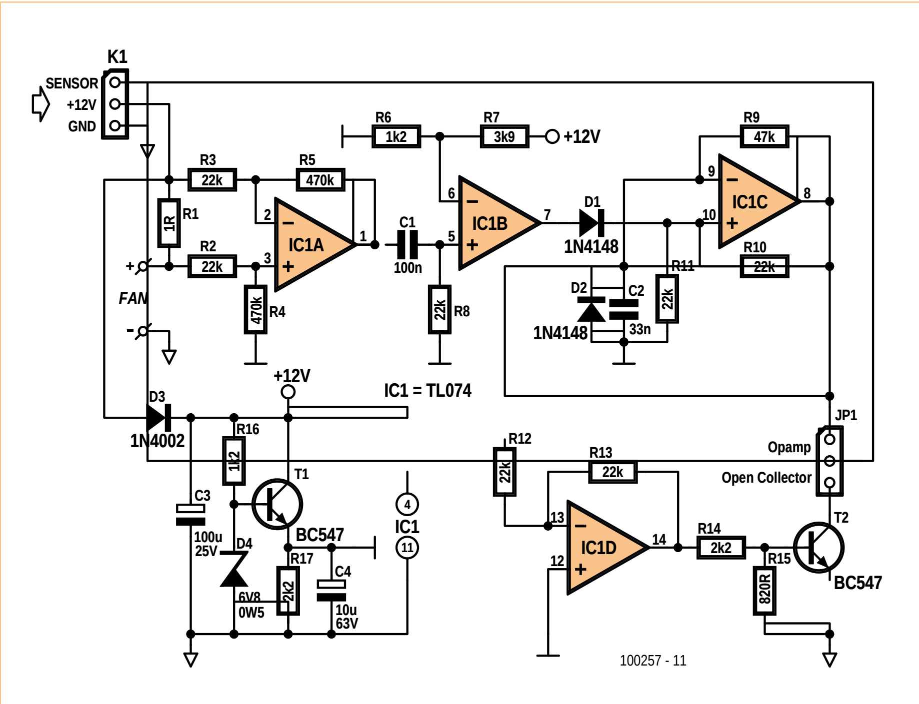


Figure 2. The circuit uses a resistor as a current sensor, with the signal being amplified by a differential amplifier before being cleaned and fed to a monostable stage.

supply voltages of less than 12 V. Soon the TL074 will be operating outside of its rated common-mode range, and the supply voltage will also soon be below the device's specification. If the speed of the fan is to be controlled by adjusting its supply voltage it is a good idea to improve the symmetry of the supply, for example by replacing Zener diode D4 by a 2 kΩ resistor (1.8 kΩ or 2.2 kΩ will do). The circuit will now operate from a supply of between 6 V and 12 V, with the virtual ground being at slightly above half the supply voltage (which does not impair performance). If the supply voltage falls to 5.5 V or below the circuit will start to oscillate: the TL074 is not designed to work at such low voltages.

The suggested component values worked well with the Canon fan. The period of the output varied from 4.15 ms (at 12 V) to 8.4 ms (at 6 V). The 'real' tacho pulse generator on the three-wire Sunon fan was in reasonably good agreement, with periods of 5.9 ms at 12 V and 10.8 ms at 6 V.

The current consumption of the circuit itself was measured at 18.7 mA at 12 V and 9.4 mA at 6 V.

Ton Giesberts (Elektor Llabs)

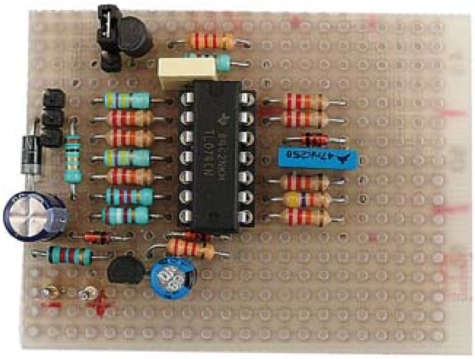


Figure 4. The Elektor lab prototype, assembled on a piece of prototyping board.

+12 V to the pin marked '+12 V' on K1, taken from the +12 V pin on the fan supply connector in the PC or other device;

the tacho signal from the pin marked 'sensor' on K1, taken to the tacho pin on the fan supply connector;

system ground to the 'GND' pin on K1, taken from the ground pin on the fan supply connector;

the two wires to the replacement fan, its +12 V positive supply being connected to the point marked '+' on the circuit diagram (at the junction of R1 and R2) and its ground to the GND pin of K1 (system ground).

The pin arrangement for K1 shown in the circuit diagram is compatible with the connector for three-wire fans usually found on PC motherboards. Sometimes the pin marked 'sensor' in the diagram is labelled 'rotation' by the manufacturer.

Operation of the circuit has been tested with MagLev-series fans made by Sunon as well as other types. The circuit may need to be adapted to suit certain types of fan.
For proper operation the circuit needs a signal amplitude of around 200 mVpp across current sense resistor R1. If this level is not achieved, make suitable adjustments either to R1 itself or to the gain of differential amplifier IC1.A by changing the ratio of R5 to R3 and of R4 to R2.

For slow fans the monostable period of 1 ms may be too short. Increase it if necessary by increasing the value of C2 and/or R9.

(100257)

Notch Filters for Intermediate Frequencies

Effective and selective

By Michael A. Shustov (Russia)

In radios designed for long distance communication, a notch filter is used to suppress or hopefully wipe out noise, whistles, buzzes, static, chirps, woodpeckers and what have you that persistently degrade the wanted signal. In this article we cover simple LC and RC notch filters for use in the radio's intermediate frequency (IF) section.

Notch filters — sometimes called or band reject filters or just notches — need to be extremely selective for the obvious reason that you do not want them to start affecting the wanted signal, although in most cases that can't be ruled out entirely. Rephrasing for technospeak, great attention must be paid to the notch filter's tuning, bandwidth and steepness of the frequency response. Notch filters occur, and may be applied at, RF (antenna), IF (intermediate frequency; typically 10.7 MHz, 9 MHz, 500 kHz or 455 kHz) or AF

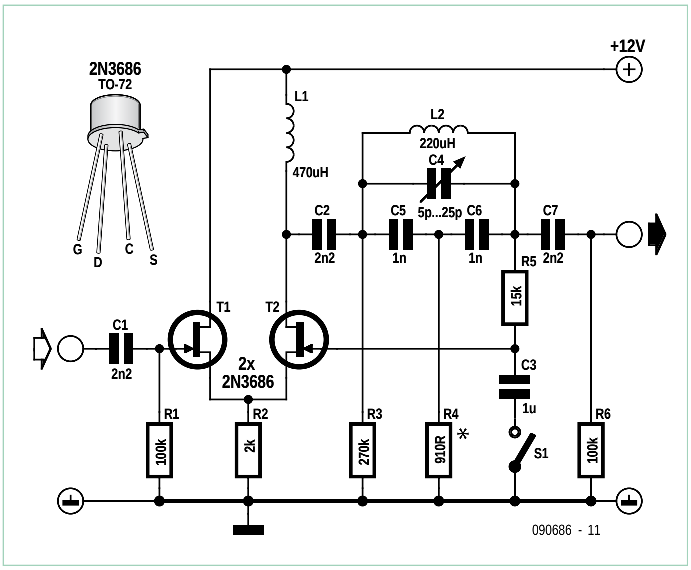


Figure 1. A peaking LC filter designed for an IF of 500 kHz. Tweak R4 to adjust the effectiveness. S1 is the 'defeat' switch and C4 acts as a fine tuning control.

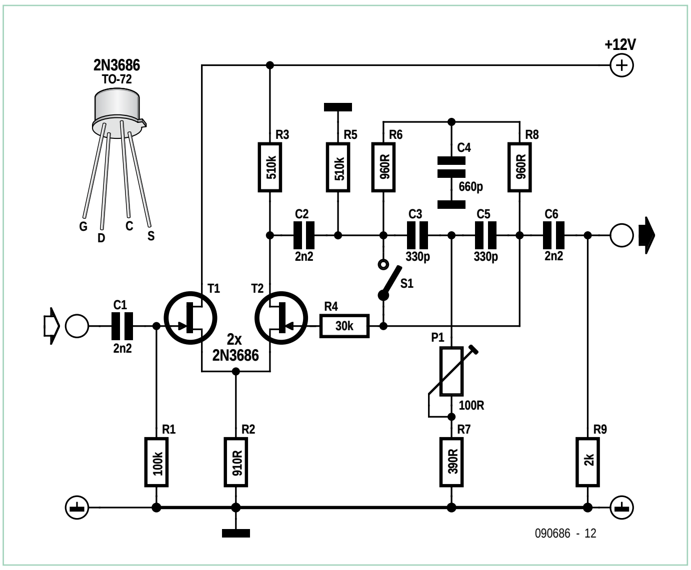


Figure 2. This filter with an RC network in the positive feedback path offers a true notch (frequency reject) response.

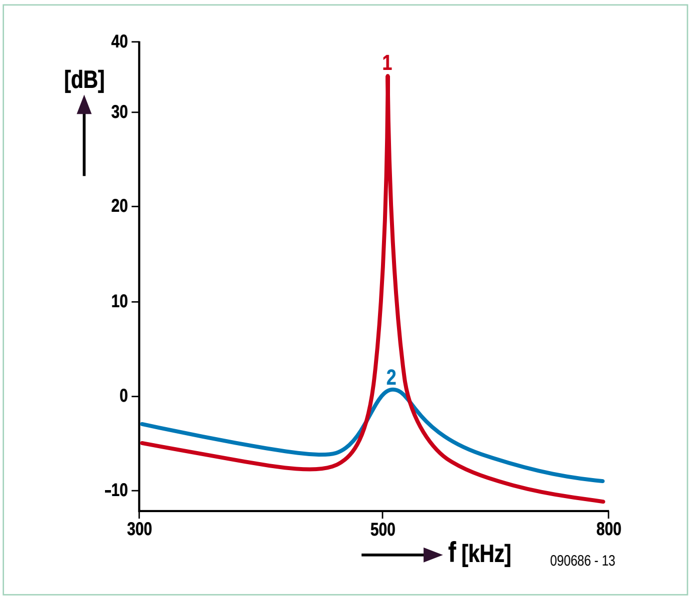


Figure 3. Frequency response of the LC filter (curve 1: S1 open; curve 2: S1 closed).

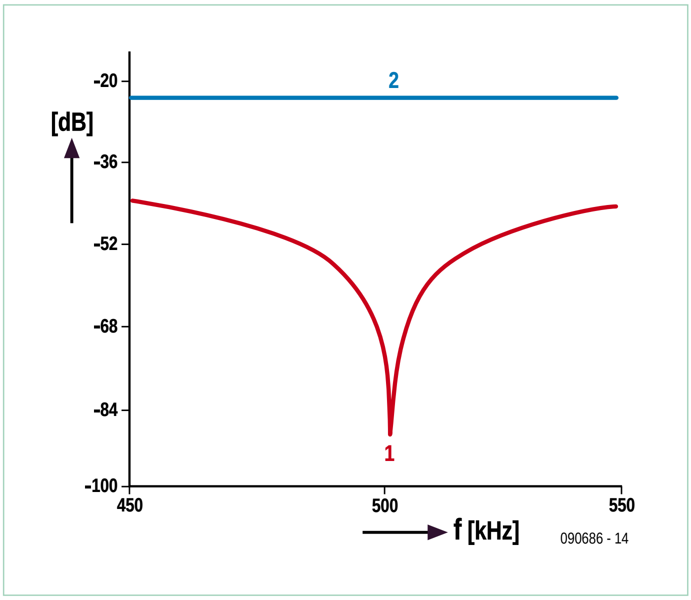


Figure 4. Frequency response of the RC filter (curve 1: S1 open; curve 2: S closed).

(audio; now the accepted realm of DSPs). A well trained radio operator is able to juggle his notches at RF, IF and AF (if available), warding off all types of interference that mess up the signal he wants to hear, decode or process. Lots of skill is required, as well as a trained ear, to continually tune notches in the fight against rapidly changing noise patterns, interfering traffic on a channel or breakthrough from local stations.

Although technically speaking not a 'notch', a very steep bandpass filter has similar effects to a notch on weak telegraphic (CW) or single-sideband (SSB) signals — zooming in, as it were, on the wanted signal heavily affected by noise either side, instead of suppressing individual noise components.

L, C, R and FET to combat noise

The notch filters described here are of the LC and RC type, and intended for application in the intermediate frequency (IF) section of a radio receiver. Their principle of operation is identical, though the circuit in **Figure 1** is a sharp filter tuned to the signal, and the one shown in **Figure 2**, a notch suppressing selected noise components. Both have an on/off control and a 'depth' (or 'peak') control included. They are designed for operation at 502.7 kHz (basically 500 kHz IF + 2.7 kHz sideband) in terms of the frequency-determining components.
The filters consist of a source follower T1 at the input and an amplifier stage T2 with a degree of positive feedback. The operating frequency of the filters is defined by the LC (Figure 1) or RC parts (Figure 2) in the positive feedback path.

The amount of positive feedback and with it the effectiveness of the filters is adjusted by selection (or fine tuning) of resistor R4 in the LC circuit (Figure 1), or adjustment of P1 in the RC circuit (Figure 2). The operating frequency (rejection frequency) of the LC filter can be fine tuned by trimmer C4. Alternatively, a varicap (variable capacitance diode) with a 25 pF range may be used in this position. Switch S1 is the On/Defeat control for both filters.

Performance

As shown in **Figure 3**, the LC filter achieves a steep 'inverted notch' response with a peak at 37 dB. By closing switch S1 the IF signal is passed with no filter action and minimal attenuation.

Compared to the LC filter, the RC variant allows effective and selective suppression of interfering signals within the IF passband, see **Figure 4**. At a rejection frequency of 504.0 kHz, depending on filter adjustment, the noise suppression can reach 83–90 dB with an overall attenuation of about 40 dB for all other signals. When switch S1 is closed, the filter is disabled you're looking at an overall attenuation of about 22 dB. Remembering that we are dealing with a 500 kHz IF signal, this should be relatively easy to restore back to its original level by adding an extra gain stage.

(090686)

Hexadoku

Puzzle with an electronics touch

A new year brings new opportunities, hopefully also for our monthly Hexadoku competition. This month we present a puzzle that's slightly more difficult than usual, but feel free to disagree and find it a walk in the park. Enter the right numbers in the puzzle, send the ones in the grey boxes to us and you automatically enter the prize draw for four Elektor Shop vouchers. Have fun!

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

Solve Hexadoku and win!

Correct solutions received from the entire Elektor readership automatically enter a prize draw for one Elektor Shop voucher worth £ 80.00 and three Elektor Shop Vouchers worth £ 40.00 each, which should encourage all Elektor readers to participate.

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Prize winners

The solution of the November 2010 Hexadoku is: **3F642**.

The £80.00 voucher has been awarded to: Luciano Poretti (Italy).

The £40.00 vouchers have been awarded to: Marc Moulin (France), David Meiklejohn (Australia) and Christian Klems (The Netherlands).

Congratulations everyone!

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

Tandberg Model 5 & Stereo Record Amplifier (ca. 1959)

By Ricard Wanderlöf (Sweden)

In the late 1950's, stereo was in its infancy as far as Joe Bloggs was concerned — what little equipment there was being firmly aimed at the rich & wealthy. While mainstream stereo radio was still a long way off, probably due to the investment in infrastructure that was required (i.e. not only radio receivers but also studios and transmitters would have needed to be upgraded), record players and tape players were starting to become available in stereo versions.

For some time in the early 1960's it seemed that audio equipment manufacturers expected stereo to completely take over from mono, but that was not destined to happen for another ten years.

1

Record players and tape recorders

Meanwhile manufacturers offered mono record players and reel-to-reel tape recorders with stereo upgrade capabilities. In the case of record players, many devices were fitted with stereo pickup cartridges, with the channels wired in parallel for mono use, but easily upgraded to stereo by a simple rewiring operation.

When it came to tape recorders, things weren't so simple. As opposed to a vinyl record, where both channels are in principle recorded on adjacent sides of a single groove, magnetic tape requires two separate tracks for stereo operation. This gives the user the obvious option of stereo recording, or mono recording with twice the recording time. With hindsight, this capability completely escaped the compact cassette format, but resurfaced in the Minidisc system many years later.

From mono to stereo

With not a lot of stereo material to record and FM stereo radio broadcasts few and far between or experimental only, many tape recorder manufacturers offered mono machines with some form of stereo playback capability using some form of external amplifier. Some manufacturers like the Norwegian Tandberg released several variations on the theme. One such machine, the Tandberg Model 5, launched at the end of the 1950s (**Figure 1**), was one of the first four track tape recorders in the world. Basically, it allows for recording four tracks on the tape — as the name implies — i.e. two in each direction of the tape.

The Model 5 is a rather unusual machine in that it has two complete amplifiers, for complete stereo playback, but only one of them can be put in recording mode. It also has just one internal speaker, but that is not too unusual; even with two speakers the stereo effect is rather limited in such a relatively small device, so many manufacturers opted to have one speaker external for stereo reproduction. In many cases the external speaker would be contained in the removable lid of the tape recorder, such as in a few Philips stereo machines from the same period.

2

An add-on stereo recording amplifier

The Stereo Record Amplifier pictured in **Figure 2** was supplied by Tandberg as an accessory to their Model 5 tape recorder. This add-on device plugs into the rather unusual DIN connector on the rear head cover of the tape recorder (**Figure 3**), supplying the lower half of the tape head (right hand channel) with a recording signal. The unit gets its power from the tape recorder via a connector with a four-pin socket emanating from the AC power cable storage compartment on the back of the machine (**Figure 4**).

The Stereo Record Amplifier contains a

complete recording amplifier for the right hand channel, with line and microphone inputs, a volume control, a 'magic eye' recording level indicator, and a speed selector switch which would have to be set to the same setting as the one on the tape recorder to get proper recording equalization. The Model 5 is the only Tandberg to employ an external amplifier in this way, and indeed I've never come across any other machine from another manufacturer with a similar setup.

3

Why Tandberg opted for the external amplifier like this is a bit of a mystery to me. Indeed, as noted above, few people would have anything to record in stereo, but given that the Model 5 already had two amplifiers, having built-in stereo recording capabilities would be mostly a question of a few additional connectors and a bit of signal switching. This machine was already the top-of-the line model at its time, so it must have been rather expensive — hence I don't think the additional cost would have made much of a difference. Perhaps the stereo recording capability was added as an afterthought, late in the development phase of the machine.

4

Before the Model 5...

Putting it all in perspective, the first stereo Tandberg was the Model 3 Stereo, introduced a couple of years before the Model 5. The '3' could play back two track stereo (it had two complete amplifiers but only one speaker like the Model 5), but recording on one channel only (left).

The rationale for that was that two-track mono was the norm in those days (flipping over the tape at each end to record on both 'sides'), but stereo was around the corner, and the natural step would be to use both channels for stereo. It was probably assumed that few people would record in stereo, the feature being intended primarily for the playback of pre-recorded tapes.

Shortly afterwards, four track recording was introduced, which I believe was deemed to be the future, and the Model 3 was followed by the four-track Model 5. With four-track capability came the option of recording either in stereo or getting twice the playing time by recording on the left and right tracks separately. The Model 5 could thus record either on the right or left tracks, or play back either in stereo, or in mono from either track, and of course, record in stereo together with the external record amplifier.

MP3 generation R U still there?

and after it...

A further variation came soon (that's right, after the Model 5) with the Model 4, which offered another variation on the same theme. In contrast to the Models 3 and 5, it did not have two complete playback amplifiers, and did not support recording in stereo at all; instead it had a preamp for the right-hand channel and required an external amplifier such as a tabletop radio for playing back in stereo. This layout was not too uncommon in those days, the rationale being that if someone wanted to play back in stereo they could provide their own amplifier for the right hand channel without the cost of the machine going up as a result of something that most people would never use.

Going further, at the beginning of the 1960s, Tandberg launched the Model 7 which had a complete stereo recording and playback system including two loudspeakers. The EM71 indicator tube had been replaced by the smaller EAM86 so that there was space for two indicators side by side for the left and right channels, and thus oddball machines like the Model 5 with its add-on Stereo Record Amplifier became history.

(100733)

Special thanks are due to Jan Didden for supplying the mint Tandberg stereo recording amplifier pictured here.

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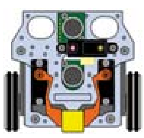

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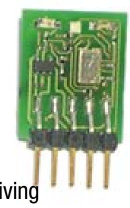

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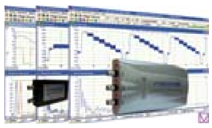

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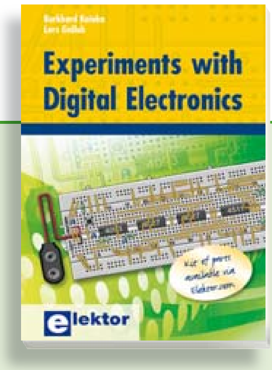

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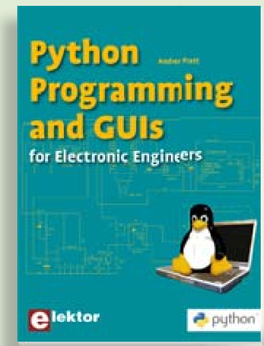

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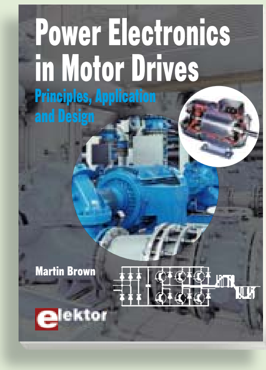

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C# 2010 Programming and PC interfacing

This book is aimed at anyone who wants to learn about C# programming and interfacing to a PC. It covers programming concepts from the basics to object oriented programming, displaying graphs, threading and databases. The book is complete with many full program examples, self assessment exercises and links to supporting videos. All code examples used are available – free of charge – from a special support website. Professional quality software tools are downloadable –also free of charge– from Microsoft. The Microsoft Visual Studio 2010 environment is extensively covered with user controls and their properties, methods and events. Detailed guidance is provided for those wishing to control hardware from a PC with PC interfacing chapters which explain the legacy serial and parallel ports, analogue interfacing using the sound card and use of Microsoft DirectX drivers. Interfacing to the ubiquitous USB port is explained in-depth with a detailed hardware and software design for a USB connected PIC-based hardware target included.

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ISBN 978-90-5381-265-5

£17.90 • US $28.90

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 • £53.00 • US $85.50

Digital Multi-Effects Unit

(September 2010)

It's a simple fact: every recording sounds better with the right sound effects. Here we prove that it's possible to generate a variety of effects digitally, including hall, chorus and flanger effects, without having to work yourself to the bone with DSP programming. The circuit is built around a highly integrated effects chip and features an intelligent user interface with an LCD. The result is a treat for the eye and the ear.

Kit of parts including PCBs, programmed controllers and EEPROM

Art.# 090835-71 • £165.00 • US $266.20

The Elektor DSP radio

(July/August 2010)

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

PCB, assembled and tested

Art.# 100126-91 • £149.00 • US $240.40

Reign with the Sceptre

(March 2010)

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

PCB, populated and tested, test software loaded (excluding Bluetooth module)

Art.# 090559-91 • £89.00 • US $143.60

Kits & Modules

Product Shortlist

	£	US $
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090328-41 .... ATmega328-20AU (TQFP32-08), programmed	11.00	17.80
Stroboscopic PC Fan		
100127-1 ...... Printed circuit board	4.50	7.30
100127-41 .... ATtiny 2313, programmed	14.20	8.75
ARM Freephone Control		
080632-91 .... ECRM40 module, ready assembled and tested	32.00	51.70
Modular LED Message Board		
100664-41 .... MC9S08SH32CWL, programmed	8.75	14.20
Speed Controller for Small DC Motors		
100571-41 .... ATtiny44-20PU, programmed	8.75	14.20
November 2010 (Nr. 407)		
Micro Fuel Cell Measures Oxygen Concentration		
090773-91 .... PCB, populated and tested with programmed bootloader	56.00	90.40
The 5532 OpAmplifier (2)		
100124-1 ...... Amplifier board (one channel)	23.00	37.10
100124-2 ...... Power supply board	17.95	29.00
Camera Interval Timer		
081184-41 .... PIC16F886-I/SP, SPDIP28, programmed	8.00	12.90
October 2010 (No. 406)		
CL-3 Digital Rotary Combination Lock		
100026-41 .... Atmel ATTINY2313-20PU, programmed	8.00	12.90
Wheelie GT		
100479-71 .... Kit of parts upgrade kit controller board + 2x Hall sensor board	105.00	169.40
September 2010 (No. 405)		
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100500-71 .... Predrilled Lexan sheets with standoffs	14.90	24.10
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090835-42 .... ATtiny2313-20PU	8.30	13.40
090835-71 .... Kit of parts including PCBs, programmed controllers and EEPROM	165.00	266.20
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The Elektor DSP radio		
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Telephone Interface for VoIP

Next month we describe a so-called Foreign Exchange System Adapter with a USB interface. This enables an ordinary analogue telephone set to be linked to a Voice over IP (VoIP) system. For the associated Linux software we're using the Asterisk IP PBX software that's well known among insiders. With this small board so you can start using your trusted landline phone for VoIP communication.

Automatic Morse Generator

There are still many radio amateurs who enjoy morse. Those who are proficient in it like to use paddles enabling the dots and dashes to be generated via separate controls (paddles) using thumb and finger. The circuit was developed specially for this type of key. It looks after a lot of time related issues such as the pauses between dots, lines, spaces, etc., and also provides a standard mode as well as an Ultimatic mode. A small monitor amplifier is also accommodated on the PCB.

Light Alarm

You've probably seen them, alarm clocks with built-in lighting that wake you up gracefully and gently. Such lights should not be too difficult to make yourself, with the added advantage of being able to adapt the software to your preferences. This circuit contains all basic functions of a so-called light alarm clock, but thanks to the availability of the source code you can make changes to your heart's content.

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

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