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December 2009

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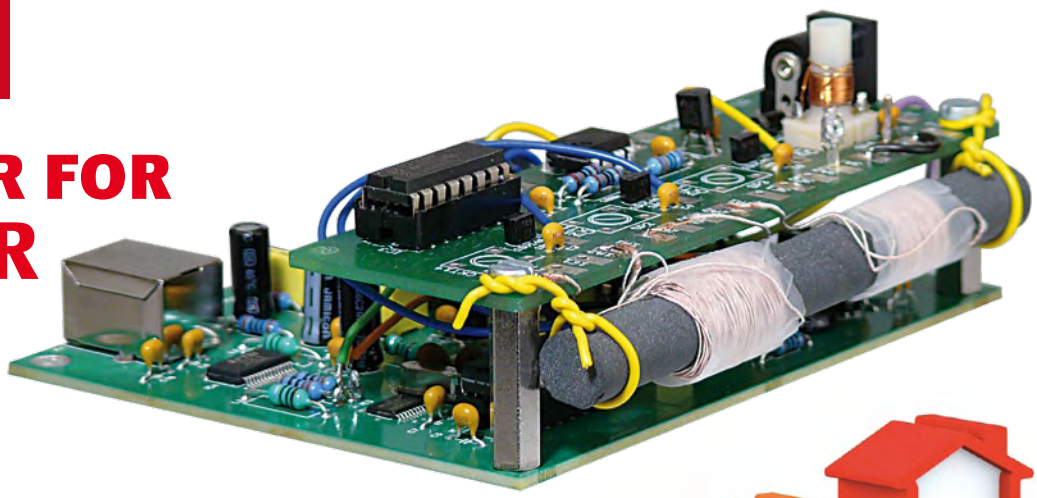
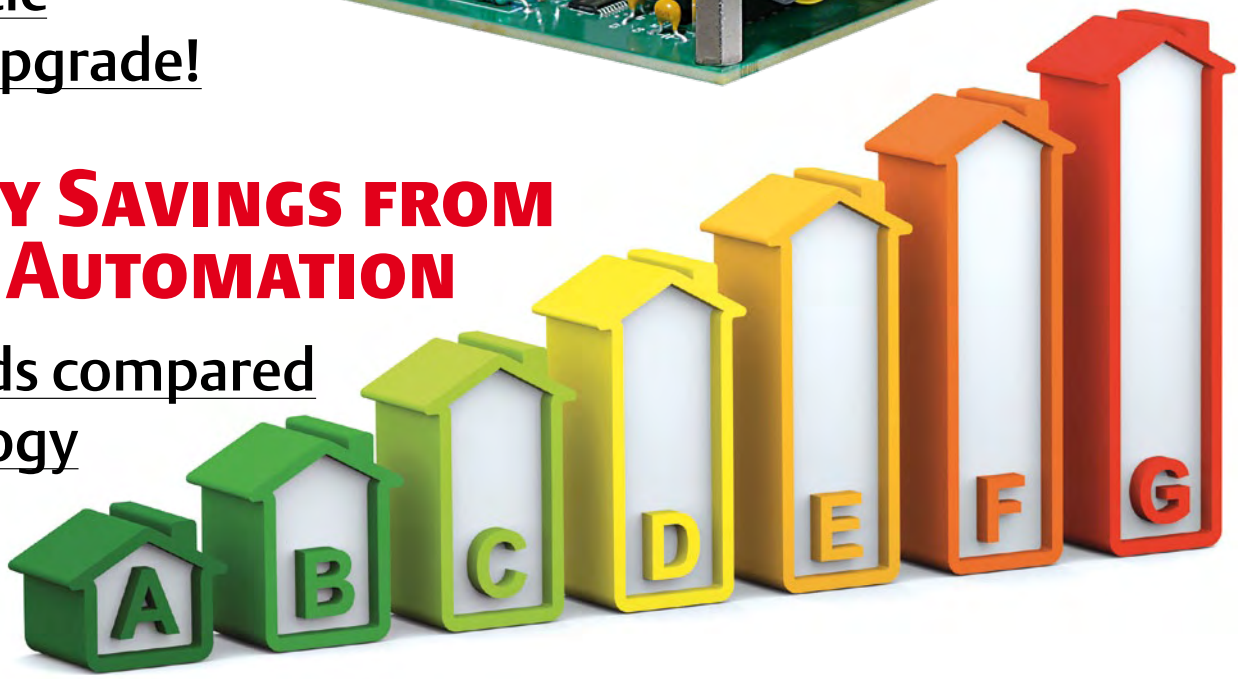


Preselector for Elektor SDR

Here's the automatic tuning upgrade!



Energy Savings from Home Automation

Standards compared
Technology
Projects

Christmas Holidays Circuits

13 pages of beginner's and junkbox projects

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The Award follow the story

12
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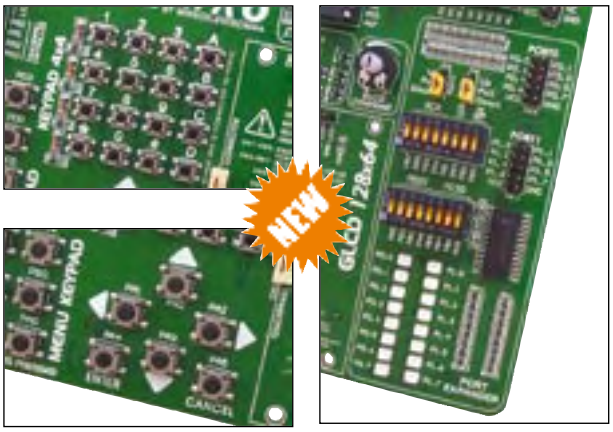

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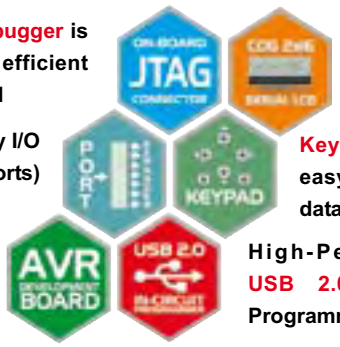

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Goodbye Standby

This piece is traditionally the last copy I have to hand to my colleague in the page layout department. Time flies — this December 2009 edition is the last of the decade, and although at the time of writing it's early Fall, January 2010 production is already upon the entire Elektor team.

This edition tackles issues that are sure to keep us busy and concerned over the next decade, with a prominent role for energy, natural resources and the environment — globally!

The European Commission is dead serious about it all and with my sincere advice to our American readers that "it ain't so bad if you see it coming", they successfully pulled all incandescent lamps with a matt bulb and/or a wattage of more than 75 from active retail on September 1. That was just the start of it — more drastic measures will follow in the new year, so let's see what's cooking — on the EC's electric hub, of course.

From January 7, 2010, new household and office equipment is limited to a power consumption of 1 (say, one) watt when switched off but in standby mode, or 2 watts when a display is still active (for example, a clock). From 2013, these limits will be tightened to 0.5 W and 1 W respectively.

An EC 'Eco-Design' initiative rules that from April 27, 2010, "external power supplies" (a.k.a. wallwarts) are forced to behave sparingly, too. They are allowed to consume 0.5 watts of power under no-load conditions, dropping to 0.3 watts exactly one year later. The efficiency of equipment in actual use is also 'regulated' by Brussels and there we have no objection, in fact the article 'Squeezing Out the Last Drop' on page 31 not only reveals mediocre design of some power supplies in respect of efficiency, but also suggests rather simple ways of saving lots of kilowatt-hours on an annual basis.

Back to the calendars, limiting values and deadlines have been set for lots of other electrical equipment like TV sets (January 7, 2010), advertising signs (February 2, 2010), electromotors (June 16, 2011) and circulating pumps (January 1, 2013). Electricity metering will also be reviewed massively as a result of flexible rates and 'smart metering', so the main two themes of this issue, energy saving and home automation, do go hand in hand.

Jan Buiting
Editor

elektor

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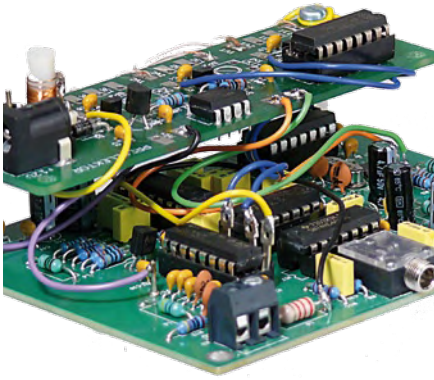

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Elektor's Software Defined Radio (SDR) is deservedly popular. The preselector described here allows the use of up to four filters, tuned under software control using varicap diodes. A tuned loop antenna is also described that lets you use our SDR without an outdoor antenna.

31 Squeezing Out the Last Drop

Your TV set is never in standby mode, and you're giving serious consideration to having a solar panel installed on your roof. What else can you do to reduce your power bill without too much fuss and bother?

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A compilation of circuits for the odd 'learn-while-u-tinker' hour you should be able to claim for yourself this December. Most of the parts used in the projects we reckon may be in your junkbox or hidden in a drawer. Good instructive stuff for the Christmas holidays period — have fun!

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

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Circuit suggestions for T-Reg

T-Reg ('A High-voltage Regulator for Tube Amps'), Elektor March 2009, article # 081089-I)

Dear Editor -- I read the T-Reg article with considerable interest, and I tried out the circuit right away. However, I replaced the two SC2910s and the two SA1208s with BF422s and BC327s, since the specified types are difficult to obtain in my country. The basic principle of this regulator is certainly clever, and the stabilization characteristics of the circuit are very good. However, I simply could not manage to make the circuit work with a normal MOSFET (such as the BUZ42 or BUZ90) instead of a tube as the pass regulator. There was absolutely nothing to be seen at the output of the circuit.
I found this rather puzzling, but a bit of study of the theory clarified the situation. A tube is controlled by a grid voltage that is negative relative to the cathode, but a normal MOSFET only responds to a gate voltage that is positive relative to the source (which takes the place of the cathode).
The T-Reg circuit is designed such that the voltage on the grid (or gate) can never be positive relative to the voltage on the cathode (or source). Accordingly, I began to have some slight doubt that the author actually managed to get the circuit to operate properly with a MOSFET. Perhaps the type of MOSFET used in the author's design (a DN2540) actually has control characteristics similar to those of a tube. If that is so, it would be a service to the reader to point this out, since many readers are inclined to use better known or commonly available components in place of rare or uncommon components.

A second criticism is the complexity of the circuit relative to what it does. I spent a bit of time developing a simplified circuit design based on the operating principle of the control amplifier (differential amplifier) used in the T-Reg, with the reference voltage provided by a pair of Zener diodes. The results of this effort are enclosed. The specified component values are chosen for an output voltage of 300 V.
This design has the following advantages relative to the T-Reg design:

1. Reduced circuit complexity and component count
2. No need for a second supply voltage
3. Comparable regulation performance, and in some regards even better (such as dynamic load regulation)
4. Use of commonly available components

It is actually possible to use any desired type of component with any desired power rating as the pass regulator. In addition to being quite amenable in this regard, the circuit can be built reliably by others.
However, there is also a significant disadvantage. With the T-Reg design, the stabilized output voltage can be adjusted relatively easily by changing the value of resistor R3. It can thus be used without overly much effort to build a bench supply for a hobby lab with an adjustable output voltage, which is admirable. By contrast, my proposed design has a fixed output voltage, although the actual the output voltage can be set over a wide range by selecting Zener diodes with suitable values.
If I have aroused your interest in this circuit, on your request I would be pleased to provide a detailed circuit description and a table of component values for some commonly used voltages (200 V, 250 V, and 300 V).

Please allow me to make two additional remarks.
In my opinion, the question as to whether delayed switch-on of the anode voltage (as suggested by the author of the T-Reg article) is worthwhile with a tube amplifier is more of an academic question than a matter of practical benefit. I am not aware of any scientific or engineering treatise according to which it can be concluded that there are any significant disadvantages associated with applying the anode voltage without delay while the filaments are warming up.
I am not aware of any circuit from the golden era of tubes that has delayed anode voltage switch-on.
The article in question also brings up another issue. To the dismay of users, authors often make use of unusual ('rare') components that cannot be found in regional electronics shops or in the stock lists of the usual postal order merchants. For future issues of Elektor, I would like to see authors mention alternative components (substitutes) in cases where they feel compelled to use uncommon components.

Alexander Voigt, MD (Germany)

We regard your comments as sufficiently interesting to publish them here. On request, we would be pleased to post the table of component values on the web page for the Mailbox section of this issue (www.elektor-usa.com/090919).
The T-Reg circuit does indeed work as described; after all, it was replicated and tested in the Elektor labs. The DN2540 MOSFET is what is called a depletion-mode MOSFET, which conducts with zero gate voltage. A negative gate voltage must be applied to this type of MOSFET to cut off the current, in which regard it does in fact behave the same way as a tube. It would have been a good idea to mention this in the article.
However, this is a good example of the fact that in most cases designers use special or unusual components due to their specific characteristics. Consequently, it is often not possible to specify other components as alternatives or substitutes, since other components do not have these specific characteristics. Also, not everyone lives in the same country and may disagree with you on what's an 'unusual' component or a 'common' one.
Delayed switch-on of the anode voltage unquestionably has the advantage that the anode current can flow immediately after the voltage is applied. This direct application of the load to the power supply prevents the voltage on the filter or smoothing capacitors from rising to the much higher no-load value. As the anode voltage is usually not regulated, this would otherwise occur while the filaments were warming up. You may have missed that practically all equipment from the 'golden era of tubes' as you call it does have delayed switch-on of the HT rail — simply through the use of a tube rectifier.
Another advantage of delayed HT is that the

voltage stress on the electrolytic capacitors is reduced. Of course, this is only true if the switch contact for delayed switch-on of the anode voltage is located ahead of these capacitors. This is not the case with the T-Reg circuit, so it is not a consideration here.
A short literature study and some digging in the Philips Technical Review archive gives evidence that tubes benefit from a reduced load on the cathodes during the warm-up phase (for example) by the fact that anode voltage switch-on is delayed during the warm-up phase in lots of Philips' professional tube circuits. However, we are confident that some of our readers will have more to say about this and may be able to provide references. As usual, knowledgeable information is always welcome.

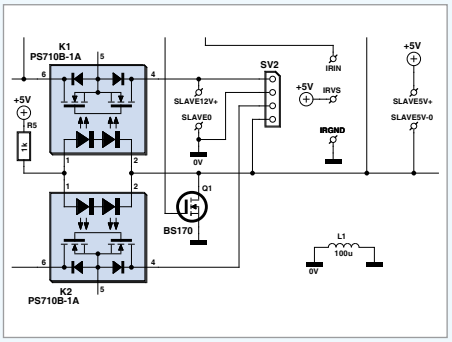
R1,R2,R3 component values		
	Tube	*MOSFET*
U_E	*350 V*	*250 V*
R1	*100 kΩ*	*10 kΩ*
R2	*1 kΩ*	*100 Ω*
R3	*1 MΩ*	*180 kΩ*

Corrections & Updates

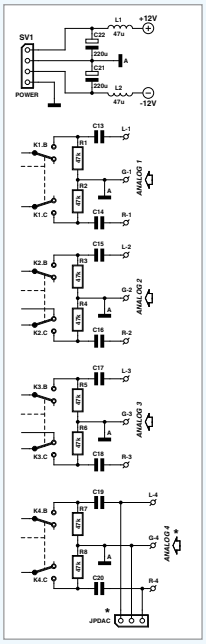
Mini Preamplifier

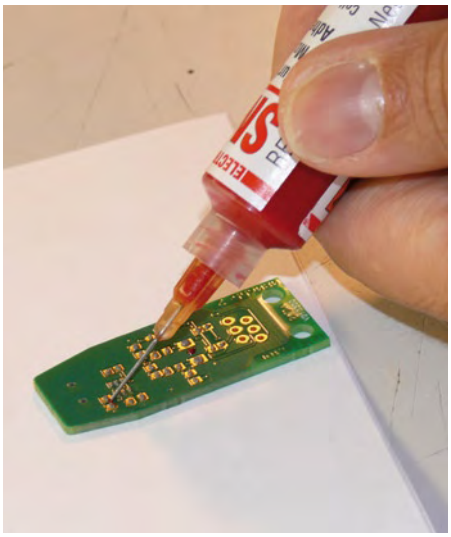
October 2009 UK edition, p. 68-71, ref. 090241-I

Regrettably a few errors have crept into the circuit diagram in Figures 1 and 2.
In Figure 1, components K1 and K2 are drawn incorrectly and an indictor is missing between the analog and digital ground lines.



In Figure 2, the relay contacts are drawn incorrectly in their non-actuated state, which suggests all inputs are interconnected. Also, two miniature chokes are missing in the +12 V and –12 V supply lines.
The corrected sections of the circuit diagrams are shown here.
The electronic version (.pdf) of the article on the Elektor website contains the corrected diagrams.





SMD soldering – double sided!

Hi Jan — I just picked up my first issue of Elektor magazine and I was excited to see the article on double sided reflow soldering (E-Labs Inside, September 2009, *Ed.*) as that is exactly what I have been trying to figure out.

I've a question for Antoine regarding his article and I looked for his email but wasn't able to find it. I wanted to find what kind of glue you used to hold down the IC chips. I have looked around a bit, but I am not sure what glue to use.
Appreciate you sharing your experience.

Aaron Moore (by email)

Antoine Authier, head of Elektor Labs replies:
It's always a pleasure to share experiences, and here are two c(g)lues :)
- ref. SMA10SL from Electrolube;
- ref. CB8006-V91 from Loctite.

We have actually experimented with both. Everything went well in both cases; the Loctite appears a bit more fluid, depending on your preferences, this may be a feature or a drawback. Both come in a 10 cc (ml) syringe, the Electrolube came with a plastic needle and a plunger, we got a Loctite Bundle so really no idea if you can have it packaged with these two accessories too. Anyway, the plunger can be replaced by a small screwdriver, any kind of "Luer Lock" compatible needle will fit. When using a hypodermic needle, take care not to stick it into your finger.
I believe that these two brands are widely available and you won't have difficulties to finding them.

To conclude I guess any kind of "SMD Chip Bonder" (key word for your favorite search engine) will do the trick. Please do not hesitate to share your experience with us.

Together with the members of the Elektor lab team I wish you a pleasant time reading the magazine and experimenting with your projects.

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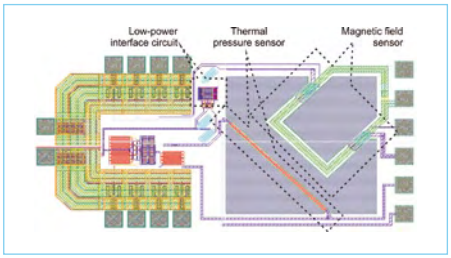
Low-power signal conditioning for resistive sensors

Researchers at the Montpellier Laboratory of Informatics, Robotics and Microelectronics (LIRMM) in France said they have developed and patented a low power interface circuit for resistive sensors. Resistive sensors typically consume significantly more power than capacitive sensors, so MEMS resistive sensors usually receive little interest for low-power applications.



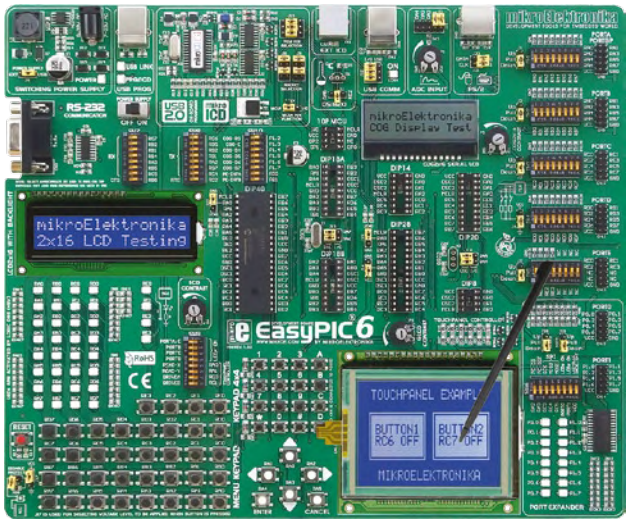
According to LIRMM team leader Pascal Nouet, resistive sensor technology can only be competitive if it is used with efficient signal conditioning and readout electronics. The concept developed by the LIRMM team consists of a low-power interface circuit for resistive sensors that utilizes the same current for resistor biasing and signal amplification. This "active bridge" technique yields significantly better performance than the traditional approach of using a resistive sensor to generate a voltage signal and then amplifying this signal.
The researchers also implemented several initial offset cancellation methods, including a digitally controlled feedback trimmer for balancing a differential bridge circuit. Direct digital output has been demonstrated with no additional power consumption.

According to the researchers, with proper design an active bridge circuit can deliver the same SNR and power consumption as a bare sensor, but with an output voltage at least two orders of magnitude higher. The effectiveness of the concept has been verified, and a very good SNR with a directly usable output signal was obtained with a very low bias current of less than 100 µA. The circuit also has good immunity to ambient conditions due to its differential architecture.

www.isep.fr/ftfc/papiers/S8_3.pdf

(090833-I)

EasyPIC®6 Development System



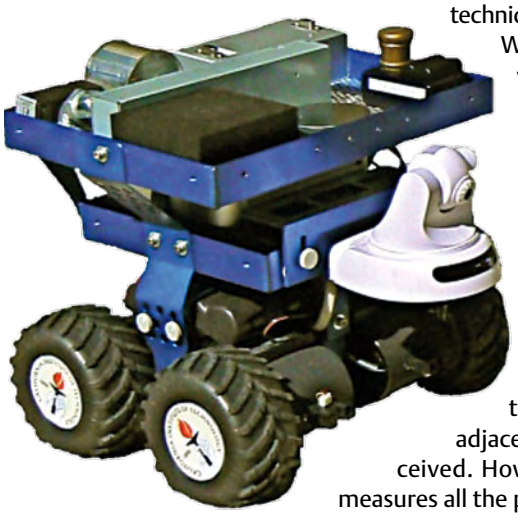
mikroElektronika recently introduced a new development tool for PIC® microcontrollers. The new EasyPIC®6 supports DIP package PIC® microcontrollers. with 8, 14, 18, 20, 28 and 40 pins. It comes complete with everything you need to learn, experiment, design and program with PIC microcontrollers. This development tools includes new features such as a 4×4 keypad, menu keypad, port expander, serial COG display, and many more. EasyPIC®6 also includes a touch panel controller so you can easily add additional inputs for prototype devices.
EasyPIC®6 has a lightning fast on-board USB 2.0 programmer with MikroICD in-circuit debugger support, so you can easily program and debug your application program. Each feature of the board is supported by sample code written in mikroC PRO, mikroPascal PRO and mikroBasic PRO for PIC. EasyPIC®6 comes with full color printed documentation. The system price is $139.00. EasyPIC®6 Board is can be purchased on the mikroElektronika website and through authorized distributors.

www.mikroe.com

(090833-XII)

Robot tests visual prosthesis designs

A new mobile robot promises to aid developers of artificial retinas and other visual prosthetics by testing the endless variations of video filters proposed to improve their effectiveness. Dubbed "Cyclops" for its single video camera eye, the wheeled robot emulates the quality of visual scenes possible with currently available low-resolution implants, performing navigation tasks that may allow engineers to perfect video filter algorithms needed to help artificial retina recipients.

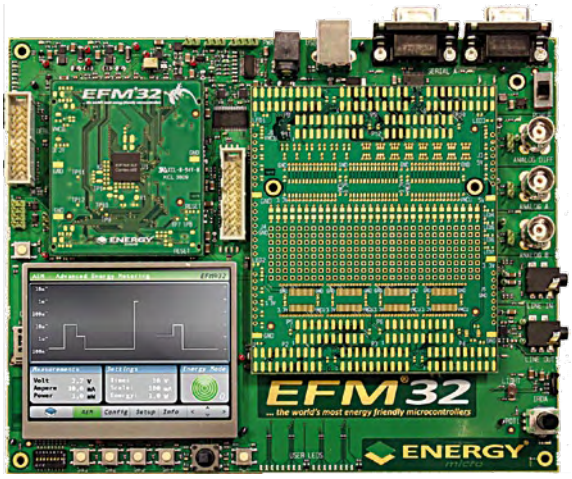


"We believe we have a better way to test new video filtering techniques for visual prostheses," said professor Wolfgang Fink of the University of Arizona, who is also a visiting associate in physics at Caltech. "Our Cyclops robot can test our image-processing algorithms at the same resolution as an artificial retina."
The main problem with visual prostheses is low resolution, but this can be partially compensated by choosing the right image processing routine. For example, if a patient is trying to find a doorway in a darkened hallway, there may not be enough contrast between the doorway and the almost equally dark adjacent wall to allow the doorway to be perceived. However, if an image processing routine measures all the pixel values and assigns full white to the

lightest pixels of the wall and full black to the darkest pixels of the doorway, a patient could perceive it more easily.
Fink and Caltech visiting scientist Mark Tarbell already have funding from the National Science Foundation to create the video filters, but testing remains a problem because patients with implants are already overloaded with testing regimes.
To reduce the burden, the researchers decided to use test subjects with normal sight. The idea was to reduce the video camera's resolution to match that of the retinal implant. This approach failed, however, because sighted test subjects were able to use image-enhancing routines built into their brains.
Cyclops, by contrast, has only the visual processing routines that Fink and Tarbell program into it. After establishing a baseline for how long it takes the robot to find a doorway using full video camera resolution, they reduced resolution to match an artificial retina. They then measured the effectiveness of their image processing routines relative to the baseline.
After trying out hundreds of variations of imaging processing routines with the Cyclops robot performing a variety of navigation tasks, the researchers were able to identify a few that consistently improved the robot's ability to perform simple navigation tasks. Once they are identified, the most promising routines are sent to artificial retina makers who test them with implant recipients.

http://media.caltech.edu/press_releases/13294 (090833-II)

Energy Micro launches ARM-based Gecko microcontrollers



Startup Energy Micro AS (Oslo, Norway) has launched its first products, the EFM32 family of microcontrollers, otherwise known as Gecko, with the claim the microcontrollers offer more than four times the battery life of existing 8-, 16- or 32-bit microcontrollers.
The devices are based on an ARM Cortex-M3 license, and Energy Micro said that the company will provide 22 different parts over the next few months, with most of them sampling in the fourth quarter and becoming available in volume in the first quarter of 2010. A development kit (EFM32 Gecko Development Kit) is available. The EFM32G feature set includes a 4x40 segment LCD controller running at less than 900 nA; an 8-channel, 12-bit 1-Msample/sec ADC running at less than 200 µA; a brown-out detector running at less than 100 nA; a 32-kHz real time counter running at 50 nA; and a UART capable of 9600 bps at 100 nA.
The microcontrollers are fabricated using the 180-nm ultra low leakage process from TSMC and have been proven to consume less than 180 µA per MHz while executing real code from flash memory, the company said. The standby current is 900 nA with an operating real-time clock, power-on reset, brown-out detector and full RAM and CPU retention, or less than 20 nA in the microcontroller's deepest sleep mode. The microcontrollers provide up to 128 KB of flash memory and up to 16 KB of RAM.
EFM32G microcontroller products are available in a variety of packages, including QFN32, QFN64, QFP100, and BGA112. The EFM32G operates from a single supply rail between 1.8 and 3.8 V. The operating temperature range is –40°C to +85°C.

www.energymicro.com (090833-III)

Self-contained Linux networking server housed in RJ-45 package

ACAL Technology has announced the first samples of XPort Pro, which the company claims to be the world's smallest self-contained Linux networking server.

Building on proven Lantronix XPort technology, XPort Pro is a production-ready server that runs on the Linux or Evolution OS operating system. With 8 MB of SDRAM and 16 MB of flash memory, the unit has significantly more on-board memory than the 256 KB of current-generation XPort devices.

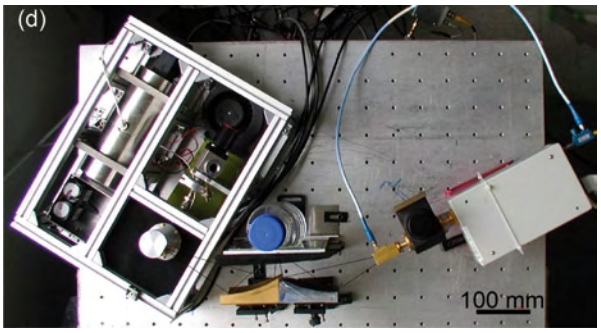
The XPort Pro draws 150 mA at 10 Mbps to minimize power consumption and is footprint compatible with existing XPort networking servers. Its high-speed 32-bit processor allows advanced applications to be deployed directly onto edge devices.
The combination of the Linux operating system with integrated IPv6 and extensive features libraries, extensive on-board memory and advanced processing provides unlimited flexibility to customize XPort Pro for a wide range of M2M applications.
Network security is provided by a range of data encryption and authentication options and enhanced by Lantronix' patent-pending VIP Access virtual IP technology.

This provides seamless integration with ManageLinx, which enables secure access to firewall-protected equipment for remote monitoring and control.

http://www.acaltechnology.com/userfiles/landing/Lantronix_XPort-Pro_PB-A4.pdf (090833-IV)

Superconducting sensor identifies liquids

Although airline passengers find it annoying, tight control of liquids and gels in onboard luggage is claimed to be essential for safety. Researchers at the Institute of Solid State Research in Jülich, Germany have developed a technology that holds promise for reliably detecting potentially explosive substances and differentiating them from harmless liquids.



The device developed by the German–Russian research team is based on the dielectric permittivity profiles of each material, which depends on the frequency of the electromagnetic waves impinging on the material. A permittivity response measured over a very wide frequency spectrum in the gigahertz to terahertz range forms a 'fingerprint' for every liquid substance. In particular, it allows quick and exact determination of the type of material.

In order to achieve the very broad frequency range necessary to obtain exact profiles, the research team chose Hilbert spectroscopy, a technique developed at the Russian Academy of Sciences in Moscow. The critical element in Hilbert spectroscopy is the Josephson detector, a nanoelectronic component based on a high-temperature superconductor. Operating at a temperature of minus 200 degrees Celsius (about 70 Kelvin), the Josephson junction detects the electromagnetic waves received from the material under test and generates an output signal proportional to the frequency.

The prototype built by the Jülich research team uses commercially available external devices to generate the electromagnetic signal and maintain the operating temperature of the Josephson junction in the desired range. The Josephson junction was fabricated at the Institute of Solid State Research, which specializes in thin-film physics. For the Hilbert spectrometer, the researchers used material based on $YBa_2Cu_3O_7$.

According to the researchers, the Hilbert spectroscope can generate a valid material scan in less than one second, which they said is much faster than competing technologies using nuclear magnetic resonance or conventional high-frequency radio or and infrared waves.

To prove the feasibility of the approach, the researchers used an oscillator that can produce frequencies up to 500 GHz. To improve the reliability of the measurements, they said that an oscillator that can cover the range up to the 1 THz or more is necessary, and this should have top priority. However, they said that the European Commission's aim of establishing a system for routine identification of dangerous liquids by 2012 will be difficult to achieve.

http://www.fz-juelich.de/iff/index.php?index=3108 (090833-V)

Triple RGB laser driver enables pico projectors

Fabricated using Maxim's newest BiCMOS process, the MAX3600 RGB laser driver supports switching times of less than 2 ns and resolutions up to WXGA or 1080 to enable designers to embed pico projectors in compact consumer electronics products.

The MAX3600 integrates three laser drivers in a 5 x 5-mm chip, allowing it to fit into the smallest enclosures. The chip is targeted at applications such as smartphones, portable media players, mobile-computing devices, digital cameras and camcorders, accessory projectors, and digital picture frames.

The MAX3600 incorporates all the functionality needed to easily interface a digital 10-bit RGB video source to virtually all industry-standard, low-power RGB laser diodes. It also features three 10-bit RGB DACs that read video data from the host device's 10-bit RGB bus. These DACs allow system designers to precisely control laser current while generating billions of colors and contrast ratios of 5000:1 or more.

Embedded pico projectors are rapidly becoming small enough to fit into the tight enclosures of today's smartphones, and they have the potential to transform the multimedia capabilities of consumer electronics. These miniature projectors enable users to display images and video from their portable devices on walls and other surfaces, effectively freeing consumers from the constraints of cramped displays.

Given the widespread integration of video capabilities in consumer electronics, there is a large potential market for pico projectors. Traditional pico projector solutions do not scale as well as laser-based projectors, which require only a single or dual MEMS mirror regardless of resolution. This means that designs can be scaled, in terms of both software and hardware, to higher resolutions without changing the imager.

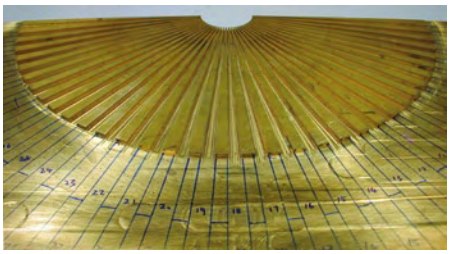
www.maxim-ic.com/Laser-DriverPeak Systems (090833-VI)

Metamaterial hyperlens focuses acoustic waves

Researchers at the Energy Department's Lawrence Berkeley National Laboratory say they have used metamaterials to fabricate the first acoustic hyperlens, potentially offering an eight-fold increase in ultrasound and sonar image resolution.

Metamaterials have previously been proposed for sonar invisibility cloaks that hide submarines by bending acoustic waves around them. Researchers at the Lawrence Berkeley National Laboratory say they have shown that metamaterials can also can be used for acoustic hyperlenses with sub-wavelength focusing accuracy and low loss over a wide frequency bandwidth.

Berkeley Lab's hyperlens uses metamaterials to focus signals on objects 6.7 times smaller than the wavelength of the sound wave. The researchers said the acoustic hyperlens can be further improved to boost the resolution



of sound-based imaging technologies such as ultrasound and sonar.
The acoustic lens prototype is constructed from 36 brass fins arranged in the shape of a fan. The fins measure 20 centimeters in length and 3 millimeters in thickness. They concentrate a beam of acoustic waves from an outer radius of 21.8 centimeters down to an inner radius of 2.7 centimeters, transforming what are ordinarily evanescent waves that cannot be imaged into propagating waves that produce sharp images.
Zhang's group previously demonstrated a hyperlens made from silver and aluminum oxide nanowires that can focus visible light below its diffraction limit. The group is currently working on a 3D ultrasound imaging system that will employ the pulse-echo technology used to "ping" submarines in sonar applications as in medical imaging.

http://newscenter.lbl.gov/press-releases/2009/10/26/hyperlens-for-sound-waves/

(090833-VII)

DIY weather monitoring made easy

With the all-new WS831DL and WS821 professional weather stations from General Tools & Instruments, you won't need the weather channel to monitor and record your local environmental conditions.
These sophisticated, easy to use systems are ideal for anyone who wants or needs to track precise outdoor weather fluctuations from the indoor convenience and comfort of a home, office, plant facility, school, or any other location. Monitoring and forecasting atmospheric conditions are essential for many activities and professions, including sports and recreation, workforce management, gardening and agriculture, greenhouse operations, storage facility maintenance, transportation operations, and more.

Remote sensors included with both systems wirelessly transmit indoor or outdoor temperature and humidity (expandable to separate zones) to a base station, along with rainfall quantity and wind direction and speed, from up to 325 feet (100 meters) away. The base station's backlit LCD monitor displays this data along with absolute and relative atmospheric pressure (with 24-hour history), wind chill factor, dew point, solar and lunar schedules and moon phases, and programmable alarm functions for high/low temperature settings and storm forecasting.
The Professional Wireless Data Logging Weather Station (Model WS831DL) includes software and cable connections that allow you to record weather information on your computer for tracking and future reference (Windows operating system required, see the specifications on the General Tools & Instruments website). A rugged, professional-grade wind direction and speed sensor with transmitter, a rain gauge that tracks daily, weekly and monthly rainfall, and one remote atmospheric sensor are included with the system, which lists for $249.99.

The Professional Wireless Weather Station (Model WS821) tracks weather data internally and includes all of the accessories and sensors provided with the Data Logging Weather Station system, but it does not offer the capacity to record data to a personal computer. It lists for $199.99.
Both units operate on low voltage (7.5 V AC/DC power adapters are included), with battery backup that enables them to continue to collect critical data during power disruptions. The wall-mount or desktop base station also functions as a radio-controlled clock with alarm and snooze options, and it displays the day and date in any of six languages.

http://www.generaltools.com/weather

(090833-VIII)

Three-axis MEMS gyro chip debuts

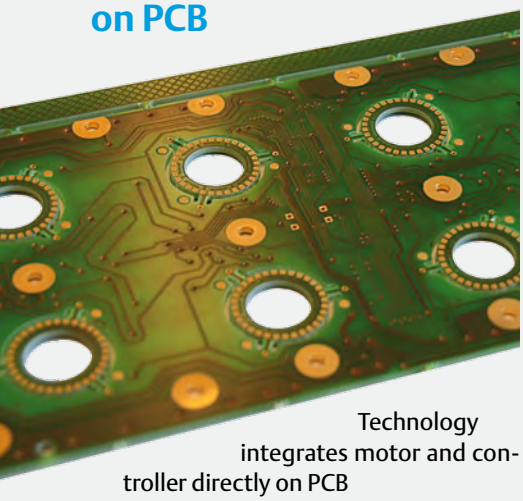
A three-axis gyroscope chip developed by InvenSense Inc. (Sunnyvale, California) combines separate MEMS resonators for motion tracking to provide an economical motion sensing alternative for game controllers and remote control devices.

InvenSense says its ITG-3200 three-axis gyroscope chip is the first of its kind for motion tracking in the X, Y and Z axes (pitch, roll and yaw). The device is based on the patented Nasiri process, invented by the company's CEO, which caps the analog MEMS chip with an ASIC of the same size to protect the delicate MEMS resonators from contamination without adding bulk to the package.
Each gyro has its own 16-bit analog-to-digital converter, includes an on-chip temperature sensor, and supplies a real-time clock output to synchronize it with an application master controller. A fast I^2C serial interface connects the gyro chip to system chips. The device is claimed to be able to withstand up to 10,000-*g* shocks without damage.
Applications of gyroscopic devices include image stabilization in digital still cameras and camera phones, dead reckoning in navigation devices (when GPS signals are lost indoors), 3D peripherals such as mice, TV remote controls and gaming controllers.

The InvenSense single-chip MEMS gyroscope is claimed to consume 50% less power and occupy 67% less board space than current two-chip solutions that combine a two-axis gyro with a single-axis gyro.

http://www.invensense.com (090833-IX)

Motor and controller integrated directly on PCB



Technology integrates motor and controller directly on PCB

PCBMotor ApS has developed a technology that allows a motor to be fabricated directly on a PCB along with the motor controller. The potential applications include spectrum analysis, laser adjustment, microscopes, and turntables.

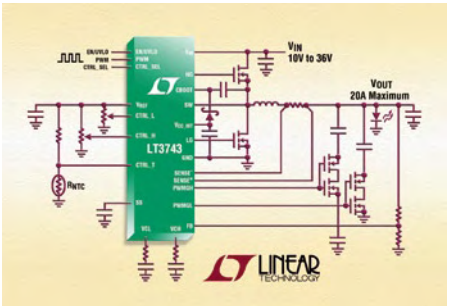
The patented technology can achieve a positioning accuracy of 100,000 steps per revolution using a high resolution sensor. The PCBMotor technology can also achieve high resolution if the motor is driven in microstep mode with a microstep clock width as short as 0.1 ms. The motor's operating frequency is 40 kHz.

A PCBmotor consists of two parts. The first part is the stator, which is milled in the PCB and holds the actuators and electrical circuitry (the PCB can also hold the driver). The second part is the rotor, which is pressed onto the surface of the stator and delivers the mechanical output. A traveling wave is generated over the stator surface, which acts as a flexible ring to produce elliptical motion on the rotor interface. The elliptical motion of the contact surface propels the rotor and the connected shaft.

Ceramic piezoelectric components with dimensions of 1x1 mm are mounted on the PCB. Motor operation depends on the friction between the moving rotor and the stator as well as the amplitude and quality of the wave traveling over the stator. The rotor can turn between 60 and 120 rpm with a torque range of 1 Nmm to more than 70 Nmm, depending on the stator diameter, the number of piezoelectric components, and the rotor design and material.

www.pcbmotor.com (090833-X)

High-power LED driver features ultra-fast current switching



For many reasons, LEDs are increasingly the light source of choice for many applications, but their use in short-pulse applications such as digital light projector (DLP) TVs has been limited up to now by the ability of driver ICs to achieve fast switching speeds.

Linear Technology Corp claims that their LT3743 IC is the first device to solve this problem. With an switching frequency of 100 kHz to 1 MHz, this DC/DC switch-mode power IC operates from a 5.5 to 36 V input and can deliver up to 12 A from a 12 V source (80 W) or 40 A in pulsed mode (160 W), with efficiency up to 95%. In addition to DLP TVs, it can be used as a driver for applications such as architectural lighting and laser diodes.

The key to the performance of the device is an architecture with two compensation loops that enable fast PWM-based dimming over a 3000:1 range. The LT3743 also provides three-state current control for color mixing, which is important for better color fidelity in display applications. The current regulation accuracy is ±6% (worst case), with 2 µs maximum recovery time between current regulation states.

The thermally enhanced device does not require any additional heat sinking and has shutdown current less than 1 µA. The outputs are protected against open loads as shorts, and the LT3743 includes output voltage regulation, overcurrent protection, and a thermal derating circuit. The LT3743 is available in a 28-lead QFN package or a thermally enhanced TSSOP-28 package.

http://www.linear.com (090833-XI)

Researchers integrate chip-level fuel cells

A research group with members from the University of Freiburg (Germany) and semiconductor vendor Micronas AG has integrated a fuel cell array on a chip. The device could power autonomous microsystems, also known as 'smart dust'.

The chip has 42 microscale fuel cells on a CMOS device plus four cells to power the control circuitry necessary to maintain a constant 3.3-V output voltage. The semiconductor structures were fabricated using a standard CMOS process, while the fuel cell elements, consisting of a palladium layer for H_2 storage, a cathode and a membrane, were added in a post-process spin-on, according to Micronas project leader Karl Hoffmann

Hoffmann said that one of the challenges was to intelligently interconnect the fuel cells in a way that allows the control circuitry to keep the output as stable as possible during the lifetime of the device. With several elements in parallel and in series, it is much easier to keep the voltage and current constant.

With a lifetime of about one year at nominal load in the triple-digit microwatt range, the device could eventually power smart autonomous systems in applications where no conventional power source is available. In Hoffmann's view, energy harvesting devices and the chip-level fuel cell are not mutually competitive, but can instead be regarded as complimentary technologies, For instance, the fuel cell could be used as a power buffer for periods when energy harvesting methods don't generate enough power.

According to Hoffmann, the technology is suitable for more than just exotic applications. For instance, it could be used for mundane tasks such a building monitoring.

www.mstonline.de/mikrosystemtechnik/mst-fuer-energie/mikrobrennstoffzelle/medien/minat-i2brenn-micronas.pdf (090833-XIII)

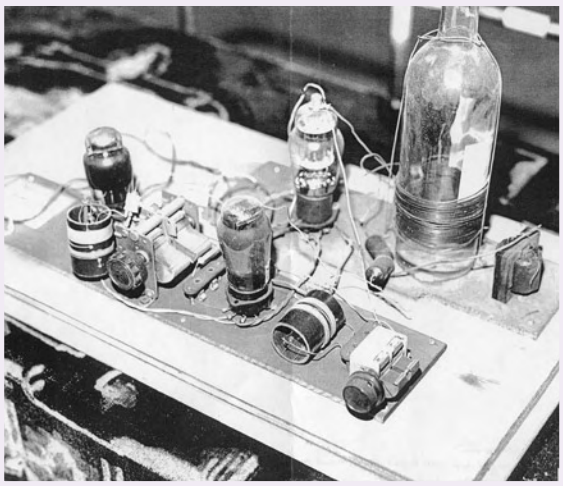
Will this robot rescue the Flemish technical education?

Bart Huyskens has been busy developing robots that can be used for educational purposes, and he's noticed a significant increase of interest amongst students as a result of it.
The number of students has doubled in schools where robots are being used in science and technology classes, and the classrooms are filling up again!
This is good news for the Flemish Ministry of Education. A few years ago they started putting up Regional Technical Centers where, with government funding, education and companies work together on new initiatives, which are meant to attract students towards technical education. But it's not just for students — teachers can get extracurricular classes on new technologies.

Bart is pressed with developing the robots. With the help of sensors they can speak to students, follow a pattern across classrooms, and play and dance to music — all of which keeps the techno-hungry crowd pleased. Thanks to Technical Center funding there are now 14 robots available for use to the students of St. Joseph Institute in Schoten, and two more will start touring with the TechnoTrailer vehicle. The students will be able to program the robots for different kinds of utilities. The robot itself runs on E-blocks technology and speaks Flowcode, but is fluent in Flemish as well.
Bart's enthusiasm has played a big part in the success of the robots. Over the past couple of years he has developed the concept, managed to sell it and make a full-fledged product. More importantly: he has managed to kindle an interest in electronics within new groups, and that's certainly Worth an Award! Bart Huyskens is hereby nominated for the Elektor Foundation Award 2009. The award ceremony will take place during the Elektor Live! event on November 21, 2009 in Eindhoven, The Netherlands.

Radio to the rescue!

Emergency services (such as the police force and fire brigade) know the vital importance of good communication. In order to avoid chaos and unnecessary casualties, it is essential to know where help is needed and what kind of help is needed. This is often easier said than done, as can be seen only too clearly from the situation with the C2000 emergency services radio system in the Netherlands. It works well in theory, but in practice it's a different story. Emergency aid in event of a major disaster often requires creativity and unusual actions.



In 1953, the North Sea broke through the dikes and submerged large portions of the southern Netherlands. Nothing was spared: people, animals, and buildings all fell victim to the merciless flood waters. A certain Mr Hossfeld was caught in the middle of this catastrophe. Taking his son with him, he plunged into the ice-cold water, and fortunately they managed to swim to a house where they could enter through an open window and climb onto the roof. The next day they were brought to safety. After they reached dry land, they found that the emergency services were desperately short of communication equipment. Everything had literally been swept away, and the town of Zierikzee was totally cut off.
Mr Hossfeld (now 83 years old) did what he could and must do: using a few radio valves (EL3, EL6 and 807) and some coils made by winding wire around a bottle, he put together a transmitter that could deliver 10 watts of power to a 450-ft longwire antenna. This was enough to make contact with the outside world (and in a manner of speaking, it was the spiritual ancestor of the C2000 system). For five days and nights, a team of four people constantly manned the PAoZRK transmitter to coordinate assistance activities for Zierikzee.
Radio amateurs such as Mr Hossfeld played a vital role in the initial hours and days of the 1953 floods. Many lives were saved as a result of their efforts.
Our objective with the Elektor Foundation Award is to pay tribute to events such as these: people who managed to make a difference with their knowledge and efforts. Mr Hossfeld is one of the candidates for this award. The award ceremony will take place during the Elektor Live! event on November 21, 2009 in Eindhoven, The Netherlands.

More information on the Elektor Foundation Award may be found at www.elektorfoundation.org

Home Automation Standards
Roadmap or Tower of Babylon?

By Jens Nickel (Elektor Germany Editorial)

Automatic control of house lighting, heating and other household installations from a central controller is not only convenient but can help reduce your carbon footprint. There are currently many competing systems to choose from. We give an overview, with the pros and cons of some of the more important ones on the market.

Figure 1.
A home automation user interface: All control switching is brought together in a single unit. The status of any point in the system can be displayed.
(picture: Z-Wave system from Merten, photo Constantin Meyer, Cologne).

Home automation (also known as domotics systems — a European Continental coinage) offers a number of benefits for the home owner. The control of house lighting, window shutters, heating, ventilating and air conditioning can all be orchestrated by a central controller executing a programmed sequence of actions triggered by the time-of-day or in response to external events detected by sensors. Motorized awnings above windows which deploy automatically to offset heating effects of the sun and pre-programmed combinations of room lights which turn on whenever a room is occupied all make the house a more comfortable place to live. More interesting is the potential for such a system to reduce our 'carbon footprint' by intelligently monitoring and reducing the amount of energy consumed by a household. Add to that an improved level of security and we start to see some of the real benefits such a system can offer, more of which we have listed below.

System components

A home automation system basically consists of four components: sensors, actuators, central control unit and of course the interconnection medium to link all the parts together. Sensors are available which measure physical properties such as light level, sound, movement, temperature and humidity. Reed switches detect whether an external door or window is open or closed. It may seem a bit over the top to fit the system with a weather station but if a motorized awning is part of the temperature control measures it is important to ensure it is safely stowed if the wind speed gets too high. Gas, water and electricity meters with an S0 or M-bus interface can be connected to the home automation system and other types of meter may be readable via an optical link. An RFID reader, used to identify authorized personnel can also be included in the list of sensors along with manual switches and adjustable controls to enable the occupier to switch lighting and adjust heating levels. The full flexibility of a home automation system can only be realized if the conventional domestic 'user interfaces' such as light switches are included in the system (**Figure 1**). In this way a single switch can be programmed to turn on any light or any combination of lights in the system.

The actuators are connected at the output of the control system and include electrical relays or dimmer controllers for control of lighting and ventilation, electrically controlled radiator valves (**Figure 2**), motor controller for roller shutters, awnings und window blinds (**Figure 3**). The home automation central control unit is the heart of the whole system; sensor readings are input to the unit while control signals are sent out to the actuators (**Figure 4**). It is possible for example to divide the house into separate zones and control them independently but the benefits of a home automation system can only be truly realized by having a fully integrated system.

The central controller unit contains the home automation system

The benefits of home automation

- Flexibility; assign any switch to any lamp(s)
- Selection of pre-programmed light settings/effects
- Automatic on/off control of lighting (energy saving, security)
- Lighting and heating etc. controlled by a hand-held remote controller.
- Automatic room temperature control governed by time-of-day and/or householder occupancy.
- Room temperature sensor set-back when a window is opened.
- Intelligent control of heating, ventilation and window blinds
- Randomly switched events (occupancy simulation)
- Simple integration of intruder alarm using movement detection and/or glass-break sensor.
- Occupant identification using RFID tags for access control.
- Monitoring heating energy consumption.
- Smart Metering via built-in energy monitor
- Remote control of the system via Intranet/Internet using TCP/IP gateways

Figure 2. Motorized radiator valves can help save energy. The controller turns down the heating when a window has been opened. (picture: HomeMatic System by ELV).

Figure 3. A (wireless controlled) motorized awning (picture: HomeMatic System by ELV).

Figure 4. The system controller is the heart of a home automation system. This one is wireless with connection to a PC (picture: HomeMatic System by ELV).

controller program. The user can interact with the program usually via a touch screen in order to make changes to system parameters and programmed actions. The controller is also often fitted with a PC connector (either Ethernet or USB) which allows a PC user equipped with suitable PC software to check the system performance and change programmed behavior of the home automation system. A hand held remote controller is typically also part of the package to provide a convenient mobile method of interacting with the system (**Figure 5**).

Making connections

Sensor readings and control signals to and from the central controller can be transferred using either wired or wireless links. Twisted-pair copper cables using either one or two pairs are one of the most common methods. Less common is the use of coaxial or fiber optic cables. Some systems send the information as a modulated carrier signal on the house 115 VAC wiring (Power Line Communication or PLC). Retrofitted to an existing building these systems reduce cabling costs and the disruption caused during installation but they are prone to communication interference generated when other domestic appliances turn on and off. Another disadvantage is that a power line connection is necessary to all parts of the network for the system to function i.e. at both the actuator/motor and the input sensor. As part of a new-build house those considering installation should choose a dedicated one or two pair twisted wire network. An advantage of wired networks is that a connection to the AC power line is only necessary for the output devices, i.e. actuators and servos. Input sensors are powered directly via the network cabling. Wired networks are above all a robust method of transferring data offering excellent protection from interference. This type of network would typically have a straight line topology that can be installed and lengthened as required.

For those considering retro-fitting a home automation system to their existing home or for those in rented accommodation where the installation of cabling is impractical must consider a radio or PLC system. Both variants offer simple installation and easy system expansion. With almost all the systems it is possible to start small without a central controller and configure a very basic network linking up sensors and actuators.

Radio systems offer the greatest freedom for network installers but with this freedom comes a disadvantage: wired networks by definition transfer data over wires and this medium can also be employed to provide a power supply to all subscribers. Wireless subscribers however require an external power source either from a wallwart or battery (**Figure 6**). The use of solar power or electromechanical energy conversion (generated by pressing the switch) has not yet been widely adopted.

The control signals sent over the AC power line wiring by PLC sys-

Figure 5. A hand-held remote controller adds convenience. One press can call up a pre-programmed lighting combination
(picture: Z-Wave, RF remote controller by Düwi).

tems can sometimes generate interference in other equipment connected to the AC power line and they are therefore not popular with everyone (and not just radio amateurs). Another interesting application of PLC systems is to network domestic appliances for the purposes of energy monitoring. A new idea in this area (DigitalSTROM — 'digital current') is investigated in another article in this edition.
With all these systems it is important that an actuator acts only on commands that are intended for it, similarly sensors must be able to uniquely identify themselves to the controller. These are just the most basic system requirements, to improve reliability further it is sensible to include some form of communication handshaking between the controller and its connected devices, this is particularly useful if the transmission medium is prone to interference.

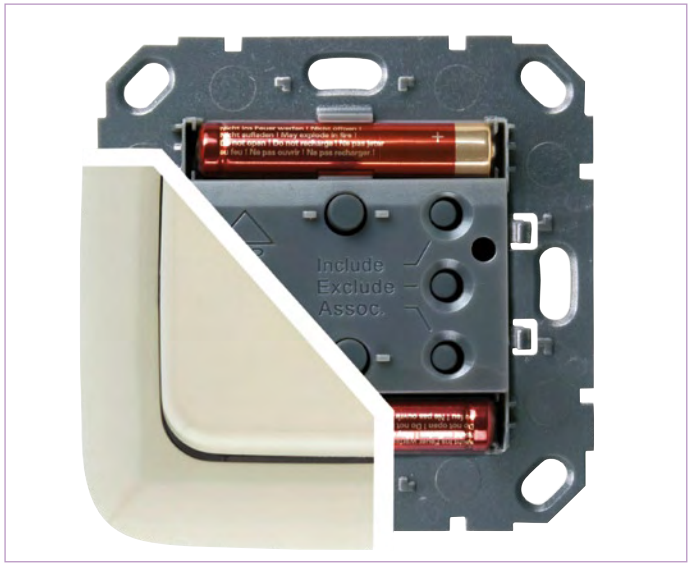


Figure 6. Radio networks allow the greatest freedom to position sensors and actuators but require batteries.
(picture: Z-Wave switch unit by Düwi).

Standards

Communication between the central controller and the sensors/actuators consists of digital data and the whole communication conforms to a structured layered model. The lowest layer defines the signal's physical properties i.e. signal levels, frequency and the modulation method used to encode the individual bits. The middle layer defines the method of checksum calculation, any data encryption and node addressing to ensure that data ends up at the correct destination. The highest layer (the application layer) handles the user interaction, interpreting the control input and displaying system status.
In order for all the components in the home automation system to successfully work together all the system layers must by well defined. There are a host of different networks standards some of which we will be describing below. Some of the standards (such as ZigBee) only specify the protocols for the lowest (physical) layer and the middle layer. Other Standards such as KNX define the middle and upper layers only and offer suggestions on how the physical layer can be implemented depending on the medium used. In practice this gives rise to different variants of the basic network standard (e.g. 'KNX RF').

EIB/KNX

Wired networks are most conveniently installed in buildings during their initial build phase. One of the oldest standards for domestic wired network standards is the EIB (European Installation Bus). It has already been in existence for at least 20 years but has so far not achieved the long awaited breakthrough to be universally taken up. In the meantime the more comprehensive KNX standard has emerged which is based on the EIB standard. EIB is in fact upwards compatible with KNX [1]. In the wired implementation the KNX/EIB-bus nodes are linked with a twisted-pair wire which also provides a 30 V DC supply (only two wires are necessary hence two-wire bus). Meanwhile both radio and PLC variants of this standard have been developed and are aimed at the potentially large market where networks are retrofitted to existing buildings. The EIB/KNX-Standard is disclosed (see also the article elsewhere in this magazine), the details of the standard can be found on Wikipedia [2] for example. There exists an increasingly wide selection of components for this standard (e.g. see **Figure 7**) most of which tend to be quite expensive.
Another networking standard which does not specify the type of communication medium is LON (Local Operating Network) [3]. The network protocol was developed by Echelon Corporation who supply evaluation boards, node builder development tools and node processors for incorporation into end-user designs. LON has achieved significant acceptance in the automation of office buildings. A technically interesting alternative system is the LCN (Local Control Network) [4]; again this system is more popular for office building installations than domestic environments. Each node in the network is wired to the AC power line using Earth, Live and Neutral as usual but an extra low voltage wire in the power cable sends data

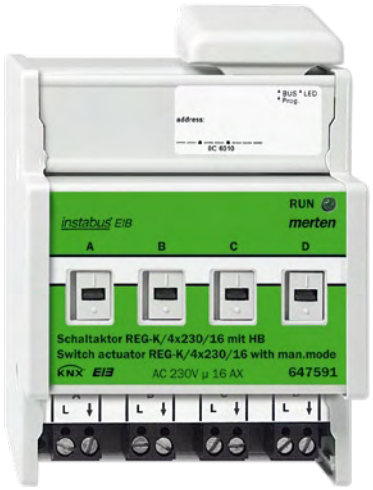


Figure 7. Four channel switching relay for the KNX/EIB bus (picture: Merten GmbH).

between nodes. When the nodes are connected into the system they identify each other and create a mesh network. Each node is connected to the supply and also to the command network effectively making each node an 'intelligent distribution socket'. The system does not require a separate communication network.

Ethernet

Ethernet networks have a special place in home automation. The term actually describes the lowest layer of the protocol therefore it is, for example possible to send KNX data over an Ethernet network. The TCP/IP protocol used for Internet communications could, in principle also be used as a basis for a home network but in order to automate the whole house it would be necessary to run an Ethernet cable to every light switch and lamp control relay. In addition it would be necessary to implement TCP/IP protocol at each node, a task that would find low-cost 8-bit microcontrollers wanting.
In practice it is usual for the home automation controller to only provide an Ethernet LAN port for connection to the Internet. The home automation network itself would typically be built using a twisted-pair LAN or similar to link sensors and actuators. A variant exists which uses an Ethernet cable run along the main axes (in each area) of a building with the final metre or so connected to the sensor/actuator via a twisted pair.

Z-Wave

Amongst the wireless home information systems available there has yet to be a front runner emerging from the pack. The Z-Wave system developed by the Danish company Zensys looks as if it could be a likely contender for the title. The company has recently been taken over by the US Company Sigma Designs. At present there are over 160 manufacturers signed-up to the Z-Wave Alliance [5]. In Europe the system operates on 868 MHz in the ISM-Band, the system makes intelligent use of each node in the system with its 'meshed network' approach. Communication between say node A and node D can be relayed or routed over an intermediate node if A and D are not within range of each other. In this way the network has a good coverage even though each node has a low effective radiated power, the sys-

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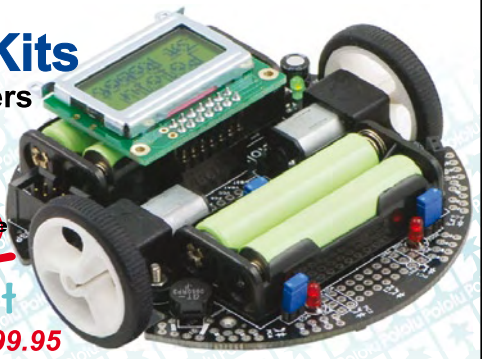

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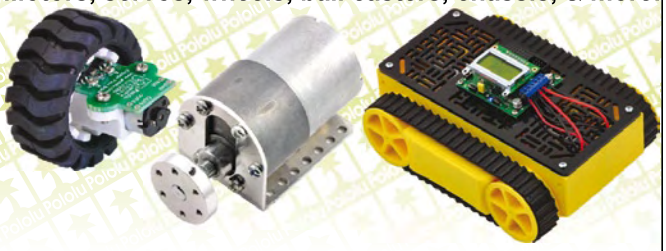

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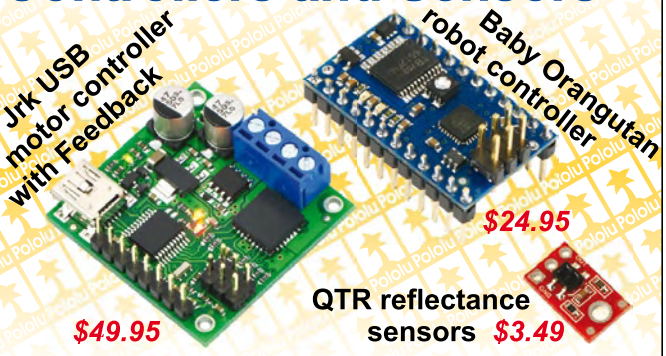

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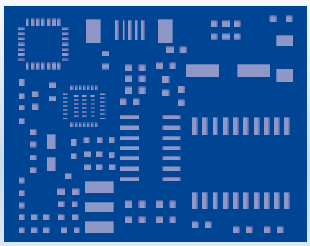

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Typical system costs breakdown

HomeMatic wireless system by ELV Germany, (approximate cost)

Flush mounted switched socket	$70.00
Dimmer socket (25 to 200 VA)	$80.00
Radiator valve actuator	$50.00
Two-way switch	$50.00
RF hand held controller (12 button)	$70.00
Humidity/temperature sensor	$50.00
System controller with PC connector	$450.00

Controller, 2 x remote controllers, 8 x radiator valve actuators, 8 x dimmer sockets, 8 x switched sockets, 16 x Two-way switch, 6 x temperature sensors: $3500.00 (approx).

tem also incorporates good interference protection. This method of routing is similar to the method used by ZigBee, which is often seen as a competitor to Z-Wave. However the latter system has been designed specifically as a home automation standard and does not have the capability to transfer audio and other data. The standard specifies data rates of 9.6 and 40 kbit/s which are more than adequate for a home automation installation. At present the range of products (see **Figures 1, 5** and **6**) for this standard is not as comprehensive as say the KNX system. There is a choice between just a few manufacturers who are marketing devices such as switches, motorized valves and other products for this standard.
One commercial example of a Z-Wave based home automation system is the Connect equipment from the company Merten [6]. The company also plans to offer KNX based equipment using twisted-pair transport medium and in addition, the company markets a gateway which links the two different types of network together. This allows say an existing wired network to be expanded later-on by a wireless network without the expense of installing additional cabling.

ZigBee

The ZigBee standard [7] specifies a radio communication in the ISM frequency allocations at 2.4 GHz and 868 MHz, with a data rate of up to 250 kbit/s. Like Z-Wave above ZigBee routes data packets around network nodes and this implies that more processing power is required in the node compared to the simpler radio networks and increases the complexity of implementation. To overcome the problem a number of manufacturers offer a complete RF transceiver module which can be integrated into a product so you only need worry about implementing the highest layer in software. Any company bringing a product to market must be a member of the Alliance and the product must undergo certification before the ZigBee Logo can be used. The annual certification costs are higher than that charged by the Z-Wave Alliance.
ZigBee communications uses advanced modulation techniques and incorporates error detection/correction algorithms to give good data security. Representatives of the ZigBee alliance reported recently that the system performed flawlessly during the Consumer Electronics Show in Las Vegas despite the many mobile phones and Bluetooth headsets in use at the event.

Simpler protocols

Besides the standardized wireless systems mentioned above there are also a host of simpler systems available operating in the 434 MHz or 868 MHz band. The lower data rate required by a relatively simple domestic installation does not necessarily require the more sophisticated protocol mechanisms such as data packet routing and collision avoidance. An acceptable level of communication security is achieved by simply repeating commands.
An example of such a system is the HomeMatic system developed by the German company ELV (in contrast to its FS20 system where the actuators send an acknowledge message) [8]. Products are shown in **Figures 2**, **3** and **4**. There are also wired systems using a twisted pair and based on the 'physical' RS485 specification such as the HomeMatic wired system. It is easily expandable and reasonably priced; a break down of a typical wireless installation is given at the end of the article.
The X10 is probably one of the best known (and one of the first) domestic systems available [9] which is mostly used in America but also to a lesser extent in Europe. X10 is a PLC network and has a number of inherent weaknesses; actuators do not send any acknowledgement messages so commands often get lost which has given the system a reputation for poor reliability. The system also only has address space for a maximum of 256 addresses in the network, when you add up all the sensors/detectors and actuators even for a normal household it doesn't take too long before you start running out of addresses!
Despite its shortcomings the X10 system is still one of the most popular domestic network installations partly due to its simplicity and the low-cost of its components. The US Company SmartLabs have built on the popularity of the X10 system with their recently introduced Insteon system which has backward compatibility with X10. In addition to the X10s communication signalling over the the Insteon system also has a radio network transmitting in the ISM band (904 MHz in the US) this gives a greatly improved communications reliability.

(090649-I)

Internet Links

[1] www.knx.org
[2] http://en.wikipedia.org/wiki/European_Installation_Bus
[3] http://en.wikipedia.org/wiki/Local_area_network
[4] http://www.issendorff.com/
[5] www.z-wave.com
[6] www.merten.de
[7] www.zigbee.org
[8] www.elv.com
[9] http://en.wikipedia.org/wiki/X10_(industry_standard)
[10] www.insteon.net

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Open Standards for the Automated Home

X10, KNX and DigitalSTROM

By Ernst Krempelsauer (Elektor Germany Editorial)

As we describe in the overview article elsewhere in this issue, there are many different home automation systems available. A few of these are sufficiently open that it is possible to build DIY hardware; they also have the advantage of being supported by more than one manufacturer.

There are essentially just three common standards for home automation, although they could hardly be more different from one another: X10, KNX and DigitalSTROM. X10 was first on the scene, being developed in the 1970s; KNX is based on EIB (European Installation Bus), which was developed at the end of the 1980s, and DigitalSTROM is an initiative for a new open standard, which started in 2007. The markets of these three systems are also geographically rather disparate: X10 is chiefly found in the USA and fairly rare in Europe, whereas KNX is the clear market leader in Europe. It is hoped that the first DigitalSTROM products will come onto the market next year.
Despite the age gap, X10 and DigitalSTROM are based on the same underlying communication method: both use PLC (Power Line Communication) and send their messages over existing power wiring. The KNX standard, in contrast, provides for four different ways of communicating data: ordinary twisted-pair wiring, as in the original EIB system, plus radio, PLC and Ethernet.
Only KNX has so far been accorded official European (EN) and international (ISO/IEC) standard status.

Thirty years of X10

X10 was developed by the Scottish firm Pico Electronics Limited [1] in 1976. For its time it was a revolutionary system, employing one

of the first ever application-specific ICs to keep costs down. Sold through Radio Shack and Sears from 1978 onwards, X10 soon became popular among more comfort-conscious American homeowners. In some European countries there is a certain cult following of X10 among DIY installers. Products are available from Marmitek in the Netherlands [2] and EuroX10/CentralCasa in Portugal [3]; these companies have distributors in other countries. The X10 Wikipedia site [4] points to various X10 newsgroups, project pages and the like.

Data, comprising addresses and commands, are transmitted on the live wire of the household AC power line wiring using a 120 kHz carrier signal. A single bit is transmitted at each AC power line (50 Hz or 60 Hz) zero crossing. To send a logic one a 1 ms carrier burst is transmitted; for a logic zero, no carrier burst is transmitted (see **Figure 1**). A consequence of the low data transmission rate of this system is that it only supports a maximum of 256 devices and a total of just 16 command codes. Transmitting one X10 data block, containing either one address or one command, takes a total of 22 zero crossings. Each data block is transmitted twice in the interests of improving reliability, followed by a gap of six zero crossings. Thus the simple job of switching on a light takes a total of 100 zero crossings: at an AC grid frequency of 50 Hz, this corresponds to a total transmission time of one second. Such a large delay can be annoying to the user.

A more serious problem with the standard X10 protocol is the lack of provision for acknowledgement messages. Communication is therefore not reliable. An extension to the X10 standard includes a status request facility, but this requires special devices. Reliability is improved, but the system is even slower.
In summary, the X10 system looks rather antiquated today, but has the great advantages, particularly for private users, of simple installation and relatively low cost.

KNX – the multi-purpose standard

The KNX standard is both international and highly versatile. Its design is the result of a lengthy development process based on experience from many thousands of buildings equipped with EIB, which has been expanded in an endeavor to include the features of the competing BatiBUS and EHS systems (see the text box 'Story of a Standard'). The cooperation of well-known European manufacturers has resulted in the KNX standard offering some unique features:

- internationally (ISO/IEC) standardized;
- 174 participating companies in 29 countries;
- over 7000 product groups;
- four data transfer media options;
- wide range of applications;
- wide range of functions;
- manufacturer-independent design and operation software;
- three different configuration modes;
- independent of particular choice of underlying hardware or operating system.

Story of a standard

1980s	Early bus systems for building automation
1990	Foundation of the EIBA (European Installation Bus Association)
1991	First EIB products available
1994	European standardisation (EN) of EIB
1996	BatiBUS, EIB and EHS (European Home System) begin process of convergence towards a common standard
1999	Foundation of the Konnex Association as an organisation to support the common standard (KNX)
2002	Publication of KNX specifications
2003	KNX becomes a European standard (EN 50090)
2006	KNX becomes an international standard (ISO/IEC 14543-3)

KNX is suitable for all technologies found in buildings, such as services metering, energy management and appliance networking, and for use in any building, new or old, from the humblest of houses to the most extensive of exhibition centers.
The standard is based on EIB (also known as 'Instabus'), which uses ordinary twisted pair (TP) cable. KNX uses a four-conductor cable (called '**TP-1**') for its bus wiring, with two of the conductors being reserved for future use. The data transfer rate is 9600 bit/s and a system can comprise as many as 65000 KNX devices.

The majority of KNX systems installed to date use this TP1 wiring. There are two further variants of the KNX standard that use existing power cables for data communication ('power line' or '**PL**'): these are called PL-110 and PL-132. PL-110 uses a 110 kHz signal with SFSK (spread frequency shift keying) modulation, running at 1200 bit/s. Communication is bidirectional (but half-duplex). The PL-110 protocol is also taken from the earlier EIB standard,

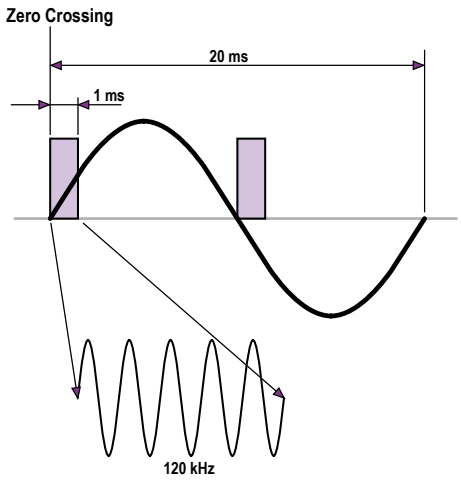

Figure 1. In X10 a logic one is transmitted as a 120 kHz burst during the AC grid voltage zero crossing.

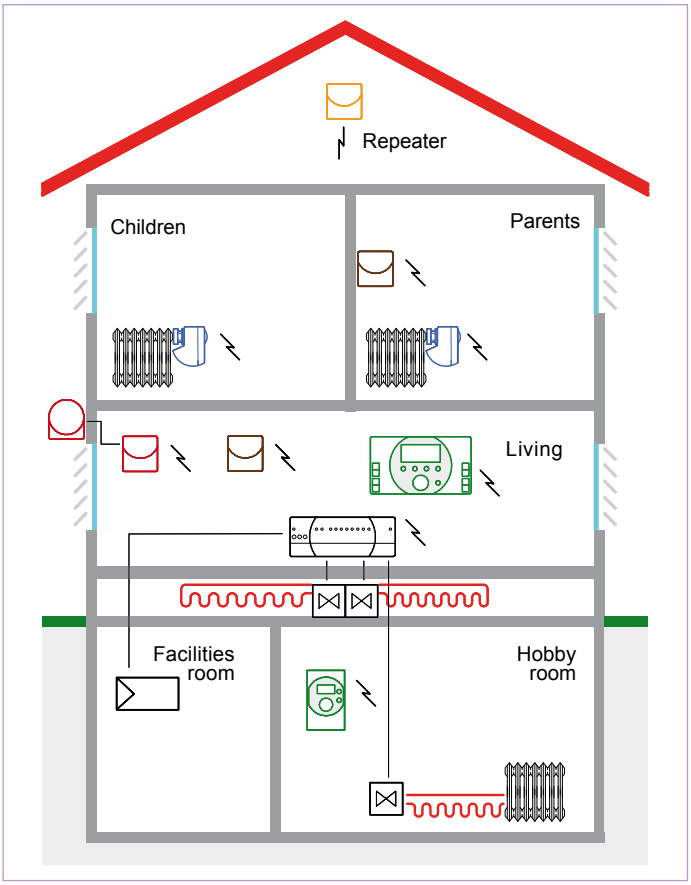

Figure 2. Layout of a house equipped with Siemens Synco Living, which uses KNX RF and KNX TP-1 buses.

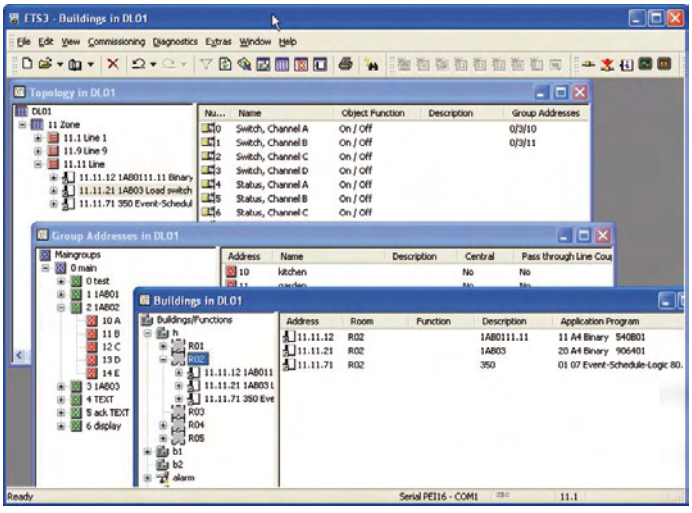

Figure 3. User interface of the ETS3 KNX configuration software (starter and professional versions).

and although in principle it supports a range of topologies and a large number of devices, in practice the low data transfer rate and achievable communication quality are limiting factors. PL-132 differs from PL-110 in its carrier frequency (132 kHz) and data rate (2400 bit/s). The 132 kHz carrier frequency is inherited from EHS, and protocol converters are available to interface EHS units to a KNX PL-132 system.

KNX RF (radio frequency) operates on 868.3 MHz with a transmit power of 10 mW to 25 mW using FSK (frequency shift keying) modulation. Manchester coding is used and data blocks are protected using a CRC. The data rate is 16384 bit/s. KNX RF components are very energy efficient, some having a battery life of six years, and there are both uni- and bi-directional units available. For example, a heating controller might be a bidirectional component, whereas a temperature sensor might be a unidirectional component. KNX RF and KNX TP-1 interfaces can be mixed in a single system, or even within a single component (see **Figure 2**). The radio communications are also compatible with the M-BUS ('meter bus') standard for services metering, so that an an energy management system can take readings from M-BUS (so-called 'smart') meters. The KNX RF standard also provides for repeaters to extend the range of the system (see Figure 2). Although the standard allows the use of components from different manufacturers in the same system, in practice the only KNX RF systems available are the Siemens GAMMA Wave and Synco Living systems and the Hager Tebis KNX system [5]. There are other, non-KNX, radio-based home automation systems, which can be connected to a KNX system via a gateway. For example, Thermokon [6] offer an interface between the EnOcean radio sensors [7] and the EIB/KNX bus.

Alongside these three communications media for connecting components, the KNX standard also provides for **IP**-based communication, using technologies such as Ethernet, WLAN, FireWire and so on. KNXnet/IP defines two basic options:

- IP tunneling allows point-to-point transfer of KNX packets over an IP network.
- IP routing allows the use of an IP network as a fast backbone for communicating between various groups of devices on a KNX network: see the description of the network structure below. KNX IP routers then do the job of line and area couplers in an ordinary KNX network, depending on their configuration.

A significant aspect of the KNX standard is the use of configuration modes and manufacturer-independent **ETS** (engineering tool software) to design and configure a KNX system. There are three configuration modes:

- **S-mode**: system mode, configured using KNX ETS
- **E-mode**: simple mode, configured at each device or using a simple programming unit
- **A-mode**: automatic configuration ('plug and play')

The most widespread components support either S-mode or both S-mode and E-mode. A-mode was intended for use by 'intelligent' household appliances and has not yet seen wide use. S-Mode is inherited from EIB, and requires the use of ETS (current version ETS3) on a PC. The ETS can configure all the KNX components, setting functions, parameters and group addresses. ETS can also be used (**Figure 3**) on an existing system at any time to modify it. For example, it is possible to change which light is operated by a particular switch entirely under software control, without needing to touch the wiring. Reconfiguration is also possible over the Internet using the iETS tool.

There are many variants of E-mode which define how the settings of a component are configured either at the component itself or via Hager's TX100B 'configurator' tool (**Figure 4**).

KNX bus structure and hardware

Each participating device in a two-wire bus (TP-1) system is connected to both bus lines (**Figure 5**). One cable with up to 64 (in the extended version, 256) connected devices forms a 'line', the smallest group in a system. Up to 16 lines can be joined together to form an 'area': thus an area can comprise up to 16 times 256, or 4096, individual KNX components. A KNX network (**Figure 6**) can contain up to 16 areas, allowing for a grand total of 4096 times 16, or 65536 components. The total length of cable involved can be up to 1024 km!

Each line is connected to an area's main line via a line coupler; likewise, the area main lines are connected to the 'backbone' using area couplers.

The two-wire bus not only carries data but also supplies power at a nominal 30 V DC. Each participating device is allowed to draw up to 12 mA from this supply. A KNX device that requires more power than this must have its own ('external') power supply.

As Figure 5 shows, each line has a dedicated power supply, connected via a pair of chokes. The permissible bus voltage of this SELV (safety extra low voltage) supply is from 20 V to 32 V.

The KNX TP-1 bus is specially designed to avoid the need for termination resistors. It uses a CSMA/CA (carrier sense multiple access/collision avoidance) protocol, and a participating device only transmits on the bus when it has data to send or if asked to send data. There is no regular cyclic polling by a bus master, which helps reduce the load on the bus and keep transmission delays short. Bus collisions are avoided using the following protocol: while a device is transmitting, it checks that the bus is free. Only logic zero is 'actively' transmitted; a logic one is indicated by no activity on the bus. A zero bit is sent by a device briefly applying an additional load to the bus, resulting in a brief dip in the supply voltage. The inductance of the series chokes means that when the additional load is released, the supply voltage briefly overshoots its original level, giving a typical behavior like that shown in **Figure 7**.

Standards of openness

Whether a standard deserves to be called 'open' is a matter of definition. KNX and DigitalSTROM describe themselves as 'open'; and X10 is regarded by its users as an 'open industry standard' but this is something of a special case as the patents dating back to the 1970s have already expired.

The definitions given at [17] and [18] for open standards largely apply, but this is not to say that access to the technologies involved is free of charge. KNX and DigitalSTROM both charge money for membership of their organizations, and the fees are greater for larger companies. Membership of the appropriate organization is required in order to obtain support and the legal right to use the intellectual property for commercial purposes. However, once these fees are paid, companies are not required to pay further licensing charges. For KNX the documentation, being a European and international standard, is also available from national standards bodies, and a considerable amount of KNX documentation is available on the Internet and from manufacturers. Universities and research institutes enjoy special terms: for example, they can join the KNX association for $350 per year as a 'scientific partner' with access to software and the organization's FTP server. It is possible to register at digitalSTROM.org without charge as an 'interested party' and gain access to the organization's simulation software.

Figure 4. TX100 Configurator for simple commissioning of KNX-TP and KNX Radio systems in E-mode.

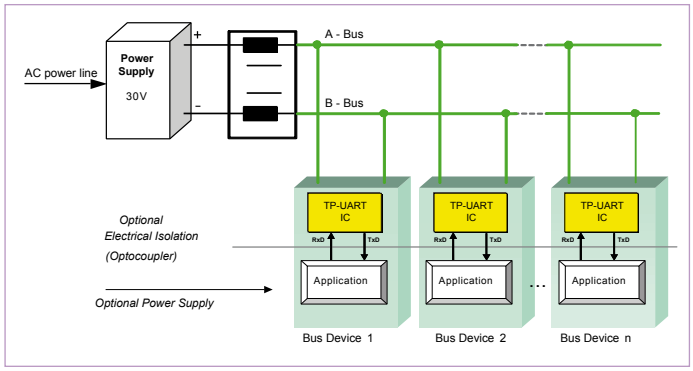

Figure 5. KNX components wired to form a bus line. Each line has its own 30 V supply.

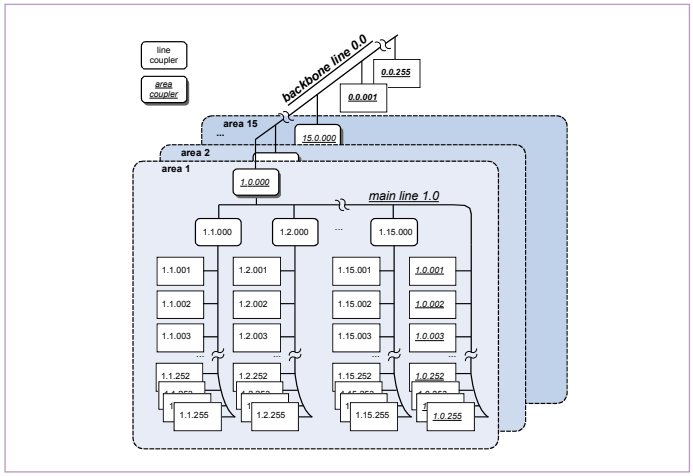

Figure 6. A KNX network is divided into areas and lines, joined by line and area couplers (or KNX routers).

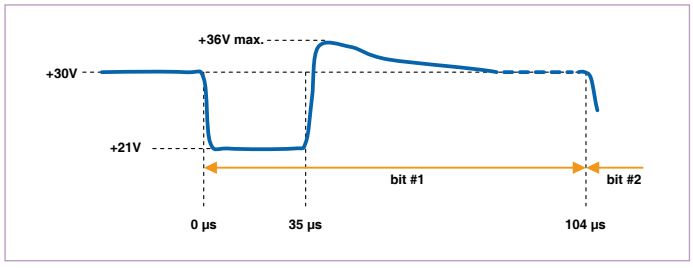

Figure 7. A zero bit is transmitted on the TP-1 bus by a brief dip in the power supply voltage.

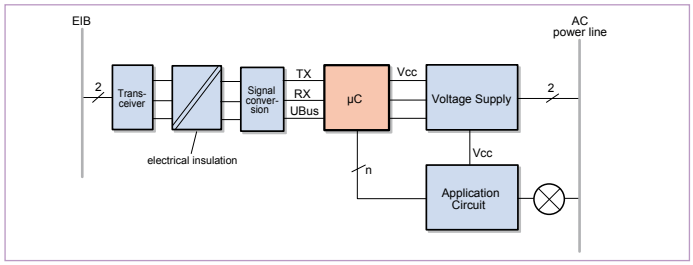

Figure 8. Block diagram of a KNX/EIB lamp dimmer.

The point of using an 'active 0' and a 'passive 1' is that if two devices try to transmit a message on the bus at exactly the same time, a zero sent by one device will dominate a one sent by the other. The losing device can detect that a collision has occurred and can cease its transmission, while the winner continues to transmit. As a result the bus is never jammed, even under heavy load, and so transmission delays are kept low.
Figure 8 shows a block diagram of the internals of a KNX/EIB light dimmer, an example of a device with its own power supply. In the early days of EIB special bus interface transformers were used, but now special-purpose ICs and modules are available. A TP-UART is available from Siemens, as is the FZE1066 integrated EIB twisted pair transceiver. Also available is a KNX bus controller, which can be combined with the TP-UART to make a KNX chipset [8]. The controller is in fact a µPD78F053x microcontroller from NEC, programmed with KNX certified firmware (the KNX System 2.5 stack).

KNX information and projects

The authoritative website is that of the KNX Association [9], available in 12 languages. A little judicious clicking and searching will give a good overview of the system and the activities of the association. Some free documentation, a KNX Journal and KNX demonstration software can be downloaded. There are many links and indexes, leading to the websites of manufacturers, user groups and forums. The 'official' KNX user group can be found under 'Partners', as can a list of universities participating in KNX-related activities, while clicking on 'News & Press' and then 'Links' brings up a list of forums in a range of countries and languages. Not listed is the site of the open source project 'Freebus' [10], which deals with DIY construction of KNX (EIB TP-1) compatible modules and which has already published a range of projects. Data sheets and software tools of interest to KNX developers are also available via Georg Luber's website [11].

Also recommended is the KNX site run by the Vienna University of Technology [12] and Friedrich Praus' graduation thesis [13] (in English), which gives a comprehensive introduction to KNX/EIB and describes a versatile microcontroller board for KNX/EIB applications. When searching for other KNX projects on the Internet, it is worth trying 'EIB' as an alternative keyword to 'KNX'.
EIBMARKT [14] gives information about and prices for KNX products. For example, a KNX gateway, interfacing a PC to a KNX system via a RS232 or USB port, is available for under $250.

DigitalSTROM

This concept, in equal measures ambitious and fascinating, is a new twist on the old PLC idea. First, there is no high-frequency carrier,

and no frequency modulation; and second, the hardware has been shrunk down to a single chip (the 'dSChip'), which fits inside a chocolate block. Data transfer is performed, as in the X10 standard, during the zero crossings of the AC power line signal. There the similarity ends, however. A slave device transmits by slightly increasing or decreasing the (real) power consumption of the appliance for a few microseconds, whereas the bus master transmits by shorting the AC power line supply for a few microseconds. Since the AC power line voltage is near its zero crossing, very little current flows.

Data bits are thus essentially carried in the modulation of a current. Each dSChip, like a 1-wire bus device or RFID tag, includes a unique assigned address. The chip itself dissipates just 300 mW and has over 60 functions built in: phase angle power control for appliances rated at up to 120 W (including low-energy light bulbs), appliance power consumption measurement, various interfaces and lots more besides. The device is not yet available to buy, but there is plenty to read about the development of the system at the homepage of digitalSTROM.org [15] and on the website of the company developing the IC, aizo AG [16]. And as soon as we can lay our hands on a working dSChip at the Elektor labs, we will be sure to report on it.

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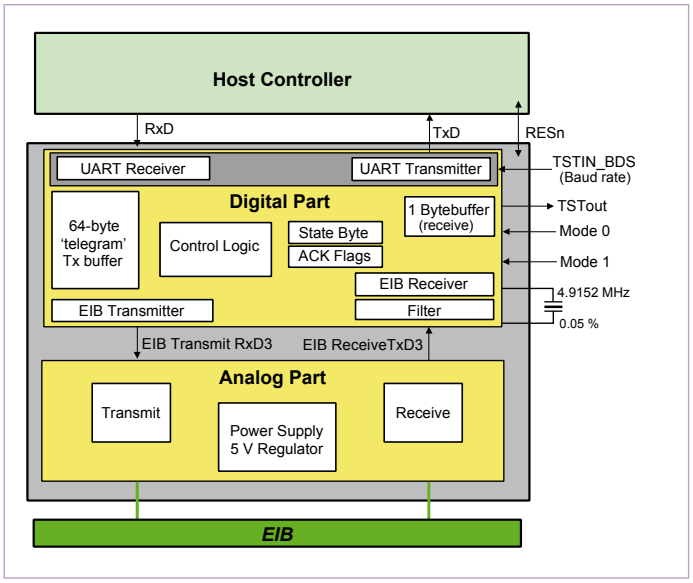


Figure 9. Block diagram of the Siemens TP-UART IC. Add a microcontroller, and you have a complete bus component.

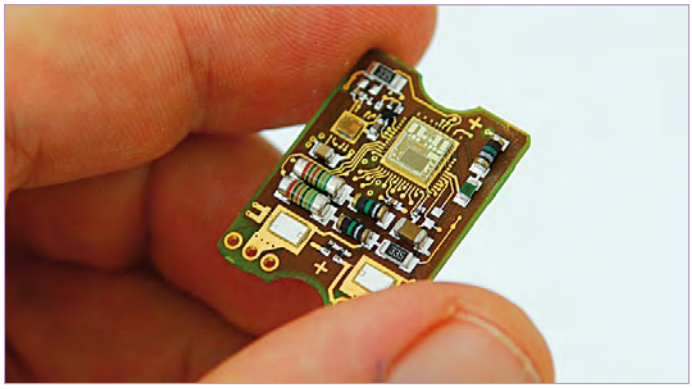


Figure 10. The printed circuit board carrying the DigitalSTROM chip is powered from the AC grid and fits inside a chocolate block.

Image sources

Head illustration and Figure 4: Hager Tehalit

Figure 2, Figure 5, Figure 9: Siemens AG

Figure 3, Figure6, Figure 8: KNX Association

Figure 7: Andreas Krebs, Freebus.org

Figure 10: digitalSTROM.org

Internet Links

[1] www.xnumber.com/xnumber/microprocessor_history.htm

[2] www.marmitek.com/

[3] www.eurox10.com/

[4] http://en.wikipedia.org/wiki/X10_(industry_standard)

[5] www.hager.com/

[6] www.thermokon.com/

[7] www.enocean-alliance.org/

[8] www.opternus.com/en/siemens/knx-chipset.html

[9] www.knx.org/

[10] www.freebus.org/ (in German)

[11] www.knx-developer.com/

[12] www.auto.tuwien.ac.at/a-lab/knx-eib.html

[13] www.praus.at/files/diplomarbeit_fpraus.pdf

[14] www.eibmarkt.com/cgi-bin/eibmarkt.storefront/EN

[15] digitalstrom.org/index.php?id=115&L=2

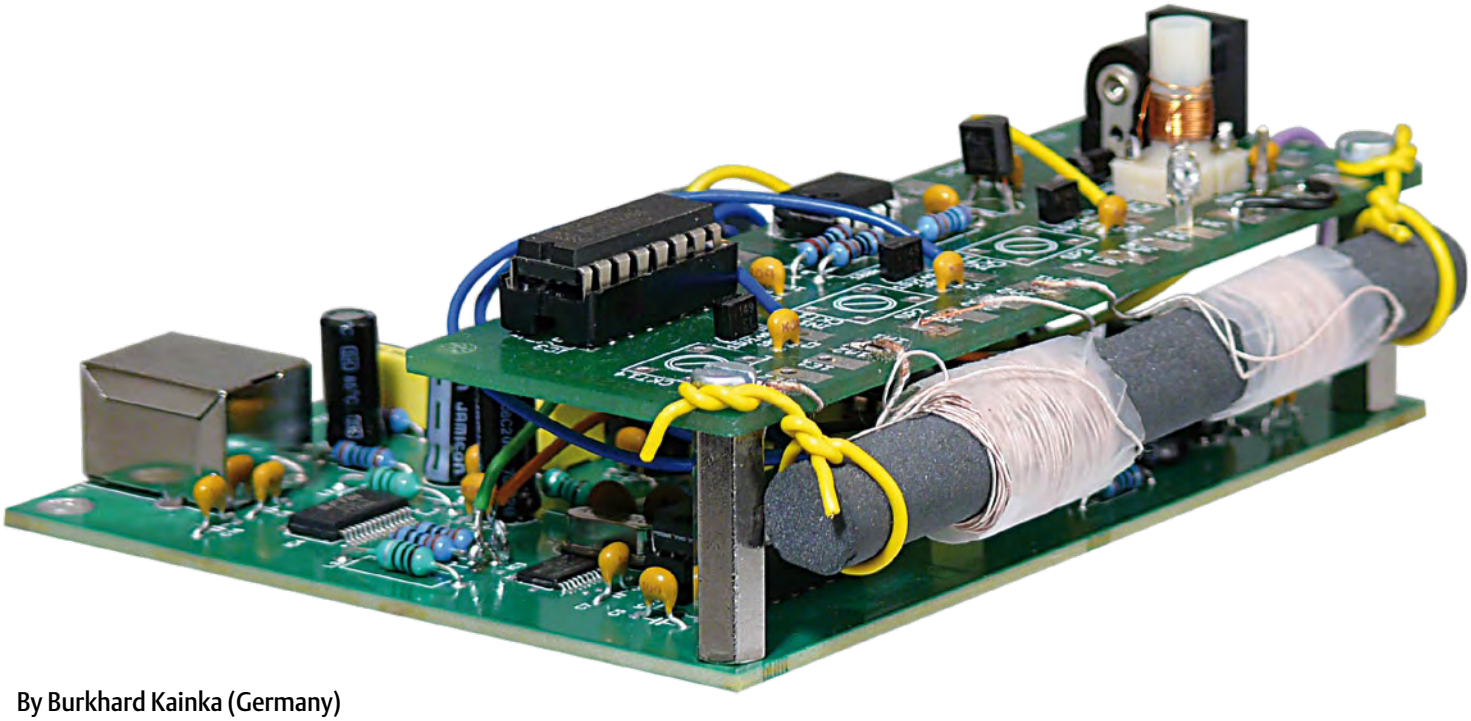
[16] www.aizo.com/en/

[17] www.itu.int/ITU-T/othergroups/ipr-adhoc/openstandards.html

[18] http://en.wikipedia.org/wiki/Open_standar

Preselector for Elektor SDR

Here's the automatic tuning upgrade!



By Burkhard Kainka (Germany)

The performance of a receiver depends to a large extent on its input filters. A selective input circuit improves antenna matching and immunity to interference from other strong signals. The preselector described here allows the use of up to four filters, tuned under software control using varicap diodes. A tuned loop antenna is also described that lets you use the Elektor SDR receiver without an outdoor antenna.

Almost three years since its publication, the Elektor Software Defined Radio (SDR) [1] is still a blockbuster project, and here at Elektor we were gratified by comments from the radio amateur community like 'good value for money' and 'an excellent entry-level SDR'. The publication of the SDR hardware was also followed by a flurry of tuning and control software like Peter Carnegie's 'G8JCFSDR'.

The SDR covers practically the whole of the radio frequency range up to 30 MHz. In the design, a 74HC4051 is used as an input multiplexer, offering a total of eight inputs A0 to A7. Under software control it is possible to use the multiplexer to switch between a wideband input (A0, displayed as In1 by the software), a low-pass filter for medium wave (MW) reception (A1, or In2), and a high-pass filter for shortwave (SW) reception (A2, or In3). Input A7 is used for a 5 MHz self-test input. There are thus four spare inputs to the multiplexer, and these can be used, for example, to connect ferrite antennas or front-end circuits. The inputs have a high impedance and can therefore also be used to connect a tuned magnetic loop antenna, as shown in the examples in **Figure 1**. An annoyance when using these circuits with a software controlled radio is that the variable capacitors have to be adjusted manually, which can be rather fiddly. For this reason we have developed an automatically tuneable preselector, controlled over an I²C bus, using varicap (variable capacitance) diodes.

Features

- Four tuneable front-end circuits
- Controlled by free SDR tuning software
- I²C bus control
- Long-, medium- and short wave reception
- 500 pF varicap diodes
- Suitable for use with a wire antenna, a loop antenna or a ferrite rod

Four front-ends

The preselector circuit (**Figure 2**) sports four front-ends using 1SV149 varicap diodes. Depending on the tuning voltage, these devices have a capacitance that varies from around 20 pF to 500 pF. The tuning voltages are generated using a PCF8591 digital-to-analog converter, which is controlled over an I²C bus. Since the Elektor SDR already incorporates an I²C bus, adding the facility

for software tuning control to the preselector is just a matter of making two additional connections (SDA and SCL).
Each front-end circuit employs a coil (L1 to L4) with four connections. Each output is coupled to one of the high-impedance inputs A3 to A6 (referred to as In4 to In7 in the software) of the SDR receiver's input multiplexer via a 100 nF capacitor (C3 to C6), via an individual coupling winding.
Alternatively ferrite antennas or loop antennas with just two connections may be used. The details of these choices are left to the reader, as is the choice of which frequency ranges each preselector channel will work with. Also, inputs A0 to A2 (In1 to In3) of the SDR remain available for use.

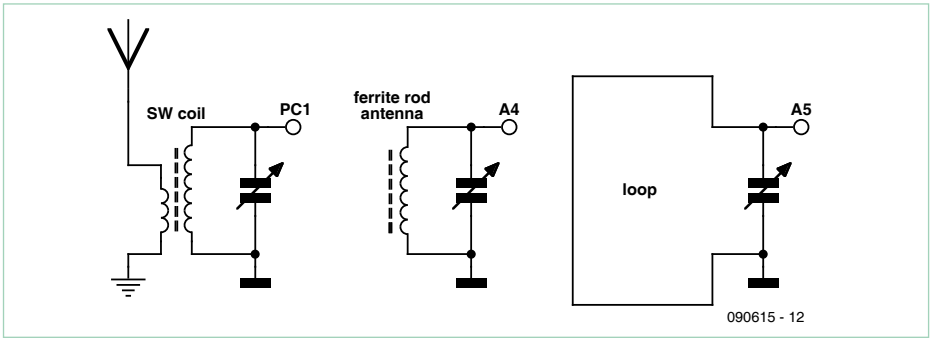


Figure 1. Simple front-end circuits, manually tuned using a variable capacitor, suitable for direct connection to the SDR board.

Construction matters

Populating the printed circuit board (**Figure 3**) should be straightforward. First mount all the semiconductors, resistors and capacitors, but leave the coils for now. The board is also available in this partially-assembled state from the Elektor Shop: the board comes with four suitable coil formers plus a ferrite rod with ready-wound coils suitable for long wave and medium wave use. You can wind the other coils to suit the particular frequency ranges you wish to use. Here are two suggestions: to receive the shortwave band from 2.2 MHz to 8 MHz via output OUT3, wind L3 with 40 turns between 3E1 and 3A1 plus a 2-turn antenna coupling winding between 3E2 and 3A2; to receive the shortwave band from 4.5 MHz to 16 MHz via output OUT4, wind L4 with 15 turns between 4E1 and 4A1 plus a 1-turn antenna coupling winding between 4E2 and 4A2.
The 10 mm by 90 mm ferrite rod is used to cover the lower frequency ranges: coils for MW and LW use can be mounted on the same rod. You can either use the ready-wound coils provided or wind your own using either litz wire or 0.2 mm enameled copper wire. A high Q factor is not essential in this case as it will be used for relatively wideband reception. To receive longwave between 140 kHz and 450 kHz via output OUT1, use 170 turns of litz wire or 0.2 mm enamelled copper wire on the ferrite rod,

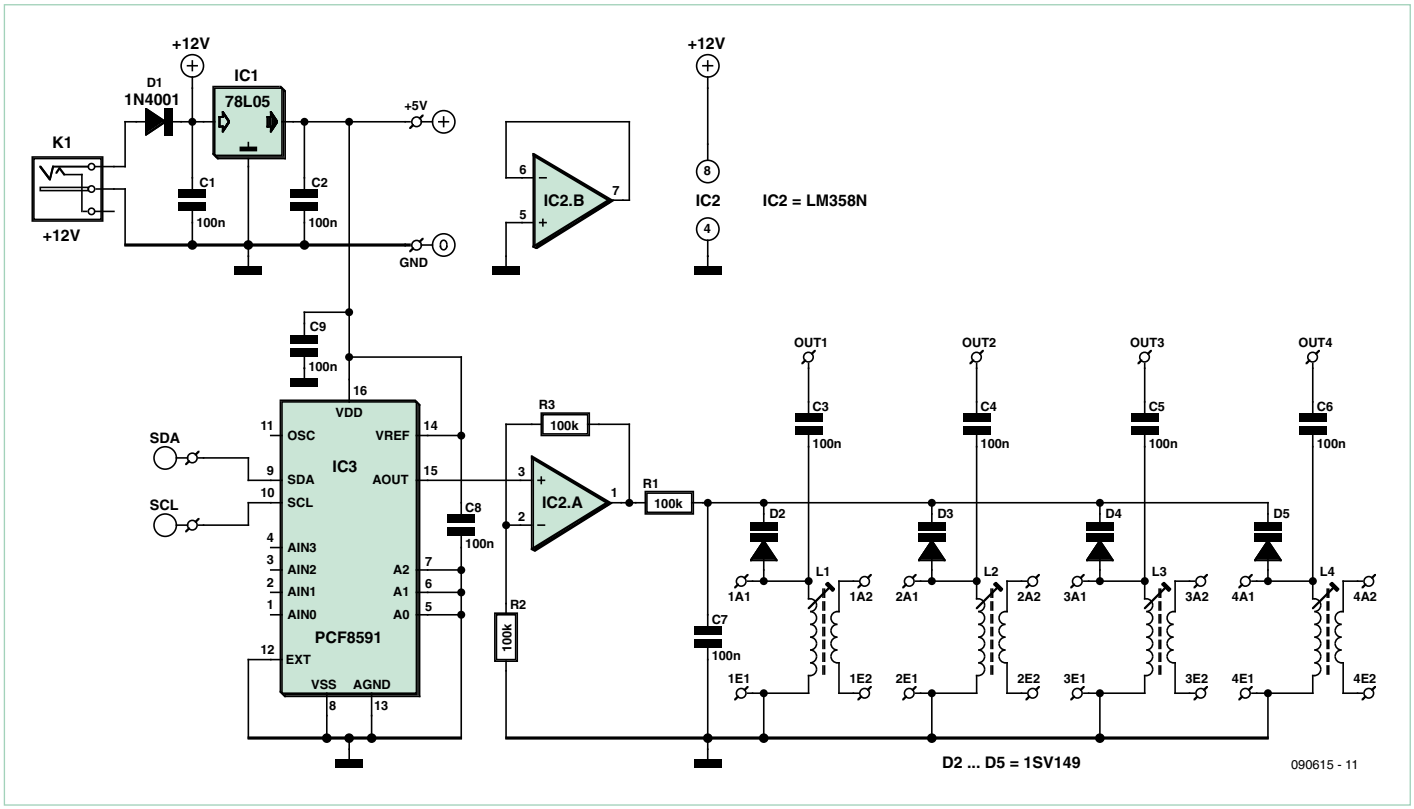


Figure 2. The circuit of the 'digital' preselector with four front-ends tuneable over an I²C bus.

COMPONENT LIST

Resistors
R1,R2,R3 = 100kΩ

Capacitors
C1,C2,C3,C4,C5,C6,C7,C8,C9 = 100nF ceramic

Semiconductors
IC1 = 78L05
IC2 = LM358N
IC3 = PCF8591P
D1 = 1N4001
D2–D5 = 1SV149 (www.ak-modul-bus.de)

Miscellaneous
4 inductors on former type T1.4 (www.ak-modul-bus.de)
DC power adaptor type NEB 21 R (Lumberg)
PCB, ref. 090615-1

Alternatively, kit of parts # 090615-71, contains partly populated board, coil formers, ferrite rod with coils

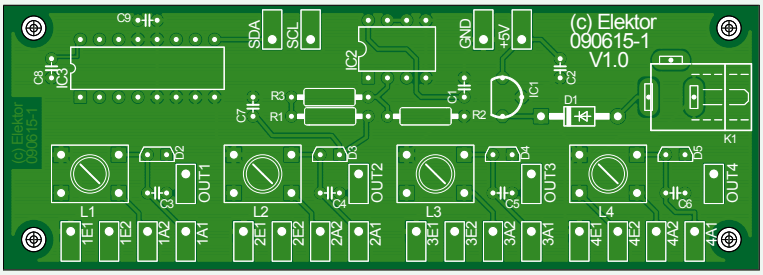


Figure 3. Printed circuit board for the preselector. All the coil connections are brought out to one edge of the board.

between 1E1 and 1A1; to receive medium wave between 550 kHz and 1600 kHz via output OUT2, use 40 turns of litz wire or 0.2 mm enamelled copper wire on the ferrite rod, between 2E1 and 2A1.
The two shortwave antenna coupling coils, between 4E2 and 4A2 and between 3E2 and 3A2, can be wired in series if desired and connected to the antenna cable without an earth, as illustrated in **Figure 4**. This has the highly desirable feature of isolating the PC ground (which connected to the ground of the circuit) from the antenna ground, which can help reduce interference considerably. There are essentially no signal voltage losses incurred by this series connection, as the coils are only in resonance at their own selected frequency and otherwise present a low impedance.

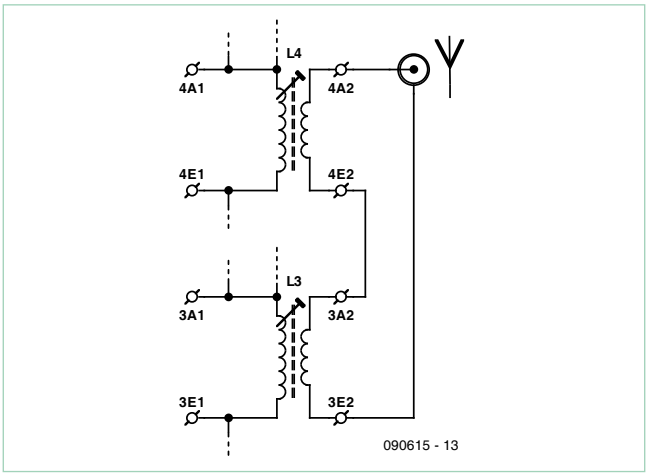


Figure 4. Antenna wiring for two short wave bands.

Mounting and wiring

The fixing holes of the add-on board are placed so that it can be fitted directly over the SDR board using spacers. The necessary wires can then be added. **Figure 5** shows the connection points on the SDR board; GND is connected to C21. The +5 V supply connection between R4 on the SDR board and the +5 V point on the preselector board should be omitted for now: see the section on the power supply below. The I²C bus connections SCL and SDA are soldered to R2 and R3. The outputs of the preselector board (OUT1 to OUT4) are taken from the points indicated in Figure 5 to inputs A3 to A6 of multiplexer IC6. In the software these are selected as In4 to In7 (see **Figure 6**).

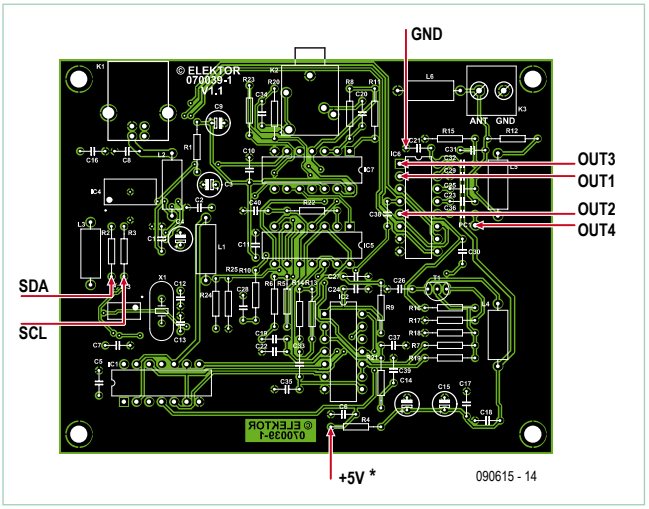


Figure 5. The points on the SDR receiver board where the preselector is connected.

Software and operation

The original tuning software for the Elektor SDR receiver has been extended with the necessary features to control the varicap diodes. The new version, ElektorSDRpre.exe, can be downloaded free of charge from [1] and [2]. As Figure 6 shows, there is now an additional slider that allows the input circuits to be tuned. The actual digital value sent, from 0 to 255, is displayed in a window. The D/A converter turns this into a voltage from 0 V to 5 V. The voltage is doubled by IC2.A, and a tuning voltage of 0 V to 10 V appears across the varicap diodes. There are two modes of operation: manual (‚Man') and automatic (‚Auto'). By default the software starts up in manual mode.
Start the software up as usual, along with a decoder such as Dream, SoDiRa, G8JCFSDR or SDRadio. Now choose input In1 or In2 for medium wave, or In3 for shortwave. Connect the antenna to the ANT terminals of the SDR board. Set the frequency to that of a known station, for example in the 49 m broadcast band.

Now disconnect the antenna and reconnect it to the preselector board. Switch to input In4 (second shortwave input). Adjust the position of the preselector tuning slider on the screen to obtain maximum signal strength. You should now see a stronger signal here than at the wideband input, as the tuned front-end circuit provides better matching to the antenna. Sensitivity is considerably improved, especially in the higher frequency bands,

In the same way, test the first shortwave band using In5. A common problem when receiving lower-frequency shortwave stations using the wideband antenna input is interference from stations at three and five times the frequency of the wanted station. The preselector considerably attenuates these images, giving access, for example, to many new stations in the 80 m amateur radio band.

The improvement is even more pronounced when listening to long and medium wave stations using the ferrite rod antenna. The signal strength obtained is similar to that from a longwire antenna connected to the wideband input, but there is considerably less interference. This is due to the suppression of images from higher-frequency stations and to the fact that the ferrite antenna receives the magnetic component of the signal, which gives better immunity to the kinds of interference found in domestic environments.

Automatic tuning

In manual operation mode it is necessary to adjust the tuning of the front-end circuit whenever you switch stations. This process can be automated, with the software calculating and setting the necessary tuning voltage. As the main tuning slider control is moved, the preselector tuning control automatically moves in sympathy. The calculations are based on a precalculated table of reference values, and the software comes with a file InitPreselector.txt which contains suitable settings for the recommended set of front-end coils.

If you are winding your own coils or making other alterations to the circuit, you will need to edit the table using a text editor such as Notepad. The structure of the file must be carefully preserved. For each of the four input resonators there are exactly ten entries in the file: each entry consists of a frequency in kHz and the corresponding tuning figure (in the range 0 to 255). The table is introduced by one comment line (saying 'In4', 'In5' etc.) and terminated by a blank line. The provided file InitPreselector.txt can be used as a starting point to create your own file.

Proceed as follows to determine the correct tuning values to enter into the file. Find ten stations in the required tuning range; tune to each in turn and manually find the optimum position for the front-end tuning slider. The spacing of the reference frequencies is up to you, but it is best if they are more closely spaced over any part of the tuning range where the front-end tuning value changes rapidly. It is also important to sort the values so that the lowest frequency (tuning value 0) appears first and the highest frequency (tuning value 255) last. Enter the values into the file and save it, preserving the filename. When the software is next restarted it will read the table and use the values in it. For any given frequency the software calculates a suitable tuning value by interpolating between the two nearest reference frequencies on either side. The relationship between frequency and tuning value is highly non-linear, changing much more rapidly in the middle of the tuning range than at the ends.

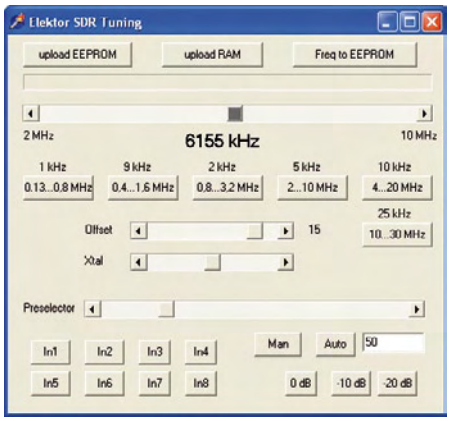


Figure 6. The tuning software now also drives the preselector.

Figure 7. The SDRadio software in action.

Tuned loop antennas

If it is not feasible or desirable to use an outdoor antenna, the best choice for long- or medium wave reception is the ferrite rod antenna. For shortwave reception, an alternative solution is to use a tuned magnetic loop antenna. This can give reception almost as good indoors as a longwire antenna can outdoors. We therefore have the ability to receive the whole range of stations without an outdoor antenna.

To use a shortwave loop antenna, omit coils L3 and L4 and replace the resonator coil with the wire of the antenna loop. A coupling coil is not required as the antenna is being connected to a high-impedance input. The diameter of the loop, the length of the wire, and the thickness of the wire jointly determine the inductance of the antenna and hence the operating frequency range. Web pages are available to help do the necessary calculations: see, for example, [3].

One practical arrangement is to use two metres of 0.75 mm² flexible (multi-

The Elektor SDR

The Elektor Software Defined Radio with USB interface was published in May 2007. Since then it has become one of the most widely-used SDR hardware projects. The SDR board can receive not only AM and DRM signals but also amateur radio (both SSB and CW), marine weather services, and stations from all over the world. SDR software is continuously being improved and new features added, also by members of the ham radio community all over the world.

The project is an ideal low-cost introduction to SDR technology. The preselector circuit described here makes a big difference to the performance of the receiver: RF preselection coupled with better antenna matching allow the radio to pick out a much greater range of stations. Furthermore, if it is not feasible or desirable to use an outdoor antenna, the preselector circuit can work as a tuned loop antenna.

Further information and a free article download are available at www.elektor.com/070039.

stranded) power cord wire to make a circle of diameter 60 cm. The inductance of this loop will be around 2.5 µH, which, in parallel with 500 pF, gives a resonant frequency of about 4.5 MHz. Empirically, a tuning range of 4 MHz to 12 MHz can be achieved. If you use the same length of wire to make a two-turn loop, the diameter will be halved, resulting in a higher inductance. A two-turn loop with a diameter of 20 cm makes a useful shortwave antenna for the band from 3.5 MHz to 14 MHz. This can be used as an indoor antenna to receive DRM signals with comparable quality to a longwire antenna.

A good option is to construct an antenna from two 25 cm diameter loops mounted at right-angles to one another. One loop should consist of just one turn and covers higher-frequency shortwave reception up to 30 MHz, while the second consists of two turns and operates from about 3 MHz (see **Figure 8**). The loops can be wired so as to replace coils L3 and L4 on the preselector board: the one-turn loop between 4E1 and 4A1, and the two-turn loop between 3E1 and 3A1.
The antenna is rather directional and it is therefore worth mounting it so that it can be rotated — in some cases, to kill interference!

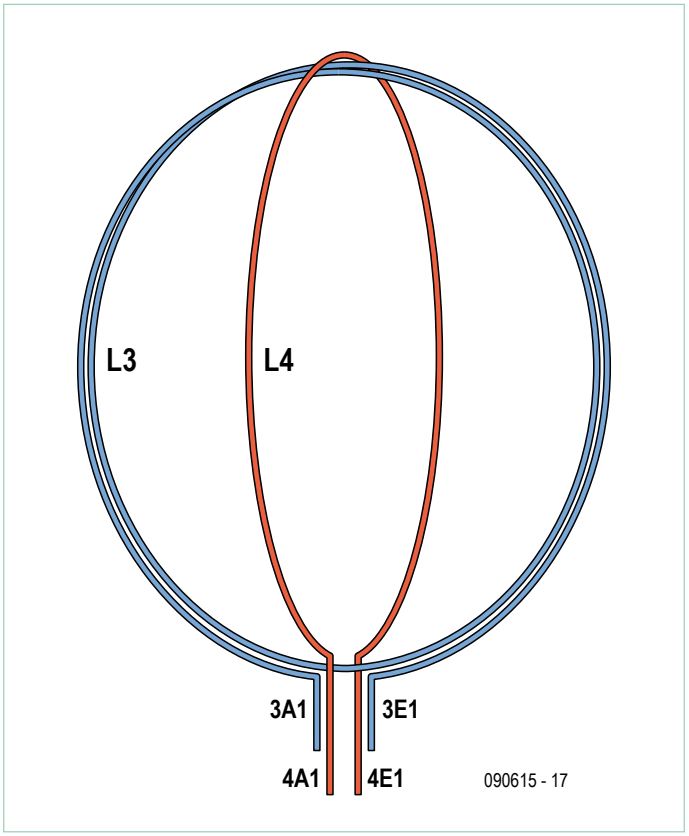


Figure 8. Construction of an antenna consisting of two loops mounted at right-angles to one another.

On power supplies

The system uses two separate power supplies. The SDR receiver board takes a +5 V supply from the PC's USB port, while the preselector board uses a 12 V mains adaptor, connected to K1. The 12 V supply is necessary because the varicap diodes require a drive voltage of up to 10 V to cover the full tuning range. A 5 V regulator on the preselector board provides power for the D/A converter.

Depending on the PC or laptop computer used the supply provided by the USB port can be noisy. This is particularly noticeable when a low intermediate frequency (IF) is used, as there is considerable noise up to around 2 kHz. With an IF of 10 kHz to 15 kHz this interference does not normally cause any problems.

However, with the addition of the preselector board, we have the opportunity to improve the power supply of the SDR receiver board by connecting the +5 V point on the preselector board with the +5 V point on the receiver board as indicated in the figure.
To ensure that the preselector board does not supply power back into the PC's USB port, it is **essential** to replace L1 on the SDR board with a diode (type 1N4001, cathode towards C2). The result will be that V_{CC} on the receiver board will be supplied from the preselector's power supply, much reducing interference at lower intermediate frequencies.

(090615-I)

Internet Links

[1] www.elektor.com/070039
[2] www.elektor-usa.com/090615
[3] www.technick.net/public/code/cp_dpage.php?aiocp_dp=util_inductance_circle

Squeezing Out the Last Drop

How to make your electronic devices even more energy efficient

By Fons Janssen and Mark Vermeulen (The Netherlands)

You've replaced all your incandescent lamps with energy-saving lamps. Your TV set is never in standby mode, and you're giving serious consideration to having a solar panel installed on your roof. What else can you do to reduce your power bill without too much fuss and bother?

It's not especially difficult to determine the standby power consumption of the electrical equipment in your house (see the article 'Economical with Energy' in the January 2008 issue of Elektor), but even if you know that your WiFi router consumes a steady 6 watts, what can you do about it? Pulling the plug when you're not actively online is rather impractical. Fortunately, there are several other approaches that electronics enthusiasts can use to reduce standby power consumption.

What ends up where?

In this article we concentrate on equipment that is normally left on 24 hours a day, 7 days a week. A good example is the previously mentioned WiFi router. This sort of equipment usually operates from a low voltage and is powered by an AC adapter. This is usually an off-the-shelf model, with the result that the adapter and the device it powers are not optimally matched. In addition, many of these adaptors still use an inexpensive iron-core transformer, which is not especially efficient.

As a practical example, let's consider a WiFi router with the Sitecom brand name. It is powered by a 12-V AC adapter ('wallwart') included with the router. The power consumption measured using a power meter is 6.2 W, which yields an annual energy consumption of around 54 kWh. If you open up the router (**Figure 1**), you see that the 12-V input voltage from the adapter is immediately reduced to 3.3 V by a buck converter built around an AP1510. If you replace the

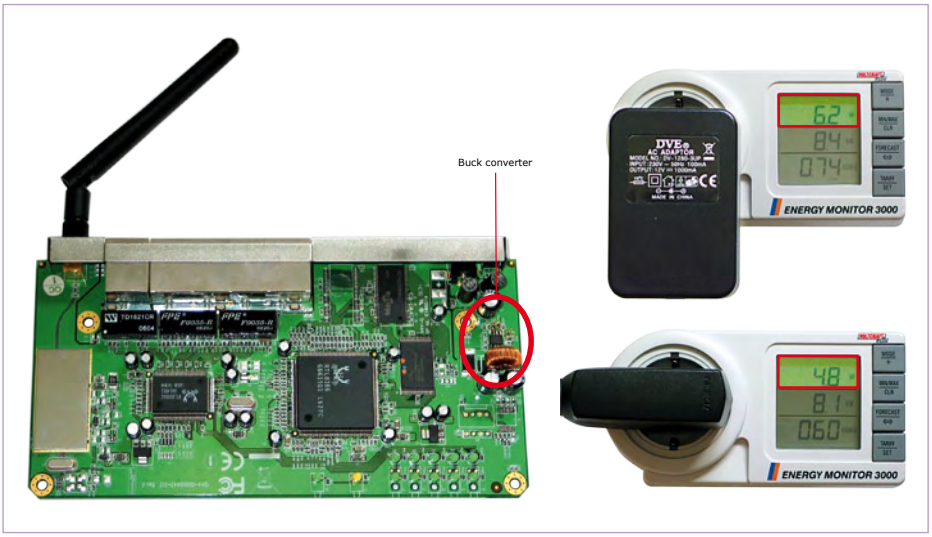


Figure 1. A look inside the WiFi router. The external supply voltage is reduced to 3.3 V by a buck converter. The power consumption of the router can be reduced by around 1.4 W by replacing the AC adapter included with the router by an adapter with an electronic converter. However, it should be noted that the phase factor of the electronic converter is somewhat lower, with the result that the reactive power of both adaptors is virtually the same. Of course, the kilowatt-hour meter in the meter cabinet registers only the real power.

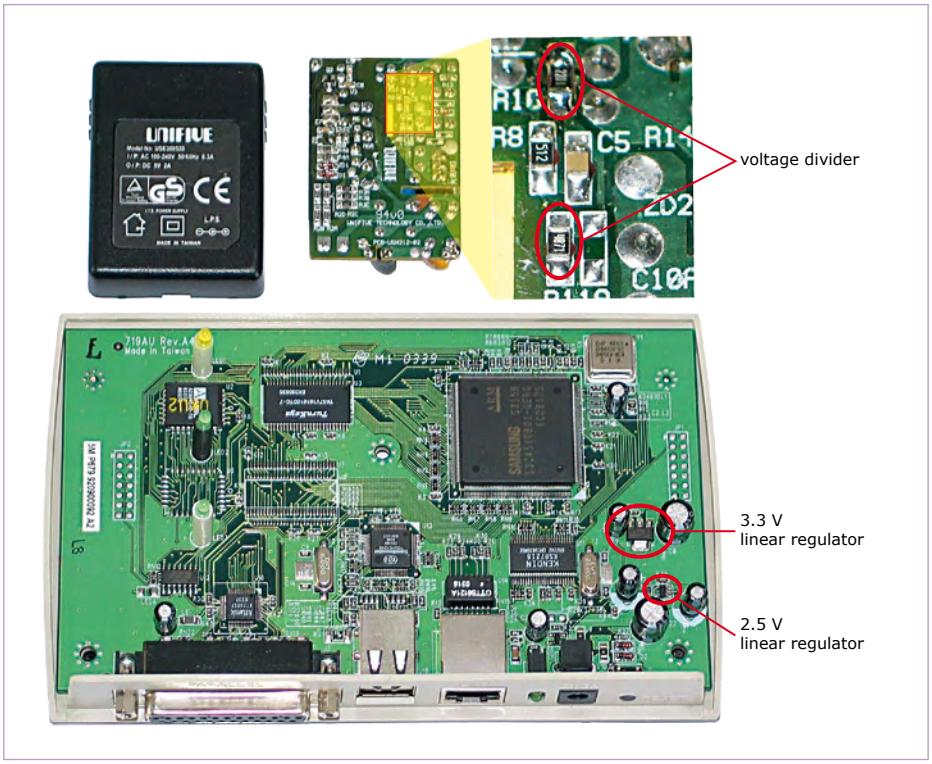


Figure 2. The motherboard of the printer server (bottom) and the included AC adapter (top). The output voltage of the adapter can be reduced from 5 V to 3.6 V by replacing the upper feedback resistor with a 2.2-kΩ resistor. The motherboard has two linear voltage regulators that can operate perfectly well with an input voltage of 3.6 V. The USB bus voltage is also reduced to 3.6 V, but printers are generally not powered from the USB port, so this does not have any detrimental effect.

adapter with a laboratory power supply, you can see that the current consumption is only 250 mA, which corresponds to 4 watts. This means that the adapter consumes around 2.3 watts of the total 6 watts you pay for. In addition, the adapter is distinctly heavy, which indicates that it uses an iron-core transformer instead of an electronic voltage converter.

A more economical adapter

The first thing you can do to reduce the power consumption is to replace the adapter. As the input voltage range of the buck converter in the router is quite large (3.6 V to 23 V), nearly any adapter can be used. We chose an electronic adapter for a cell phone no longer in use. It supplies 5.7 V with a maximum output current of 800 mA, which is well over 4.5 W. If you switch on the router with this adapter, the power meter indicates a consumption of 4.8 W, which represents a savings of 1.4 W. This may not seem like all that much, but on an annual basis it adds up to well over 12 kWh. In most countries that's enough to run your clothes dry around twelve times.

Voltage adjustment

Unfortunately, using an electronic adapter is not the solution to every problem. For our second practical example, we examined a no-name USB printer server. You can use it to connect a printer directly to your network without using a PC as an intermediary. This by itself yields considerable savings, since you don't have to leave your PC running 24 hours a day. The AC adapter included with the server looks perfectly fine at first glance. It is a lightweight model rated at 10 W output power, which unquestionably means that it uses an electronic converter. However, if you look at what happens to the 5-V supply voltage from the adapter after it enters the server (**Figure 2**), you see that the power savings achieved by the electronic converter are all for naught: the 5-V supply voltage is reduced directly to 3.3 V and 2.5 V by a pair of linear voltage regulators. This means that a good deal of the power supplied by the adapter is dissipated as heat in the voltage regulator ICs. If you can reduce the output voltage of the adapter to 3.6 V (600 mV of headroom should be enough

for the linear voltage regulators), you can achieve considerable savings.
Almost all power supplies use a voltage divider to set the output voltage, according to the formula

$V_{out} = V_{ref} \times (1 + R1/R2)$

This means that you only have to replace one resistor in order to reduce the output voltage of the adapter. If you open up the AC adapter here, you can see right away that it is an isolated resonant flyback converter. The voltage divider is present as expected, and it is used in combination with a shunt regulator (SE431) with a 2.5-V reference voltage. Here R1 and R2 have nearly the same values (4.9 kΩ and 4.87 kΩ), so the output voltage is 5.05 V (2.5 V × (1 + 1.02)). To reduce the output voltage to 3.6 V, all you need to do is to reduce the value of R1 to 2.2 kΩ.

The result is exactly what you want. Before the modification, the meter indicates a power consumption of 4.3 W, and after the modification this drops to 2.7 W. This represents a savings of an impressive 37%, which amounts to around 14 kWh on an annual basis.

Can you take this even further? The answer is yes. In particular, it would be nice to be able to switch the device off entirely during idle periods. Of course, you could use a simple timer switch for this, but it has the same switching times every day and does not take weekends into account, not to mention summer and winter time. In another article in this issue, we describe an intelligent timer switch that does take weekends and summer/winter time into account and consumes almost no power. Thanks to its compact dimensions, it can even be built into the device it controls.

(090650-I)

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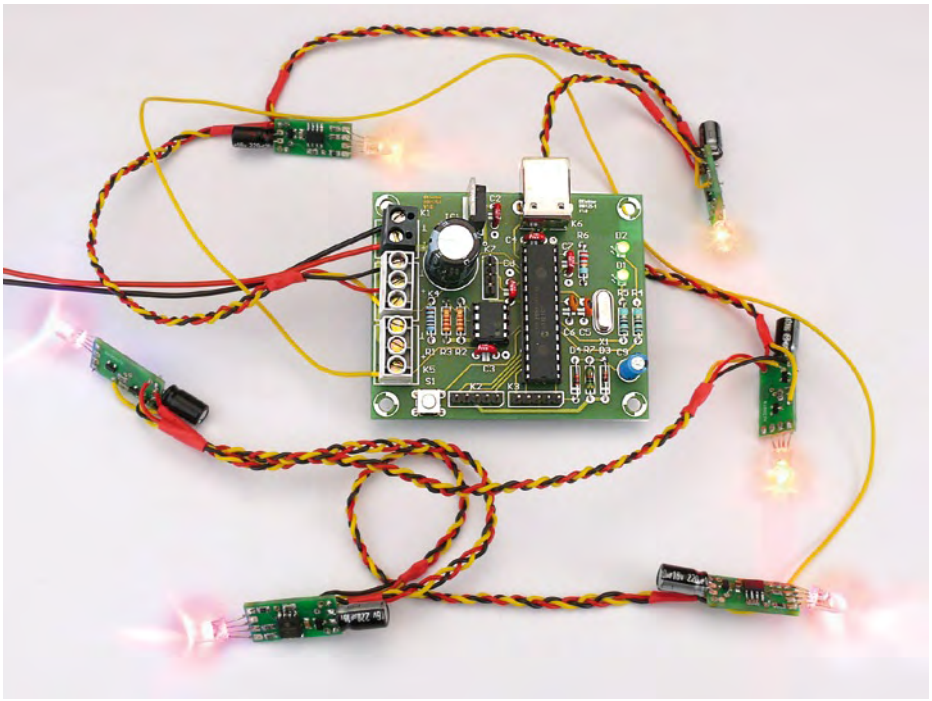
Advertisement

Top-of-the-Bill Lights Sequencer

Programmable fairy lights



By Boris Lecourt (France)

As Christmas approaches, rope-lights and fairy-lights are starting to appear in supermarkets everywhere. They're ridiculously cheap, it's true — but don't you think they're a bit short on originality? The project described in this article attempts to put this right, admittedly at greater cost, but what fun to build your very own Christmas lights, entrancing and totally unique — and what a fine present they'd make, too!

These lights let you produce the most dramatic lighting effects, by altering the countless available movement patterns (variable-speed chaser, random illumination, short or long flashes, etc.), and adjusting the color (32 levels), saturation (16 levels, including white), and brightness (24 levels) — that means over 10,000 possible color permutations!

Broadly speaking, the system consists of a master module that drives from 1 to 62 slave modules, identical in all respects (the 'lights'), with a 9 V PSU, supplying at least 2 A for 30 lights. The power supply is distributed to the master and lights in parallel (**Figure 1**).
The master drives all the lights over a single wire that carries a serial control signal. During the initialization stage, a return signal allows it to count the number of lights, which is then stored in the PIC's internal EEPROM. Thus this return signal is used only once in the fairy-lights' lifetime, and can then be disconnected, meaning that only one end of the string of lights has to be connected to the master module.
The master sends regular control signals to the lights to set the hue, brightness, and saturation for each light. The current master program runs through four types of multi-colored chase sequences and random colored or white flashes, but it's very easy to add others by programming the master's microcontroller.

The cost to build...

... is mainly affected by the price of the components forming the individual lights. By searching around on the Internet (for example, LEDs can be found on eBay for around 10 dollars for 50 pcs), the cost of each individual light can easily be brought below $5.00 (excluding PCB).

Hardware

The master module (**Figure 2**) consists of a 5 V regulator (IC1) and associated components, a PIC18F2550 microcontroller running at 20 MHz, and a reset circuit for the PIC (R7, D3, D4, and C9). It includes other sections for the extensions that are **optional**, and so **not yet implemented**:

- visual indicators (D1 and D2) to indicate the status of the master;
- a push-button (S1) for changing the movement pattern;
- a TTL-level serial port connector (K7) for communicating with the PIC;
- an EEPROM (IC2) for storing movement sequences;
- an analog input (K2) so the movement can follow the rhythm of the music — for example, by connecting a mic/amplifier circuit;
- a USB connector (K6) so the fairy-lights can be driven from a computer.

Only two pins of the PIC are needed to provide the interface with the individual lights. One pin configured as an output (CCP1) transmits the control signal to the first light via connector K4. One other pin configured as an input (CCP2) receives the

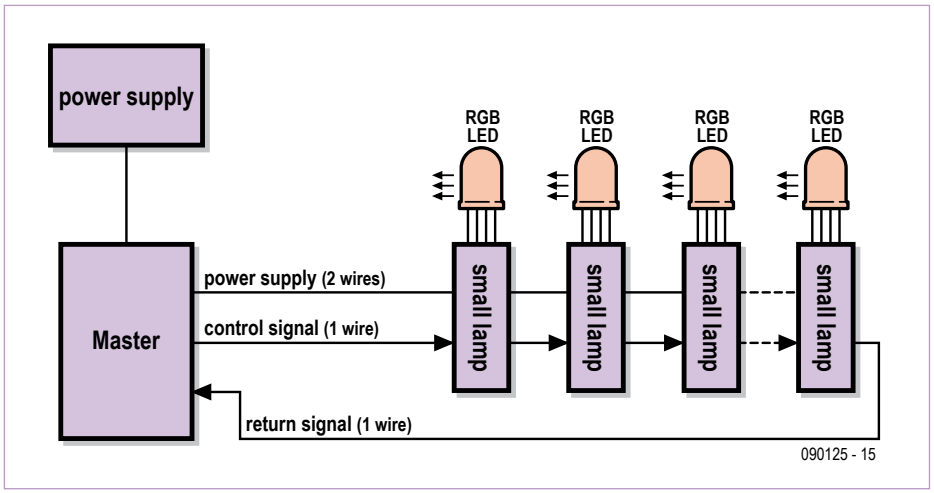


Figure 1. Block diagram of the light string.
You can connect up to 62 slave modules (individual lights).

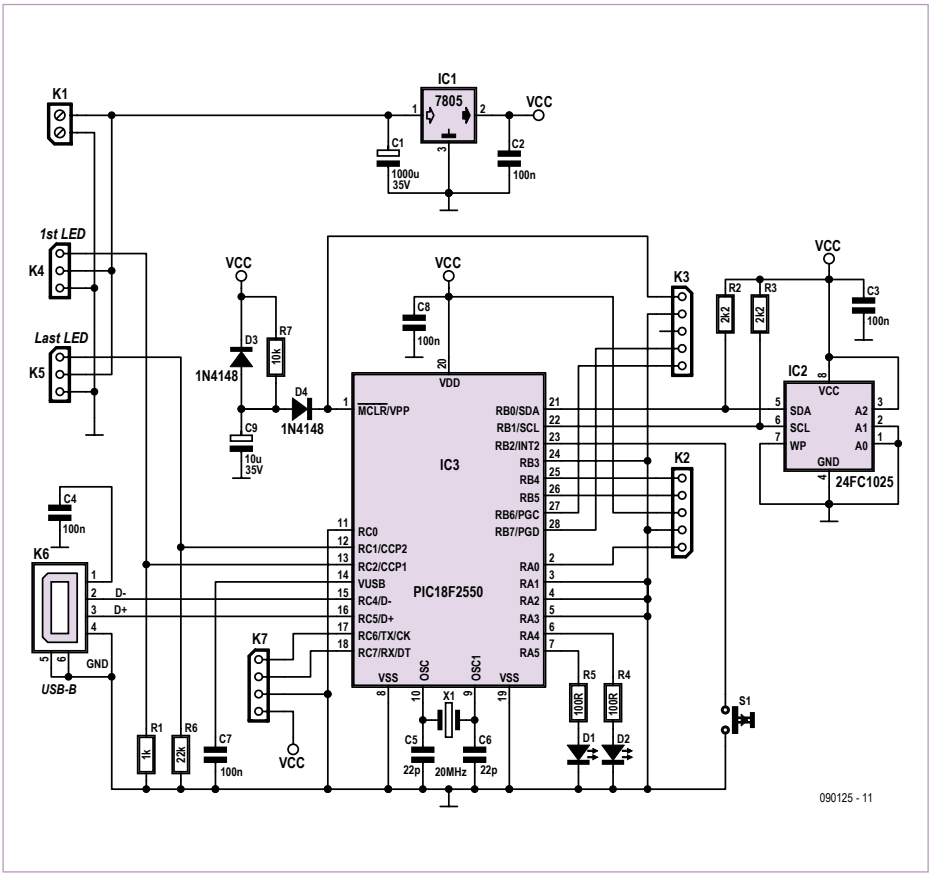


Figure 2. The master module circuit diagram.
The EEPROM IC2 could be used for storing sequences.

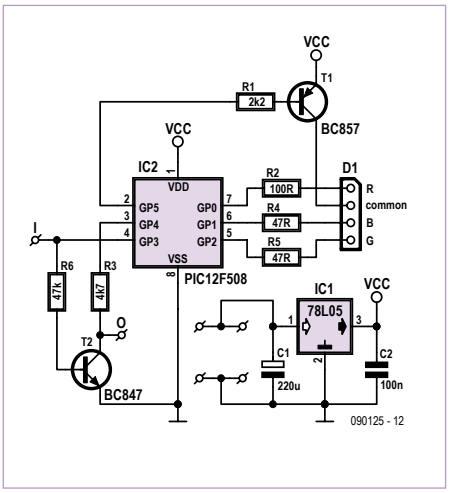


Figure 3. The circuit diagram for one of the lights. To be repeated 62 times, if you can afford it...

return signal from the last light via connector K5. These signals are pulled down to 0 V via resistors R1 and R6, for reasons which will be explained later.
Connectors K4 and K5 convey the power rail to all the individual lights in the string.

Circuit of the individual lights

Each individual light (**Figure 3**) consists of a small 8-pin 12F508 PIC microcontroller (IC2), a 78L05 5 V regulator, two switching transistors (T1 and T2), and an RGB LED (D1) with current limiting resistors. For better color rendering, you can matt the front of the LEDs using fine glass-paper, which helps improve the mixing of the R, G, and B color components.
All the input/output (I/O) pins of the PIC are used. Three pins GP0 to GP2 are configured as outputs and are connected to the LED's R, G, and B cathodes. A '0' on these pins allows current to flow in the LED elements. One pin, GP5, also configured as an output, is used for controlling all three elements together. It drives the LED anode via transistor T1, allowing a current of 60 mA to be switched, greater than the PIC output alone could handle (20 mA). PWM (pulse width modulation) signals from these pins make it possible to adjust the brightness of each element, as well as the overall brightness of the LED triad as a whole.

Pin GP3, configured as an input, is devoted to receiving the drive signal from the previous module (or from the master module, if this is the first module in the series). This signal is regenerated and inverted by transistor T2 before being passed on to the next module (see below). The collector of this transistor is fed from pin GP4 of the PIC, configured as an output. The function of GP4 is to be able to inhibit the signal sent to the next module when it is taken to 0 V. This function is used in the counting stage when the fairy-lights are first initialized.

The PIC and the LED are fed via the 5 V regulator, which can supply up to 100 mA, enough to light all three LED elements continuously at their maximum permitted current (20 mA each). This regulator is powered from the 9 V rail that comes directly from the master module's PSU.
We have designed PCBs for the master and slave modules, available from the Elektor website [1].

Software

The master module's PIC program was produced in C with the help of the MPLAB MCC18 compiler [2] (free version 3.21).
The PIC program for the individual lights was produced in C using the CC5X compiler [3] (free version 3.3A) which generates simple optimized assembler code that is very close to the C code.
The two pieces of software can be downloaded from the web page for this article [1].

All the ingenuity in these fairy-lights lies in the software, so it's considerably more complicated than the actual hardware itself. This software uses some interesting techniques that can be employed in other applications. Even though all the individual lights contain the same software, each light can be addressed individually, without needing to be configured first. The individual lights can be interchanged, or a failed one can be replaced, without changing the behavior of the string as a whole.

We're using this technique here to produce a string of fairy-lights, but by replacing the RGB LEDs with relays and using the appropriate hardware (and modifying the software, of course), you could easily produce, for example, a modular garden watering and irrigation system — or a home automation system for adjusting the lighting in the various rooms in your house. What's more, the master module can be expanded using a USB port, for example, or an EEPROM. So there's no shortage of potential applications.

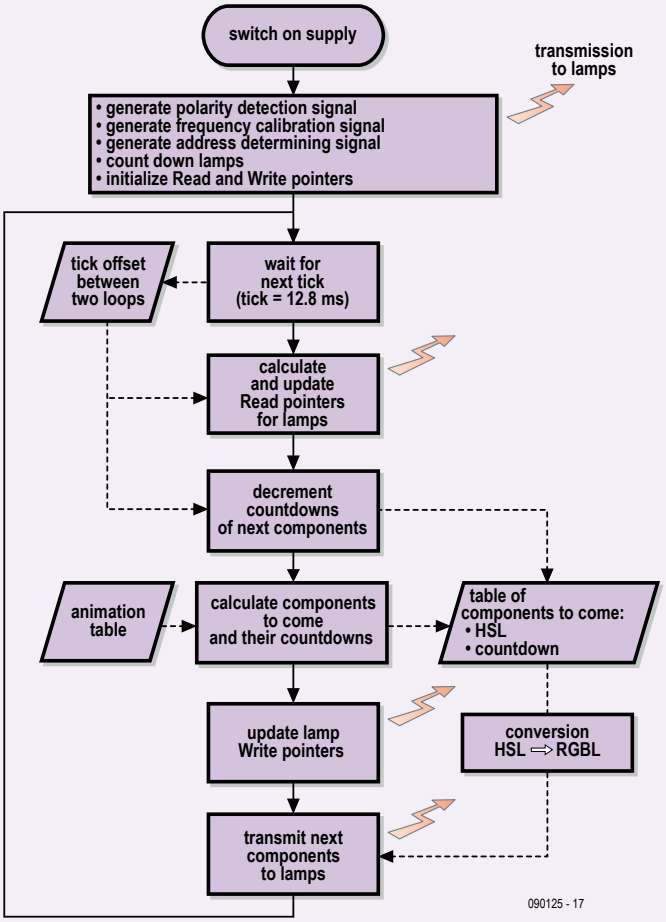


Figure 4. Flow chart for the master program.

So, how does this software work? Well, take a look at **Figures 4** and **5** for an overview, and read the following description carefully.

Initializing the light string

When power is first applied, the master and the individual lights start a 3-stage initialization process:
1. Polarity detection;
2. Frequency calibration;
3. Addressing and counting.

Polarity detection

This stage allows each individual light to determine if it is separated from the master by an odd or even number of other lights, in order to allow for the inversions caused by the T2 transistors in decoding the drive signals.

At initialization, the master PIC outputs are at high impedance, and so resistor R1 pulls the CCP1 output down to 0 V. The second light and all the others in even positions now detect a '1' on their GP3 inputs. Using a program variable that stores this polarity, these lights will from now on invert the GP3 input before interpreting it.
In the following explanations, we'll use 'N'

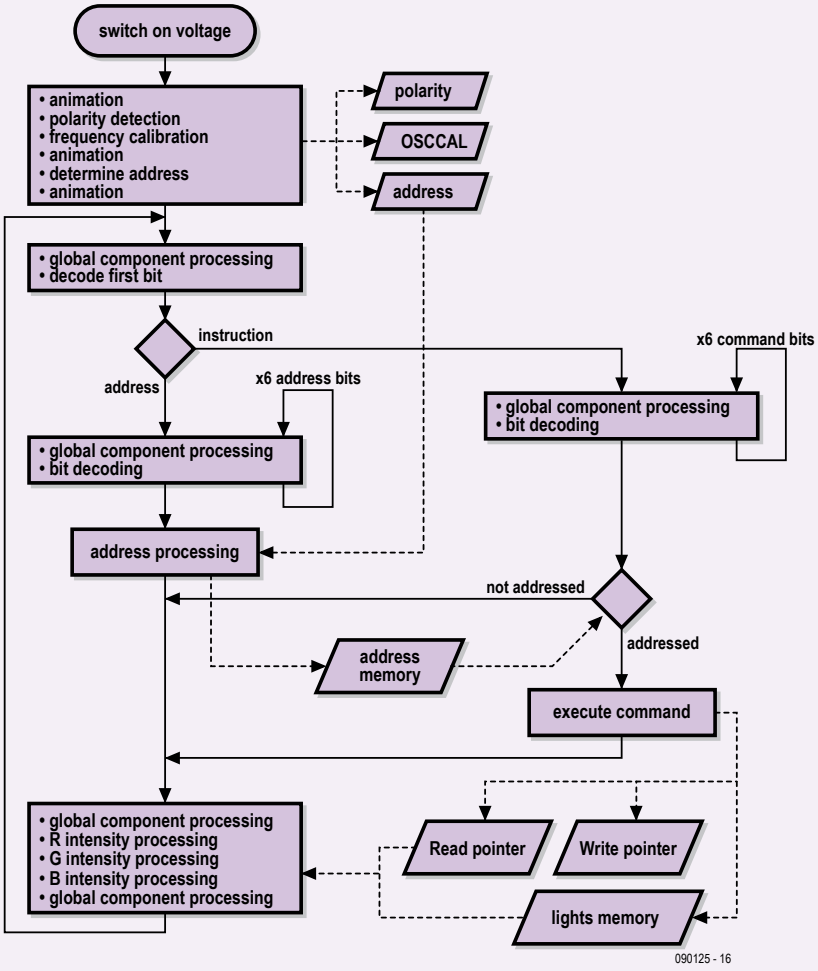


Figure 5. Flow chart for the lights program.

to describe a '0' (0 V) and 'P' to describe a '1' (5 V) on the GP3 inputs of the 'odd' lights (with no inversion of the CCP1 signal). The opposite applies to the even lights (with CCP1 inversion).

Frequency calibration

After detecting the polarity, each light waits for a P on its GP3 input. At this moment, the master starts transmitting a square-wave signal with a period of 200 µs for one second. At the same time, each light starts a process of measuring the period of the square-wave signal received on GP3 using the PIC's T0 timer register. Each time GP3 changes state, a measurement of the period is available to regulate the PIC's clock rate. This is achieved by adjusting the OSCCAL register so as to get closer to the measured 200 µs period. The process stops when the measured difference falls below a certain threshold. Lastly, to end this stage, each light waits for the master to settle the GP3 signal at N for longer than 130 µs.

Addressing and counting

After completing the preceding step, the master generates a sequence of 64 cycles of a square-wave signal identical to the previous one (**Figure 6**). The modules will then 'collaborate' so that each can determine its own address, in the following manner:

1. wait for a P on GP3;
2. wait a few microseconds for all the lights to detect this P transition;
3. enable (goes to 0) the GP4 inhibit output (through T2, which forces the following module's GP3 input to 0 V);
4. wait for two successive P/N transitions on GP3;
5. disable the GP4 inhibit output (goes to 5 V);
6. count the number of N/P transitions;
7. subtract this number from 63 to obtain the address.

If the end-of-string connector is connected back to the master module, the master too can count the N/P transitions on its CCP2 pin and in this way count how many individual lights the string has. It then stores this number in the PIC's internal EEPROM and will use it to drive the light-string sequences correctly. If the connector is not connected, the master counts zero lights, and in this event uses the value stored in its EEPROM.

Control signal

After the string has been initialized, the master module starts the sequencing. As the master only has one wire to carry its quite complex control signals, the communication protocol is also a little complicated.
The master can transmit over 1,000 words a second to the lights. A word is coded using seven bits. The value of the first bit indicates if the following six bits are an address (bit 1 = 0) or a command (bit 1 = 1). Each word is separated from the previous one by an 'End' marker. This marker makes it possible to re-synchronize any lights that might have got out of sync with the control signal.
Single-wire transmission is achieved by an asynchronous serial signal using a proprietary protocol. To transmit a '1' bit, the master module sets the control signal to 0 V for 30 µs, then to 5 V for 58.3 µs. To transmit a '0' bit, the master reverses these timings, setting the signal to 0 V for 58.3 µs, then to 5 V for 30 µs. To transmit the 'End' marker, the master sets the control signal to 0 V for 160 µs, then to 5 V for 20 µs. Hence the total period for transmission of an address or command word is 798 µs.

In order to decode this word, the individual light synchronize themselves by waiting for an N-to-P transition on their GP3 inputs. They then measure the duration of the P state using their T0 timers and deduce from this whether the master sent a 0 or a 1.

Address word

The A word (Address) enables the master to address up to 62 individual lights. The first

Table 1. Command word values and functions						
5	**4**	**3**	**2**	**1**	**0**	**Operation**
0	0	0	0	0	0	Set the component read pointer to memory 0
0	0	0	0	0	1	Set the component write pointer to memory 0
0	0	0	0	1	0	Set the component read pointer to memory 2
0	0	0	0	1	1	Set the component write pointer to memory 2
0	0	0	1	0	0	Increment the component read pointer
0	0	0	1	0	1	Increment the component write pointer
0	0	I3	I2	I1	I0	(I3 to I0) – 6 = overall intensity setting (0–9)
0	1	I3	I2	I1	I0	I3 to I0 = red component intensity setting (0–15)
1	0	I3	I2	I1	I0	I3 to I0 = green component intensity setting (0–15)
1	1	I3	I2	I1	I0	I3 to I0 = blue component intensity setting (0–15)

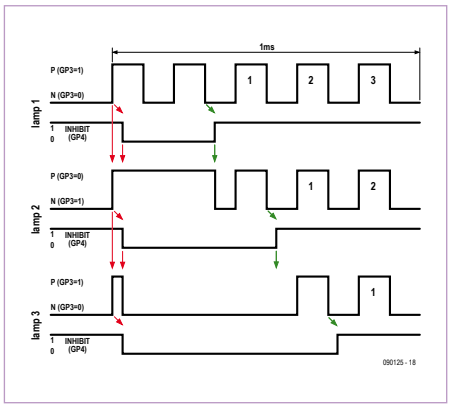


Figure 6. Timing diagram for the counting stage that enables each light to determine its own address.

light connected directly to the master has the address 1, the next has the address 2, and so on. Addresses 0 and 63 have special functions. Address 0 is used as a 'neutral' word that doesn't change the state of the lights. This word enables the master to provide a clock to the lights, which need this to be able to light up at the required brightness, even when there are no command or address words. Address 63 allows the master to address all the lights at the same time (this is a broadcast address).
As soon as a light has decoded its own address, it ignores any other addresses that follow immediately, and then executes all command words that arrive until the next address word is received.

Command words
Each individual light has four memory locations and two pointers that address them. Each memory location stores a set of four intensities, three for the RGB components and one for the overall component. These locations are addressed by write and read pointers. The master can move these pointers at will from one memory to the next, via six special commands (**Table 1**).

Four other commands enable the master to write an intensity value (from 0 to 15) for the RGB components and an intensity value (from 0 to 9) for the overall component into the memory addressed by the write pointer.

Table 2: R, G, or B component generation table.

BRI	COUNTER																															LEVEL
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	
0																																	0 %
1	1																1																6 %
2							1										1											1					9 %
3					1								1								1								1				13 %
4					1							1						1						1							1		16 %
5				1					1					1						1					1					1			19 %
6	1					1				1					1				1					1				1					22 %
7			1				1				1				1				1				1				1				1		25 %
8			1			1			1			1			1				1			1			1			1			1		31 %
9		1			1			1		1			1			1		1			1			1		1			1			1	38 %
10		1		1		1			1		1		1			1		1		1		1			1		1		1			1	44 %
11		1		1		1		1		1		1		1		1		1		1		1		1		1		1		1		1	50 %
12	1	1		1		1		1	1	1		1		1		1	1	1		1		1		1	1	1		1		1		1	63 %
13	1		1	1	1		1	1	1		1	1	1		1	1	1		1	1	1		1	1	1		1	1	1		1	1	75 %
14		1	1	1	1	1	1	1		1	1	1	1	1	1	1		1	1	1	1	1	1	1		1	1	1	1	1	1	1	84 %
15	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	100 %

The master moves the read pointer ('read' from the point of view of the individual lights) over a set of data it has previously written. In so doing, it selects this set as the illumination set-point for the light. By using the broadcast address 63, the master can change the illumination set-points of all the lights in the string at once, producing a simultaneous effect.

For example, to make the lights all light up red at the same time, the master can send the following words one after the other (assuming that at the outset, the individual lights' read and write pointers are at the first memory location 0):

A-3F: address word 0x3F, 63 in decimal, broadcast address,
C-05: command word, moves write pointers to location 1,
C-0F: sets overall components to maximum (9),
C-1F: sets red (R) components to maximum (15),
C-20: sets green (G) components to 0 (unlit),
C-30: sets blue (B) components to 0 (unlit),
C-04: moves the read pointers to location 1 (illuminated red).

Applying the illumination drives

The individual light modules generate the illumination drives by altering the chosen lit/unlit duty cycles of the LED elements. This generation takes place periodically in two cycles:

1. a 25.5 ms cycle for the RGB components and
2. a 798 µs cycle for the overall component.

RGB component generation cycle

Systematically every 798 µs, a light receives a command or address word from the master. Each time, it increases a counter that runs in a loop from 0 to 31. This counter, with the intensity set-point to be applied, enables it to step through a component illumination table (**Table 2**). If the table contains a 1, the light lights up the component by setting a 0 on the relevant GP0, GP1, or GP2 output. If the table contains a 0, the light extinguishes the component by setting the output to 1.

As this counter can take 32 values, the intensity set-point generation cycle has a period of 32 × 798 µs = 25.5 ms. As this duration is longer than the eye's 20 ms persistence of vision, this could cause a slight impression of twinkling. A number of choices have been made to reduce this effect:

- a minimum of two illuminations are carried out during the generation cycle and
- these illuminations are positioned in a specific way within the cycle.

You will notice that the intensity set-point is not exactly proportional to the element's illumination level during the cycle. This lets us compensate for the Weber-Fechner law [4] (stating that "the sensation varies as the logarithm of the stimulus") and allows our eyes to perceive an intensity that is substantially proportional to the set-point.

Overall component generation cycle

The successive operations (bit decoding, command execution) an individual light performs during the 798 µs word transmission cycle are broken down into nine segments by special processing devoted to generating the intensity of the overall component (**Figure 5**). At the start of the cycle, the light resets a counter to 0. At each step of the processing, the light sets the PIC's GP5 output to 0 (lit) if the counter value is lower than the intensity set-point, or 1 if it is higher. Each time, the light increments the counter by 1.

Combining the components

Combining the RGB and overall components lets us adjust the brightness over a wide range. This is particularly useful where a color is obtained from a mixture of two components, as in the case of orange, obtained by mixing the red and green components. A good orange color is obtained by setting the RGB components

Advertisement

COMPONENT LIST

Master module

Resistors
R1 = 1kΩ
R2,R3 = 2.2kΩ
R4,R5 = 100Ω
R6 = 22kΩ
R7 = 10kΩ

Capacitors
C1 = 1000µF 35V, radial, lead pitch 5.08mm (0.2 in.)
C2,C3,C4,C7,C8 = 100nF
C5,C6 = 22pF
C9 = 10µF 35V, radial, lead pitch 5.08mm (0.2 in)

Semiconductors
D1, D2 = LED, 3mm (see text)
D3, D4 = 1N4148
IC1 = 7805
IC2 = 24FC1025-I/P (Microchip) (see text)
IC3 = PIC18F2550 (Microchip)

Miscellaneous
K1 = 2-way terminal block, lead pitch 5.08mm (0.2 in.)
K2, K3 = 5-way SIL pinheader, lead pitch 5.08mm (0.2 in.)
K4, K5 = 2-way terminal block, lead pitch 5.08mm (0.2 in.)
K6 = USB-B socket for IC (see text)
K7 = 4-way SIL pinheader, lead pitch 5.08mm (0.2 in.)
S1 = pushbutton, 1 make contact (see text)
X1 = 20MHz quartz crystal, HC49/U case
PCB, ref. 090125-1 [1]

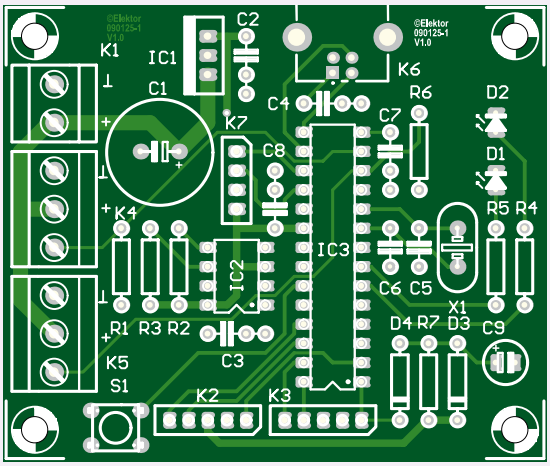
Miniature lamp (each)

Resistors (SMD 1206)
R1 = 2.2kΩ
R2 = 100Ω
R3 = 4.7kΩ
R4, R5 = 47Ω
R6 = 47kΩ

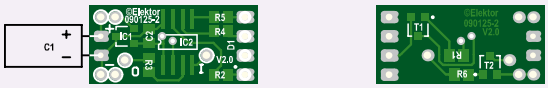
Capacitors
C1 = 220µF 25V radial, lead pitch 2.54mm (0.1 in.)
C2 = 100nF (SMD 1206)

Semiconductors
D1 = LED, RGB, common anode
IC1 = TS78L05CX, SOT-23 case
IC2 = PIC12F508-I/SN (Microchip, SOIC-150)
T1 = BC857, SOT-23 case
T2 = BC847, SOT-23 case

Miscellaneous
PCB, ref. 090125-2 [1]



Master module component layout.



Slave module layout, component side (left) and soldering side (right).

to 15, 6, and 0 respectively. By reducing these values moderately and proportionately (for example, to 10, 4, and 0), we can obtain a lower intensity without changing the orange color too much.
However, it becomes hard to reduce the intensity still further, as this would lead to a more drastic change in the color. The ratio between the perceived luminous intensities of the R and G components would depart too far from the initial value that gave us the orange color. To obtain a greater intensity reduction, it's better to act upon the overall component.

Just to finish off...

After reading the rather detailed description of the software, you may be feeling like a bit of a change. Well, make the most of that to wire up the lights — you've got another 62 to go!

Warning: the master module software published on the site works fine with around 30 lights, but has not been tested with a greater number — the limit will be related to the maximum rate at which commands can be sent out from the master module. And while you're trying to solder the SMD components, you'll be able to have a think about other applications for this dynamically-addressed 'single-wire' network (using four wires).

Send us your suggestions, and photos or videos of your fairy-lights, and we'll publish the best of them in a future issue and/or on our website.

Happy Christmas!

(090125-I)

Internet links

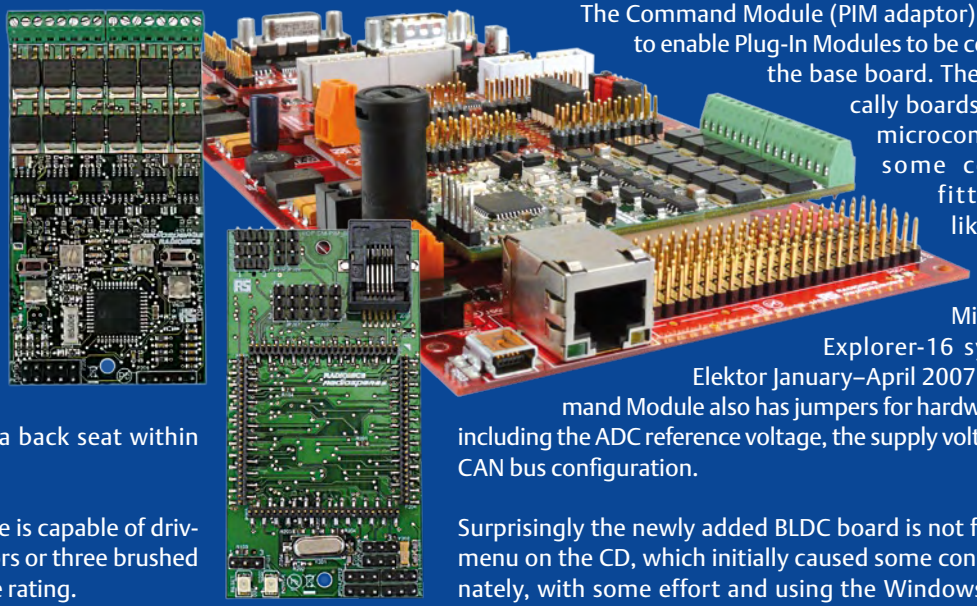
[1] www.elektor-usa.com/090125
[2] www.microchip.com/stellent/idcplg?IdcService=SS_GET_PAGE&nodeId=1406&dDocName=en010014
[3] www.bknd.com/cc5x/index.shtml
[4] en.wikipedia.org/wiki/Weber%E2%80%93Fechner_law

BLDC and PIM modules added to RS Components' EDP

By Luc Lemmens (Elektor Labs)

In our earlier encounter with the Embedded Development Platform (EDP) from RS Components published in the December 2008 issue it was already mentioned that RS had more modules in the pipeline for release in 2009. Two of these, the BLDC (brushless DC) motor controller and the PIM (plug-in module) adapter for Microchip MCUs recently arrived for review here at Elektor labs. Green boards this time, of solid build quality, ready to plug on to the 'stations' provided on the baseboard.

The RS EDP is aimed at the professional market where hardware cost is not so much as an issue as the hours engineers have to spend on getting turnkey embedded systems up and running, based on industry-standard microcontroller platforms like the ST ARM9 and Infineon XC167. The new PIM board allows engineers to build industrial, motor control and automotive applications around Microchip's PIC24, dsPIC33 and the latest PIC32MX devices — all of these are supported by vast amounts of ready to run code and in all honesty I would expect the Microchip MCUs to confine the ST and Infineon product to a back seat within the EDP.



The new BLDC module is capable of driving two 24V 4 A motors or three brushed motors with the same rating.

The problem with versatility

Although the EDP is based on a sound design concept that should go a long way, its very versatility may well turn out to be a point of concern. The growing number of processor engines available requires many modules to be 'rejumpered', or even PCB tracks to be cut and rewired to other pads on the board. For example, the DIO45 board (digital input/output) has no silk screen for the jumper configuration. If you want to do the 'jumpering' with any level of confidence, the settings have to be duly noted from a (hard-copied) page found in the manual, also using a table that's not at all simple to understand and interpret. From everyday experience I can vouch that this is fiddly work, fraught with pitfalls and mistakes are easily made, inevitably leading to tiresome faultfinding exercises or the odd whiff of PCB smoke if something is really amiss.

Instructions for use

The full documentation complement for the EDP is on a CD-ROM, which is not my favorite medium. The version number appears in small print; version 1.4 is the one describing the dsPIC and PIM adaptor. It appears however that the operation and use of modules has not been integrated into the system documentation (i.e. the base board and the plug-on peripheral modules).

The CD-ROM contains MPLab V8.20, however this platform has been updated a few times since the release of EDP and is currently at V8.36. Fortunately, the product is freely downloadable from the Microchip website. The installation of the IDE from the CD is not automatic — the software is in a .zip archive forcing a manual installation procedure.

Enter PIM and BLDC

The Command Module (PIM adaptor) is designed to enable Plug-In Modules to be connected to the base board. These are basically boards with just a microcontroller and some connectors fitted, much like the ones applied within Microchip's Explorer-16 system (see Elektor January–April 2007). The Command Module also has jumpers for hardware settings including the ADC reference voltage, the supply voltage and the CAN bus configuration.

Surprisingly the newly added BLDC board is not found in the menu on the CD, which initially caused some concern. Fortunately, with some effort and using the Windows Explorer a folder called Microchip_BLDC was found that contains all relevant documentation and software to get started with brushless motors.

Conclusion

Although RS have again underscored and extended the versatility of the EDP, the 'logistics' are not smooth and getting a brushless DC motor running using, say, the STR912 ARM9E CPU module and the Basic Communications module, is far more complex than the basic web server we succeeded in configuring in no time at all for the previous review using the launch version of the EDP. We are waiting with baited breath for yet more EDP modules like the NXP ARM Cortex, Bluetooth, WiFi and FireWire to see how easily these can be added to the system.

(090800-I)

Elektor Developers'

DEVCON #01

By Antoine Authier (Elektor Labs) &
Clemens Valens (Elektor Editorial France)

In line with its vocation as a platform for electronics technicians from all round the world, Elektor recently organized an international conference for developers: for two days, DevConf #01 brought 20 or so people together at Elektor HQ to consider new projects to be developed by and in Elektor. Half of these participants were external consultants or developers invited by the engineers of the Elektor laboratory.

In a relaxed atmosphere, the group, which comprised no less than seven nationalities, watched presentations by the external developers of their individual projects and their current concerns and work in progress. Each presentation was followed by a discussion, allowing the group to go further into points of particular interest, clarify certain details, and address related subjects.

GNU Radio

Martin Dudok van Heel, from the Olifantasia company, assisted by radio amateur Pascal Schiks, presented his work on open-source Software Defined Radio: GNU Radio [1]. Both are keen supporters of SDR and Linux. Martin's company distributes the Universal Software Radio Peripheral in Europe. The USRP is a hi-tech open project that makes it possible to receive any radio signal between 0 and 6 GHz, depending on the baseband demodulator installed. Two models of USRP exist, able not only to receive several channels simultaneously, but also to transmit.
The great advantage of SDR is the possibility of using the same equipment for all types of radio communication, since all the intelligence is in the software, and so it is programmable. An SDR lets you listen to the FM band, for example — but also to demodulate a cellphone or GPS signal. With SDR, you're all set for the future: when a new communication technique comes along, all you'll have to do to decode it is to load the appropriate software module. The tool that makes it possible to produce or modify the modules for SDR is GNU Radio, a powerful environment with a user-friendly graphical editor.
The power of USRPs combined with the flexibility of computers makes some interesting experimentation possible. It is, for example, possible to record the greater part of the whole VHF band. Of course, that takes up a lot of space on your hard drive — but it does let you record all communication channels and off-air (rare) or down-converted TV channels going on there at once, instead of just one. Perhaps more interesting is the ability to analyze the spectrum at leisure in the event of interference problems, in order to find the cause of the disturbance.

Martin also talked about passive radar, a subject he's very interested in. A passive radar does not send out pulses or other signals to listen to their echoes like a conventional radar, but instead uses the reflections of radio signals already present on the airwaves. It's a bit like the way our eyes use sunlight to build an image of our surroundings.

Telemetry for modelling

Michel Kuenemann has already published a number of articles in Elektor. His favorite subject is aeromodeling, particularly (larger) scale model aircraft with I/C engines; everyone

’ Conference Edition 01

remembers his model engine test bench published by Elektor [2]. For DevCon#01, Michel presented his new telemetry system designed for fine adjustments to an aerobatic scale model flown by one of his friends, an ace pilot. The difficulty with aerobatics lies in achieving perfect fluidity in the plane’s movements. What is already quite a feat for a pilot sitting in the aircraft can’t fail to be more difficult still for a plane controlled remotely. Michel is working on a system for recording key flight parameters, namely pitch, yaw, and roll, as well as speed and position. The system sends the data over a Zigbee link to the ground, where a receiver connected to a portable computer stores them on the hard drive. An application written in LabVIEW, the graphical programming and development environment from National Instruments (NI), displays the parameters in real time, making it possible to analyze them on the spot. The system also records the pilot commands so as to compare the actual movements of the plane with the movements requested by the pilot.

A change of pitch may, for example, cause an undesirable roll. The aim of this system is to distinguish disturbances due to the plane itself from piloting errors. If the plane is the cause, you can try to improve its aerodynamic properties. But if it’s the pilot, then s/he’ll need to train some more. And if it’s the weather — maybe you’ll want to consider changing to model railways!
Michel’s prototype comprises an ARM7 development board from Keil supported by LabVIEW for ARM [3]. The development kit for ARM7 was loaned to him by NI; Michel wouldn’t have been in a position to obtain one otherwise. The Zigbee communication is based on the MRF24J40MA device from Microchip. The prototype has already flown and is operational.

Household robot

Bart Huyskens trains future electronic technicians in Belgium and devises new teaching methods. Did you know that in Belgian secondary schools they hardly mention transistors any more? [4][5]. Now it’s all MOSFETs used for switching and op-amps as amplifiers. What’s more, all the projects are based

around a microcontroller or FPGA. Bart confirms this, and according to him, it’s working: the pupils are much more motivated. And what if they’re not wrong? (Yes, that’s throwing down the gauntlet, do send us your comments.)

Bart has developed an educational robot which he demonstrated to us rather successfully.
Cased in Perspex, Bart’s robot can speak and is obviously stuffed with electronics: ultrasound transducers for measuring distance, optical detectors for following a line marked on the ground, multi-colored LEDs to make a mouth and eyes on his very expressive articulated head, and a little red laser just for fun. If it wasn’t in the middle of his forehead, it could have been used as a willy.
The creature moves around on two motorized wheels. Everything is controlled by several microcontroller boards, which might seem like overkill, but Bart wanted to make a modular robot, so that each stage of the construction brings its own share of excitement.

Metal detector and digital oscilloscope

Tomasz Kwiatkowski presented his numerous projects, among them a metal detector and a digital oscilloscope.

It's amusing to note the extent to which a subject as trivial as metal detection arouses the interest, even passion of participants who till then had been fairly quiet. Quite spontaneously, the discussion veered off onto the likelihood of miscellaneous objects' disturbing a magnetic field in a supposedly uniform environment. Even SDR was mentioned as a possible tool!
On certain points, Tomasz's oscilloscope ties in with the acquisition principle of Martin's SDR (here we go again!) and the Laboratory is already working on a cheap, flexible acquisition board which will let you... shush!... you'll find out soon enough in these pages.

ATM18: new developments

Detlev Tietjen, who has recently joined the CC2 project (Computer:club² in Germany [6]), presented his latest ideas, and more specifically, the improvements he plans on making to the ATM18 module. A new 'small but powerful' board should soon be unveiled, and will in particular make it possible to experiment with and understand the mechanisms of the USB bus: emulation of keyboards, mice, HID (Human Interface Device) peripherals, etc. Making 'on-the-fly' password coding secure (an obsessional issue in Germany) will also soon be tackled. We had a long discussion too about a weather station we hope will soon be seeing the light of day (or the sunshine).

Then we laid down the bases for a microcontroller with a BASIC (Beginner's All-purpose Symbolic Instruction Code) interpreter that's cheap and easy to reprogram *in situ*, intended for 'occasional household tasks'; watch this space...

Art in Electronics

Another of our faithful retainers presented his baby called Sceptre, a multi-function board around an ARM7 heart, on a confetti of silicon, stuffed with peripherals and equipped with Bluetooth technology and little surprises, which should be occupying our readers in the depths of Winter and for some time afterwards. Patience, Hard Thing! (after G.M. Hopkins)

After a brilliant introduction on the subject of Arduino boards [7], Peter Groen presented for us his projects derived from this easy-peasy development tool particularly popular with artists. His creations are on display in Groningen (Netherlands) in the form of two successful artistic presentations. Here, we'll just mention the Morse Poet: at nightfall, certain of the city's prominent buildings light up intermittently, calling out to each other with dreamlike speeches (in silent Morse code!)
Peter is also working on the installation of a Fab Lab [8] in the city of Groningen. These creative workshops, originating in Boston's renowned MIT, allow anyone who will share their works free use of a 3D-printer as well as a number of other pieces of expensive and often inaccessible equipment. Practical, instructional, Fab Labs enable students to innovate.

Is there going to be a DevCon#02?

During this conference, we tackled numerous subjects and discussed at length various aspects of technology and its evolution in our magazine. We are giving consideration even more actively not only to putting these developments into practice, but also to the conditions for sharing them (just as in the world of free software). The goal to be achieved would be to eventually offer Elektor readers each month fewer single-purpose projects than modules designed to be re-usable, like building blocks. Following on from the success of this first DevCon#01, the challenge to which we need to rise is to get new generations interested in electronics. Maybe the subject of DevCon#02 will be how to get the older generations interested in modern electronics — or vice versa!

(090821-I)

Internet Links

[1] gnuradio.org
[2] Automatic running-in bench, Elektor nos. 370, 371, & 372 (2009)
[3] www.ni.com/arm/f/
[4] www.sjs.be
[5] www.rtc-antwerpen.be
[6] www.cczwei.de
[7] arduino.cc
[8] fab.cba.mit.edu/

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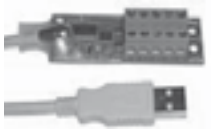

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Christmas Holidays Circuits

Nicely timed for the Festive Season we present a compilation of circuits that make excellent workbench projects for the odd 'learn-while-U-tinker' hours you should be able to claim for yourself this December. Most of the parts used in the project we reckon may be in your junkbox or hidden in a cupboard or in a box in the attic or cellar. Good instructive stuff for the Christmas holidays period. Have fun!

Bat detector

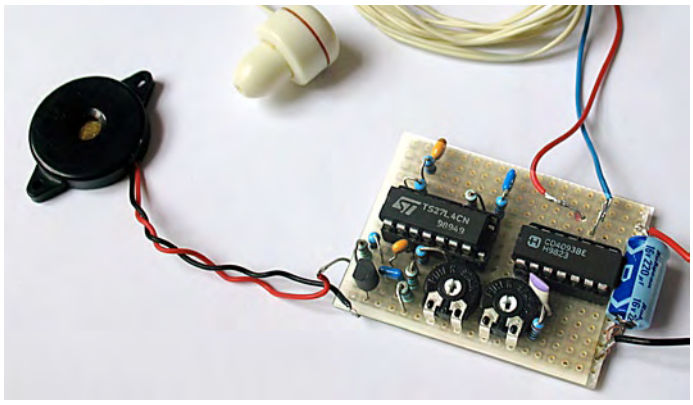
By Thomas Scarborough (South Africa)

Bats are truly amazing creatures. Even in pitch-darkness they can still sense their surroundings by first producing a sound burst that's inaudible for humans and then listening to the reflections – a technique humans have mastered only relatively recently using electronic equipment called radar. The bat's brain then forms a picture detailed enough to recognise any form of potential food. To gain a little insight into the life of a bat the author has developed a bat detector. It almost seems as if the bats thought being a flying mammal wasn't enough to make them stand out. Their ability to 'see' with their ears works so accurately that it allows them to find their way in the dark of night and hunt for the tiniest of mosquitoes. As David Attenborough would say: stunning!

As already mentioned we can't hear the sounds produced by bats, since the frequency lies far above the upper limit for humans. A bat creates clicking sounds (burst) with a frequency between 12 and 150 kHz, in rapid succession with a rate between 20 to 100 times a second. The exact parameters depend on the species.

To convert these clicking sounds into something audible, you'll need a bat detector. In contrast to other designs, the project straightforward and compact; nevertheless it works perfectly.

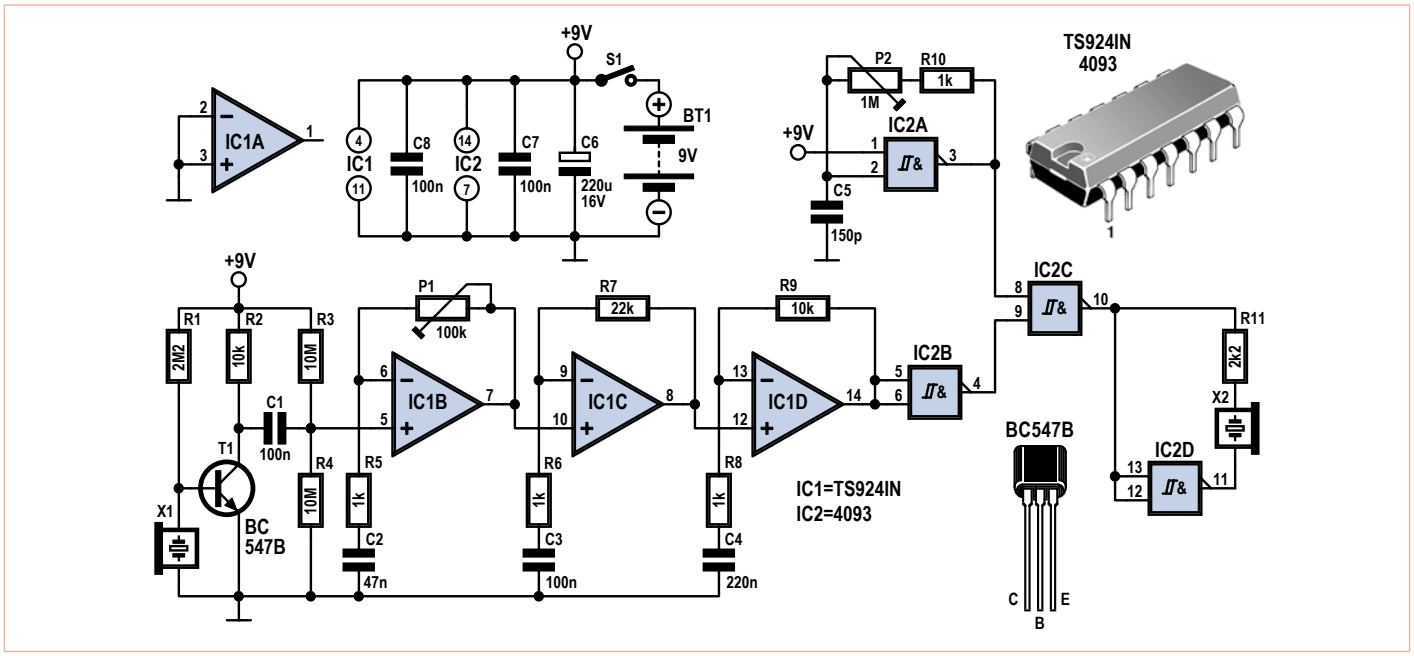
When Thomas tested his detector for the first time, he was startled by the sheer volume these animals produce. It almost seems as if the bats were screaming their lungs out!



Regardless of volume, this circuit itself can handle the full bat sound spectrum. The only limiting factor is the microphone, for which Thomas 'misused' a so-called 'piezo-conetweeter'; a piezoelectric high-tone loudspeaker with a cone shaped membrane (as shown in the picture). A similar loudspeaker can pick up sound waves with frequencies up to 50 kHz, which is adequate to detect most species of bats.

You could also experiment with a common piezo buzzer (as shown in the picture of the pre-built prototype) or with a piezo-horn tweeter. It worked for Thomas, so it should be worth a try.

Two methods exist to convert the ultrasonic bat sounds to something audible. The first simply compresses the ultrasonic sound spectrum between 20 and 100 kHz to an audible range (for exam-



Bat 'transmit' frequencies	
Greater horseshoe bat	83 kHz
Lesser horseshoe bat	95–125 kHz
Whiskered bat	30–80 kHz
Natterer's bat	30–80 kHz
Dauberton's Bat	30–80 kHz
Greater mouse-eared bat	30–70 kHz
Bechstein's Bat	30–80 kHz
Common Pipistrelle	40–45 kHz
Serotine bat	25–80 kHz
Common Noctule	15–50 kHz
Barbastelle	30–70 kHz
Brown long-eared bat	15–50 kHz
Grey long-eared bat	15–50 kHz

ple, covering 2 to 10 kHz). In other words, it maps all the high frequencies to a range which is audible to humans.
A less complicated method — from a technical point of view —in the present design relies on the interference patterns which appear after mixing a frequency generated by an oscillator with the frequencies emitted by the bats. The resulting signal is composed of frequencies of both the sum and difference of the two input waves, like in superheterodyne receivers. So let's assume we pick up a constant tone of, for example, 40 kHz while the oscillator is set to 35 kHz. The mixer output signal will be composed of two frequencies: 5 kHz (the difference) and 75 kHz (the sum). The latter one is still inaudible, since it's outside our hearing range, but we'll hear the 5 kHz note without any problem. Using this approach, it's essential to set the oscillator to a fixed value which produces audible sounds after the mixer.

The circuit

Now for a more detailed approach. First, the bat cries picked up by microphone X1 (or, in our case, the piezoelectric tweeter), get substantially amplified by three opamps, IC1B, IC1C and IC1D. The circuit gain is controlled by preset P1 acting as a potential divider.
The three opamps are all housed in the same IC, the type TS924IN to be precise. This chip contains a total of four opamps. Since the fourth opamp (IC1A) remains unused in this circuit, its two inputs are connected to ground to ensure the component stays inactive.
After the amplification process, the signal gets fed through NAND gate IC2B, where it essentially gets NANDed with itself, the upshot being that it's turned into a neat square wave. Next, the signal is mixed in NAND gate IC2C with the adjustable frequency generated by oscillator IC2A and its surrounding components. The NAND function of this gate causes the difference of the two frequencies to appear on the output, which is then fed to the earpiece (X2). Hopefully, this process has produced a frequency within the audible range.
The remaining gate of the CMOS IC 4093B, IC2D (which, again, contains four separate gates) is used for a nifty technical trick. The gate is used to invert the signal at the other side of the earpiece. This trick essentially doubles the sound volume, because it makes the membrane in the earpiece move both inward and outward relative to its quiescent state. Without this trick, the membrane would only move in one direction; either constantly to the inside, or constantly to the outside, depending on the polarity of the earpiece.
The use of an earpiece like the one in the picture is highly recommended. The superheterodyne principle on which the circuit is based is quite sensitive to acoustic feedback between the microphone (X1) and loudspeaker (X2), which could cause a characteristic screech in the sound. This sensitivity is mitigated by placing the sound source straight in to the ear (hence the name earpiece). Another way of reducing the feedback issue, is to increase R11 (which is used for current limitation) to 1 megohm or to place the microphone X1 in a cylinder (a piece of PVC tubing for example). The latter solution even makes a kind of directional microphone!

Calibration and practical use

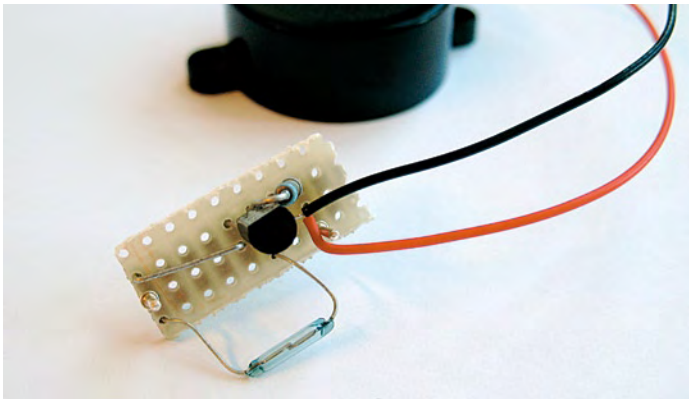
The calibration doesn't necessarily require a bat as a test subject. Your own voice creates inaudible high frequencies (which can be heard by cats) whenever you produce a 'sssssh' (like in the word 'shell') or a 'psssst sound. The higher harmonics which are then produced can be used for the calibration of the circuit when in a quiet environment. Even snapping your fingers or rubbing dry hands together produce ultrasonic waves!
Connect the power supply, keeping in mind that the circuit requires approximately 10 mA, which can easily be supplied by a 9 volt battery. Then insert the earplug in your ear. Make sure P1 and P2 are set at maximum resistance, so both the volume and oscillator frequency are at their lowest. Now keep turning the sensitivity potentiometer P1 until the higher harmonics (which can be produced as indicated above) can be heard clearly. This allows the bat detector to be calibrated with relative ease. Anyone who wants to go the extra mile can fine tune the circuit by holding it close to an old cathode ray tube TV. Parking radars on cars are also known to produce ultrasonic sounds.
Now the hunt for bats can begin! But please bear in mind that bats aren't the only creatures to emit ultrasonic sound bursts in nature. A wide variety of animals like birds or crickets also produce ultrasound waves. To make sure you're really hearing a bat, you need to point the microphone at a flying bat. You should then hear a rattling or clicking noise. If the results are poor, potentiometer P2 might need some adjusting.
It should be noted that bats are protected animals in most countries, so never disturb them in their natural course of action!
One last tip: the detector described here can be used to listen to many other sources of ultrasonic sound. For example, it can aid fixing a bicycle tyre by locating the leak! Gas escaping through a narrow exit also produces ultrasonic sound.

(i-00553)

Back door alarm

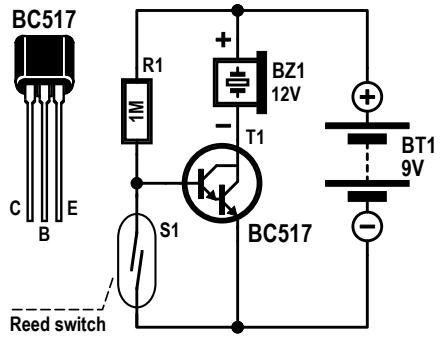
By Ton Giesberts (Elektor Labs)

Although common sense repeatedly tells us that inanimate objects can't move by themselves, it sometimes sure seems like they do. No matter how sure you are that you closed the back door, it will always find a way to sneak back open and let the cold air in, which is unacceptable in winter time considering the low temperatures outside and energy prices. Not to mention the lengthy discussions arising from a simple question like "Honey? Did you close the back door?" Both rea-



sons, and others, prompted the Elektor lab to find a solution. This simple yet effective circuit solves all these problems with a mere four components (well five if you count the battery), as shown in the diagram.
The circuit can be fitted in a small ABS casing, which would ideally contain a space for a 9 V battery, and should be located on the door frame. Next, you will need to attach a small but strong magnet to the door itself.
The sensor of this circuit is based on a reed switch. That's basically a switch which only conducts when placed within a sufficiently strong magnetic field. The presence of the magnetic field caused by the magnet on the door is detected by the circuit, causing it to buzz or to remain silent. Although it will probably take some experimentation to get the magnet at the correct distance from the reed switch so that the alarm will go off if the door is even the slightest bit ajar, this is always possible.
We selected a reed switch instead of a micro switch because the latter requires physical contact to influence current, while a reed switch doesn't. As long as the door is closed, the magnetic field will cause the reed switch to conduct, which causes the base of the transistor to be connected to the negative pole of the battery. Consequently the Darlington transistor blocks all current through the buzzer causing it to remain totally silent.
As soon as the door opens, the distance between the magnet and the reed switch becomes so large that the reed switch stops conducting, causing the base of the Darlington transistor to be effectively disconnected from the negative pole. Even though R1 has a very high resistance, it nonetheless conducts enough current to activate T1, causing it to conduct, which in turn causes the buzzer to emit sound.
A Darlington transistor was selected for this circuit because of its ability to considerably amplify currents and because of the very small current it needs to start conducting. This allows R1 to have a very large resistance so only a small amount of current is used when the door is closed (which means that S1 conducts current). This can be proven using Ohm's law: I = U / R = 9 V / 1 MΩ = 9 µA. The upshot is that a simple 9 V battery will last for months!
We decided to use a 12 V piezo buzzer in this circuit (and, to be more precise, a CEP-2260a in our prototype), which emits a loud tone and seems to work fine at 9 V and below. You can basically use any buzzer which works at 9 V, provided it doesn't consume too much current. Do not attempt to use a buzzer that draws more than a few milliamps. When the buzzer is activated, the current rises from 9 µA to approximately 4 mA.
Due to the simplicity of this design, you could easily omit the prototype board altogether and just solder the components directly — although having a circuit board does look more professional. Technically speaking it doesn't change the fact that this circuit will work like a charm.

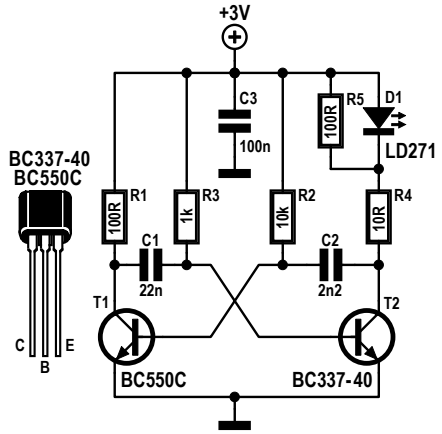
(i-00656)



Poltergeist

By Ton Giesberts (Elektor Labs)

Sometimes, and luckily on the rarest of occasions, our in-house designers suddenly stop being serious and start mucking around a bit. The result, which always ends up on editors' desks, is usually pretty neat, most of the time plain weird, hardly ever useful or even practical, but invariably fun to build. This Poltergeist is one of those projects. It's the perfect circuit to give your roommates the payback they so justly deserve.
The vast majority of modern remote controls for televisions employ an infrared signal (the versions which work with ultrasound have all but disappeared). The remote control normally contains an oscillator which produces a square wave (the carrier signal) with a frequency between 33 and 40 kHz. One commonly used standard is called RC5; this uses a 36 kHz carrier signal. Information is carried by switching this signal on and off in a predefined manner. This method of modulating information is called AM (Amplitude Modulation) and uses a 'modulation depth' of 100%. The resulting signal is used to pulse an infrared LED, which radiates the signal through space right up to the TV set. The television set contains an infrared detector which reacts to carrier signal so the information can be received and recovered.
So, what if you create a circuit which constantly sends a signal with a frequency of 36 kHz, and point it in the direction of the IR detector on the front of the television set? Since the television is constantly receiving a signal, any signal sent by a real remote control will be jammed so it won't show up! The decoder in the television won't be able to differentiate between the two signals, causing it to stop reacting to the commands sent by the remote control. This is our Poltergeist's evil master plan.
The circuit is quite simple. Transistors T1 and T2 are part of a regular astable multivibrator. Its workings aren't that hard to understand. If T1 is in its conducting state, the voltage on the collector drops to 0 V. This change in voltage is passed through C1 to the base of T2, causing this transistor to stop conducting. In this state, current flows



to C1 through R3, eventually allowing the voltage across the capacitor to rise high enough to open up T2 again. This, in turn, causes the right side of C2 to be pulled down by T2, which causes T1 to block all current, allowing C2 to be charged by R2 until T1 starts conducting again, leaving the cycle right where it started. This goes on for all eternity. Well, at least until the battery dies...

We chose a standard transistor, type BC550, for T1. T2 is a slightly more powerful device type BC337, which can handle currents up to 500 mA (or 1 A for short periods of time) allowing it to switch the relatively high current (150 mA at 3 V) through the infrared LED D1.

The frequency of this simple oscillator can be calculated using the R-C time. If R2×C2 equals R3×C1, the time the transistor conducts theoretically equals R×C×ln2, where ln2 is the natural logarithm of 2.

A low battery voltage and the voltages at which the transistors switch can mess things up a little. This causes the frequency to vary with a changing voltage. The threshold voltage of D1 also exerts some effect, though this is more or less compensated by R5, which sits in parallel with D1 and improves the charging of C2.

The following table gives an impression of the change in frequency in our prototype:

Power source voltage U (V)	Frequency f (kHz)
2	29.8
3	31.8
4	33.6

The required current is highly dependant on the supplied voltage, as can be seen in this table:

Power source voltage U (V)	Current I (mA)
0.8	7
1	10
1.5	23
2	47
3	97
4	147

When the voltage drops below 0.8 V, the oscillator becomes unstable. We also recommend not using a voltage higher than 4 V. Two AA batteries are ideal, although a small wallwart (AC power adapter with DC output) could also be used.

A circuit like this is very open to experimentation. By changing the value of C2 to 1.5 nF, the frequency becomes exactly 36 kHz, when using a power source of 2.5 V. Furthermore, if C1 is changed to 18nF, the frequency becomes 40 kHz between 3 V and 4 V, which is exactly the frequency Sony uses in their remote controls. The current consumption can be limited by changing the ratio of the two capacitor values. If the ratio of C1 and C2 is increased, the pulse through D1 becomes shorter. In other words, the duty cycle is shortened.

We tested this circuit in the lab at a frequency of 40 kHz. The Poltergeist was placed at a distance of 3 m (10 ft.) from the television set. The remote control didn't show any sign of control when used at a distance greater than about two metres (7 ft.).

This Poltergeist can be improved by using a higher voltage than 3 V, or by replacing the LD217 (D1) by an LD274. The latter creates a more focussed bundle of light, creating a more intense beam. The Poltergeist will need to be directed more accurately though.

The construction of the circuit is pretty much self evident. The whole circuit can be built in half an hour on a piece of prototyping board, as is shown in the picture. Oh, and remember: a little teasing is fun, but don't take it too far!

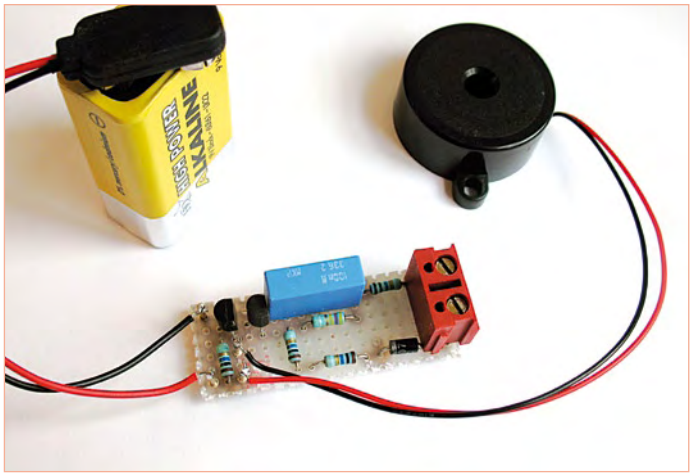
(i-00683)

Power cut alert

Apart from the icecaps melting, the ozone layer vanishing and crazed meteors crashing into us, there's still one thing you can rely on, at least in most countries: the national power grid. Or can you? Even in these days of technology, power cuts happen more often than most people realise. Depending on when you get round to figuring out what's wrong, the consequences usually vary from finally getting a good night's rest due to your alarm clock failing, to finding your prize turkey defrosted and dripping goo in the freezer. If you don't like a good night's rest or if you really like turkey, this circuit might be something for you.

Whatever the case, you'll always discover the truth too late (a statement which can be inferred from Murphy's Law). To prevent problems from occurring due to a power cut, this power cut alert has been made. The circuit continually keeps an eye on the AC grid voltage and gives an acoustic alert when it drops below 50 V or so for more than a second roughly.

The circuit is very simple. In fact, it actually isn't more than a potential divider connected to a buzzer. The divider, which consists of the resistors R1, R2, R3 and R4, reduces the voltage from the AC grid to a voltage which can be handled by the rest of the electronics. The circuit is designed for 230 VAC, so readers on 110-120 V grids have to redimension the components accordingly. Diode D1 rectifies half of the alternating current so the circuit is fed with a 'kind-of' DC signal (pulsing).



Under normal circumstances, the voltage across R3 is high enough to keep T1 in conductance. The gate of T2 receives a too small voltage to keep this MOSFET conducting so no current from the battery can flow through the buzzer, resulting in silence.
As soon as the national (or state) AC grid voltage drops below 50 V, the voltage across R3 drops below the threshold needed to keep T1 in conductance. When this happens, the voltage at T2's gate becomes high enough (through R5) to start conducting. Now a current can flow through the buzzer by way of T2, causing a loud tone, indicating that a power cut has occurred.

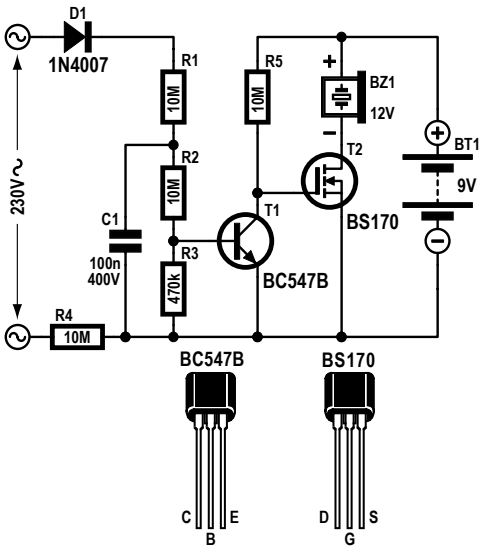
The details

We chose a value of 10 MΩ for the resistors of the potential divider (R1, R2 and R4) because these are widely available. Make sure you get resistors which can be used at voltages of at least 350 V! With a total resistance of 30 MΩ, the maximum current passing through these resistors is roughly 10µA, which is negligible. The value for R3 is 470 kΩ so the circuit kicks in when the AC grid voltage drops below 50 V. Because the power coming from the grid is alternating current (AC), the voltage drops below the threshold 50 times (or 60 times) a second. We don't want the circuit to respond to these perfectly normal dips, so that's why C1 was added. This capacitor causes the circuit to react if the voltage has been low for longer than a second only. Keep in mind though, that this capacitor is also directly connected to the AC grid. Therefore, it must be capable of handling voltages of at least 400 V. T1 is a standard NPN transistor. For T2 we chose a MOSFET to allow R5 to have a high resistance (10 MΩ). The current which runs through the circuit in normal circumstances (when T1 conducts) is just 1 µA, allowing the battery to stay good for years. It's best to use a normal battery instead of a rechargeable one, since rechargeables are subject to much greater self discharging. If a normal BC547 would have been used for T2, the resistance of R5 would have needed to be lowered to about 47 kΩ, causing the required current to increase by 0.2 mA!
The buzzer in our prototype is a CEP-2260A, which draws just 5 mA at 9 V. If we assume a battery capacity of 500 mAh, the circuit can buzz for four whole days. 12 V buzzers which draw 50 mA are also available, but the use of them is discouraged.

The construction

The circuit can be built on a piece of prototyping board of just a few square centimetres, but keep in mind that the whole circuit is at AC grid potential. Mistakes in the assembly could have life threatening consequences!

At the very least, the circuit needs to be made safe to touch, by encasing it in a proper ABS housing. Furthermore, the AC power line connector may NOT be directly soldered to the circuit board. It needs to be connected through a terminal block, with a distance of at least 5 mm (0.2 inch) between the terminals. All the copper pads need to be removed around all pads which are connected to the AC grid voltage (and around the resistors R1 and R4) to ensure an uninterrupted electrical isolation distance of at least 3 mm (see the picture of bottom

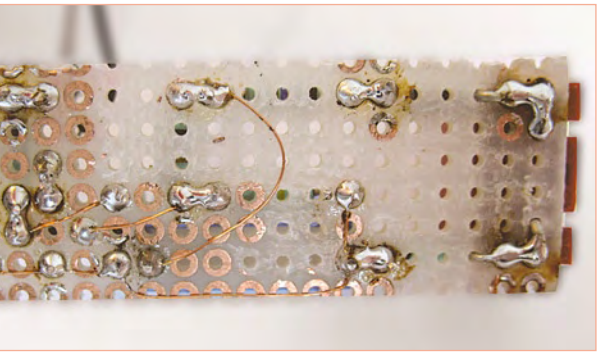


of the prototyping board). Here we should repeat that it is critical to use resistors which can handle voltages up to 350 V for R1 through R4, and a 400-V rated capacitor for position C1.
The power cut alert can be tested after construction by plugging it into the AC power outlet, and then by pulling the plug again. The buzzer should produce a loud noise.

Remember: Never change the battery while the circuit is still connected to the AC power line!

All now all that's left is a good night's rest, and a tasty turkey!

(i-00705)



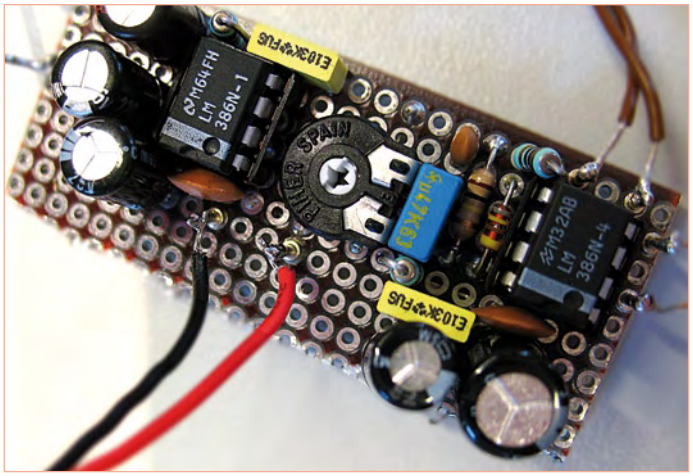
Mini radio gives maxi sound

By Thomas Scarborough (South Africa)

The author was introduced to a very well kept secret, which he will pass on to you through this article... if you promise to keep quiet about it. The secret tells the story of certain audio ICs which double as excellent AM radio receivers. In the circuit we are about to show you, the author has (mis)used the well known amplifier IC LM386N (although it's perfectly reasonable to misuse the LM380N and CA3130E too) for this exact purpose, resulting in a simple, minimalist AM radio receiver with an unexpectedly high sound quality.
In principle, the only things you need to receive an AM radio station are an inductor, a variable capacitor (for the tuning), a (germanium) diode and a crystal earpiece. The inductor and the capacitor create a resonant circuit which is set to the frequency you want to receive. The diode detects the presence of an audio signal, which is then made audible on the earpiece. The beauty of this design is that it allows you to receive two or three strong stations (if you're lucky) with nothing but a long wire antenna and a decent earth connection. You don't even need any transistors or batteries!

The drawback of this solution, however, is the very low sensitivity. Though this is nothing a little amplification won't fix. Fortunately no special high frequency transistors or ICs are required to accomplish this. All you need is a handful of parts available to almost every hobbyist to create a mini radio which produces enough sound to thoroughly annoy your neighbours...

The heart of the receiver is easily recognisable in the left part of the schematic. The resonance loop is built from L1 and C1. The loop resonates to the tiny electric field which is picked up by the antenna, producing a small voltage. This voltage is fed into IC1 for further amplification.
The combination of D1, R3 and C6, which are connected on the output of IC1, take care of the demodulation of the high frequency signal. Basically, the high frequency carrier wave on which the actual information (the audio signal) is modulated using a changing amplitude, is short circuited by C6, leaving nothing but the low frequency audio signal, which is what we want. Actually, D1, R3 and C6 aren't really necessary, since IC1 already achieves a certain amount of demodulation, although the extra parts do contribute to a noticeable higher quality of output signal. Because of the amplification in IC1, you don't need to use a diode with an extremely low voltage drop (like the germanium diode). The LM386 amplifies the signal enough to overcome the 0.7 V drop caused by a regular silicon diode.
Although you could already connect a crystal earpiece (if you can find one) to the top of C6, we recommend using another LM386 for what it's actually designed: audio amplification. This setup will produce enough power to drive a small speaker. Potentiometer P1 controls the volume.

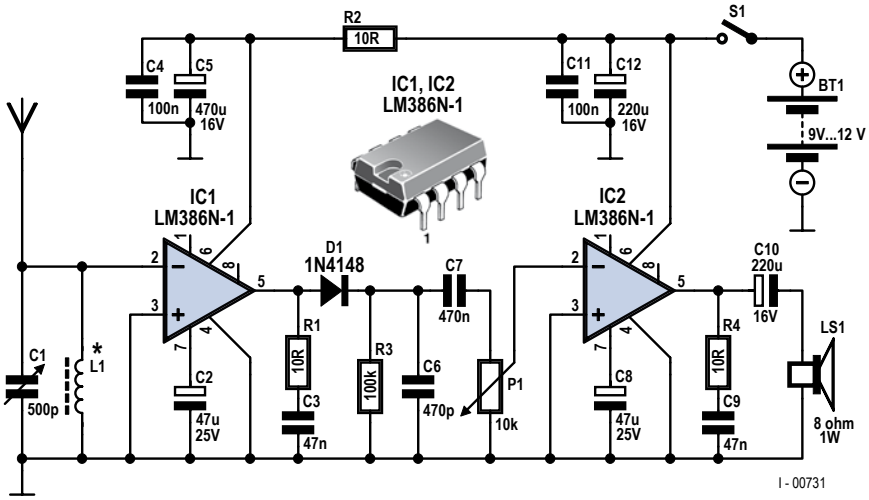


A few details

To increase the stability of both ICs, two RC networks (R1 in combination with C3 and R4 with C9) are connected on their outputs. The 47 µF capacitors (C2 and C8) attached to the bypass connections of the ICs suppress the odd irregularity in the supply voltage. This becomes important when the battery runs flat and its internal resistance increases. Just to be safe, IC1 is decoupled with R2 and C5. Components C4 and C11 add an extra high frequency decoupling. Make sure to use ceramic capacitors and to fit them as close as possible to the IC power pins.
The tuned loop comprising of C1 and L1 is open to any experimentation you like. You could use the antenna coil from an old AM radio, but you could also wind the inductor yourself. We tried both options in our lab, and they worked just fine.
The first prototype was made from a ferrite rod 10 mm thick and 37 mm long, to which we added 100 turns of 0.3 mm enamelled (lacquered) copper wire (CuL). This gave an inductance of 390 µH. The second version was made from 80 turns of 0.4 mm CuL on a ferrite rod 12 mm thick and 190 mm long, resulting in an inductance of 550 µH. With this information, it's possible to calculate the value of the capacitor you need to be able to tune across the medium wave (MW) range. Capacitors with values between 200 pF and 500 pF are best, although it's also possible to use a smaller variable capacitor and a fixed capacitor in parallel.

Construction and operation

Like most of our circuits, this design can be built on a piece of prototyping board. Just keep in mind that this is an RF (radio frequency) circuit! This means that you need to take special care to place IC1 and its surrounding parts close together and maybe even to divide the high and low frequency parts with little metal screens. Special care needs to be taken with the soldering of the tuned circuit, since you are working with very low voltages and currents. Messy construction will guarantee a bad result. Preferably, the finished circuit should be built in to a metal casing (leave the ferrite rod outside the case), and take care that the metal frame and the axle of the tuning capacitor are properly grounded.
The amplifier IC type LM386N is available in four different flavours (LM386N-1, -2, -3 and -4). The versions with suffixes -1 and -3 are best for IC1. The rule of thumb for IC2 is: the higher the number, the more sound the speaker will produce. We advise the LM386N-3 device when using a 9 V power supply, because it can supply around 0.7 watts of audio power into an 8 Ω speaker.
Without an antenna and a proper earth connection, your radio



won't work as it should. A few meters of copper wire suspended across the ceiling should work as an antenna, and a connection with an unpainted metal central heating or water tube is enough for a good earthing. For safety reasons, it's better not to use the ground connection in an AC power socket.

Finally, the circuit works fine with a voltage between 9 and 12 V. A 9 V block battery is a fine power source for the radio, especially because the current consumption is just 10 mA (with the volume control closed).

Happy building and have fun listening to your favourite AM radio station!

Nostalgic tube sound from an IC

By Ton Giesberts (Elektor Labs)

Even now, the real audio 'connoisseurs' can't agree on one basic thing (which incidentally says enough about the 'connoisseurs'...): Which is 'better', an amplifier using vacuum tubes, or one using transistors? One will shout that the 'warm' nostalgic sound coming from tubes is 'the best', while the other points out the benefits of unnoticeable distortion coming from a well designed transistor amplifier. Happy to stay out of this discussion, we are still proud to present this experimental *digital* amplifier, which produces a sound which one could interpret as 'tube-like'.

A digital amplifier? The guys at the Elektor Labs must have had a drink too much, since **amplifiers** are clearly analogue circuits. Well, although this is usually the case, it isn't strictly necessary, since if an amplifier is treated as a '*black box*' which amplifies any given input signal, it doesn't really matter what kind of electronics are inside.

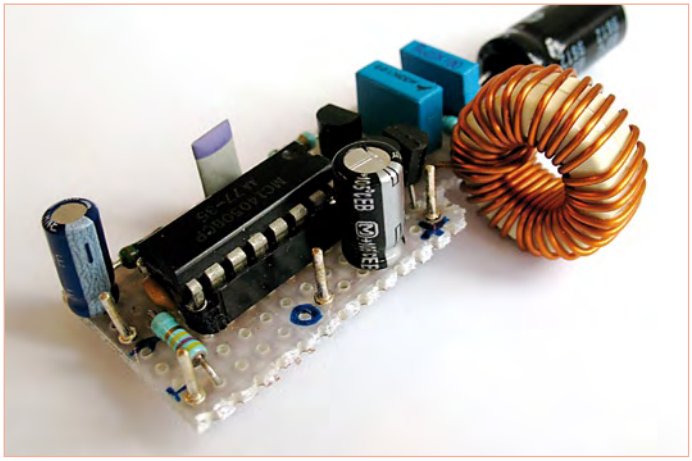
Strictly speaking, we've made an amplifier which no other self-respecting engineer would have made: our amplifier oscillates like a madman! This oscillation is caused by a self-oscillating pulsewidth modulator. Quite an impressive name for something as simple as an oscillator which merely produces square pulses with a width dependent on the input signal. The higher the voltage on the input, the wider the pulses will be on the output.

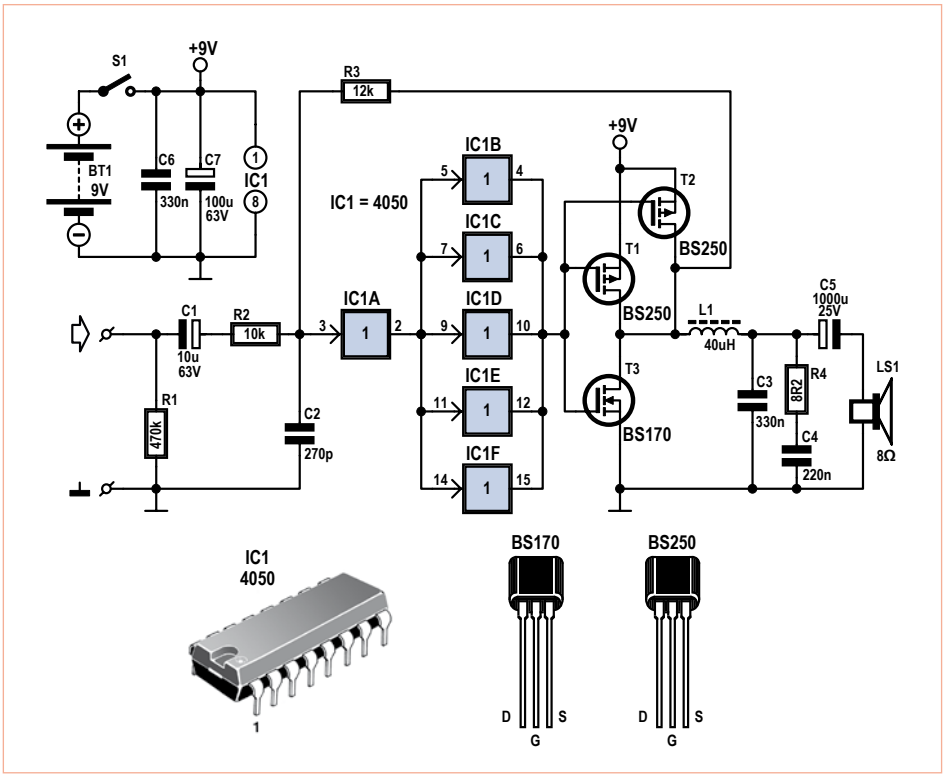
To summarise, our 'digital' amplifier works as follows: The low frequency input signal modulates an oscillator circuit in such a way that the *width* of the produced pulses vary in the rhythm of the input signal. This results in a pulse-density modulated (PDM) signal which controls a few transistors which can supply enough current. A low-pass filter on the output restores the information with a low frequency which is then fed to the loudspeaker. The big advantage of this approach is the low power consumption. Only the final transistors need to switch between a fully conducting and a fully insulating state, so only a little bit of power is lost.

The details

The final amplification of the signal is taken care of by three small MOSFET's (T1, T2, T3) which can supply 0.5 A each. Because the types shown in the diagram have a high on-state resistance, which is 5 Ω for the BS170 and 14 Ω for the BS250 when using a 10 V power supply, we need to use two BS250s in parallel to be able to supply the loudspeaker with a symmetrical signal. Because of the two transistors in parallel, the on-state resistance is effectively halved to 7 Ω.

The circuit is powered by an asymmetrical 9 V power supply; in our case a simple 9 V battery. This calls for decoupling capacitors (C1 and C5) at the input and output. To correctly drive the transistors, a few buffers from the '4000' CMOS logic series are used. Although these are extremely slow in comparison to the high-speed 74HC





series, the 4xxx series isn't as picky as regards supply voltage, happily working at supply voltages ranging from 3 to 18 V. And this application doesn't require the buffers to switch rapidly anyway. Of the six available buffers in IC1 (a 4050), two are placed in series to furnish adequate levels of amplification. The remaining four buffers are connected in parallel to the second buffer, which improves the way the transistors are driven.

Components L1, C3, C4 and R4 form a low-pass filter, which only allows frequencies humans can hear to reach the speaker. A standard choke can be used for L1, as long as it can handle *at least* 0.5 A. The amplification of the circuit as a whole is determined by the ratio of R2 and R3 and the impedance of the signal's source. If the impedance is way lower than the resistance of R2 (10 kΩ), the amplification will be around unity (1×).

Construction and specs

This circuit is quite straightforward to build. There aren't any components which need to be fitted at a critical location, nor any other serious design measures to be taken, as long as it's built compactly on a piece of prototyping board. It's also best to insert IC1 in a DIL socket. Keep in mind that pins 13 and 16 of the IC **should not** be connected. Also, a metal casing should be used to prevent the high switching frequency of this circuit (approx. 900 kHz at 9 V) from interfering with other appliances.

Running off a 9 V source, the amplifier can supply about 650 mW to an 8 Ω loudspeaker, which can cause a whole lot of noise! The distortion is about 5%. When the circuit supplies just 1 mW, the distortion decreases to about 0.15%. Capacitor C5 determines the bandwidth. With C5 at 1000 µF, the bandwidth is approximately 25 Hz to 22 kHz.

Admittedly this little amplifier is a far cry from its high-end or hi-fi brethren. On the other hand, it is very useful to get some experience with the principles of PDM. And, of course, it's great fun to watch what's happening at various points in the circuit with an oscilloscope.

(i-00734)

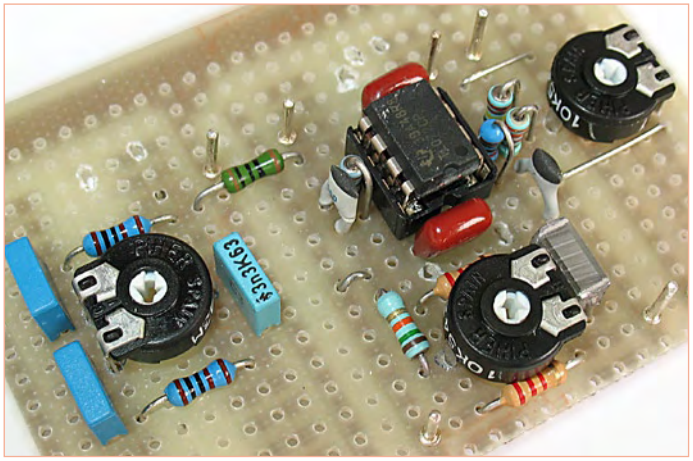
A higher note...

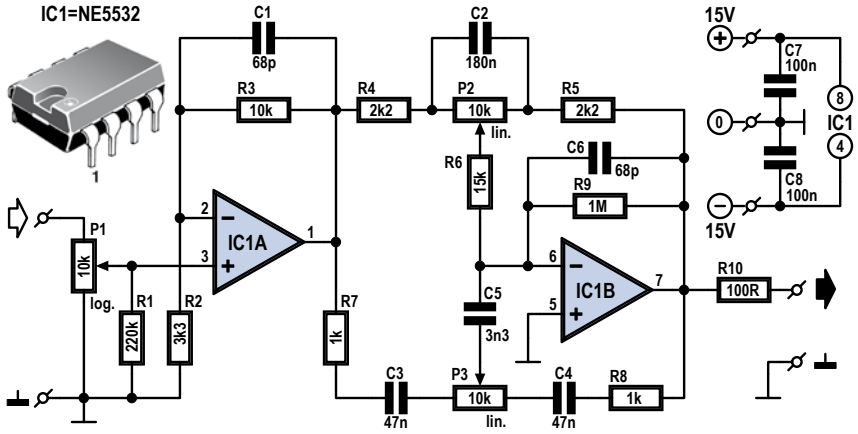
By Ton Giesberts (Elektor Labs)

If as a child you are sent to the butchers to fetch an ounce of ham, you'll no doubt have heard the good man saying "Does it matter if it's a little more?" well after cutting the stuff. Likewise, the trigger to design a tone adjustment circuit was a question I recently overheard within an all-technical environment: "Does it matter if the tone's a little higher?"

In the article on the tube sound mimicking amplifier elsewhere in this Xmas supplement, we mentioned on the side that the audio world can be divided in to two factions: the side containing vacuum tube enthusiasts and the side propagating transistors. This isn't the full story though, since we can draw a line between two other groups: the purists and the relativationists. To the purists, 'equalising' (or tone adjustment) is a very dirty word, and the ideal preamplifier consists of nothing but a length of copper wire (preferably gold-plated), although they have been known to add a potentiometer here and there for volume control to keep the peace around the neighbourhood. The second group is less strict and doesn't have a problem with amplifying or muffling pieces of a music signal to fit their liking. If you belong to the latter, this tone adjustment design is something you might be interested in

The design of this equaliser could be classified as 'classic'. Furthermore, the circuit also amplifies the signal at least by 4 times, which



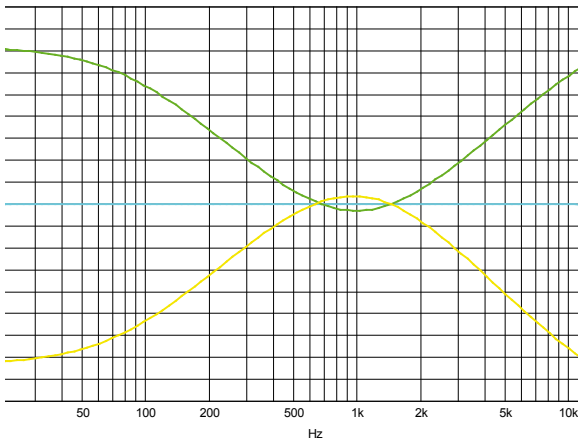


allows this circuit to bear the designation of 'full-fledged preamplifier. It is the ideal supplement to the above mentioned PWM amplifier, especially when you're not using high-end speakers. The range of adjustment is approximately 14 dB (at 20 Hz and 20 kHz), so if this isn't enough, there's definitely something wrong with the speaker connected up!

Looking at the circuit diagram from the left to the right, the first thing you see is potentiometer P1, which controls the volume. This is followed by the buffer/amplifier chip, IC1a. This is a non-inverting amplifier which is configured to produce a gain of 4 times (R3/R2 + 1). At a ±15 V symmetrical power supply, this amplifier can easily process a 2 V signal from a MP3, CD or DVD player.

Next comes IC1b which takes care of the actual tone adjustment. This opamp is wired as an inverting amplifier with two negative feedback loops in parallel, one for the high frequencies, and one for the low ones. The workings of this part of the circuit aren't hard to understand if we look at the two extreme ends of the frequency range: very high and very low.

First, the very low frequencies. The capacitors C3, C4 and C5 create a high-pass filter which effectively hinders all low frequencies from being transferred, removing P3's influence on the low frequencies. Capacitor C2 also blocks low frequencies, causing the amplification of the low frequencies to be determined by the setting of P2. The maximum amplification is (R5 + P2) / R4 = 5.5× and the minimum amplification is R5 / (R4 + P2) = 0.18×.



Now for the very high frequencies. As opposed to the low frequencies, C2 short-circuits all high frequencies, removing P2's influence on them. C3, C4 and C5 also have a very low resistance, which causes the high frequencies to be passed through P3, allowing them to be controlled. Superficially, one might say the range of amplification is between (R8+P3) / R7 = 11× and R8 / (R7+P3) = 0.09×. In practice, the amplification is between 6.5× and 0.15× due to the fact that R4 through R6 are actually in parallel to the high-frequency circuit. In any case, P3 controls the high tones.

Of course we've tested this equaliser in the lab, the results of which are shown in the graph. The green curve is the frequency distribution when both potentiometers (P2 and P3) are set at their maximum, and the yellow curve was measured with P2 and P3 at their minimum. The blue curve, which is actually a very neat straight line, was measured with P2 and P3 at their middle position. From this graph you can see the range is very wide!

Volume control P1 is at the input of the circuit instead of at the output to prevent the equalisation from being overdriven.

The actual construction is fairly straightforward. Just like in the picture, building the circuit is easy on a piece of prototyping board. Remember to solder neatly and to keep the wiring to the potentiometers as short as possible.

We picked an NE5532 dual opamp to take care of the amplification, since it's specially designed for audio signal processing. This opamp causes a distortion of just 0.002% at an output voltage of 1 V for frequencies up to 20 kHz. The drawback of this opamp is its relatively high power consumption (7.5 mA). If this is unacceptable, a 'regular' dual-opamp like the TL072 can also be used. This reduces the power consumption to approximately 3.8 mA, which allows the circuit to be powered by two 9 V batteries, instead of an AC power adapter. The distortion in the signal does increase to 0.007% at 20 kHz when using the TL072, which is still acceptable.

R2 can be left out of the circuit if you feel that the first amplification of the signal in IC1a is a bit high. The buffer will then amplify just 1×.

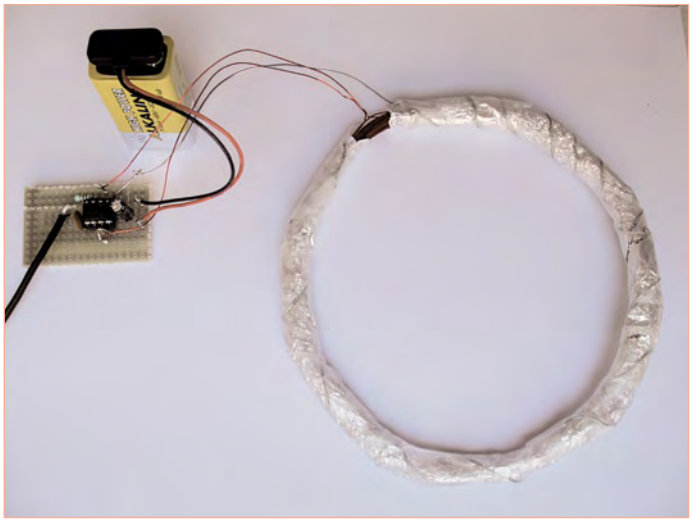
The circuit was designed for use with small loudspeakers. When larger speakers are used, the value of C2 needs to be increased, which decreases the bandwidth. The range of adjustment can be decreased by decreasing the capacitance of C5 a little.

Enjoy the build, and have fun using the circuit!

(i-00740)

Poor man's metal detector

By Thomas Scarborough (South Africa)



Imagine a pleasant stroll on the beach with your trusty old metal detector, when suddenly it gives off a loud tone. After digging for a few minutes you stumble upon a ceramic pot filled to the rim with antique coins and jewellery... Eternal fame and great wealth lie ahead of you (after the government has taken its fair share...)! Admittedly, these strokes of good fortune do no happen very often, but it's still the dream of any treasure hunter. Bu then, once or twice a year there's a short article in the paper about some lucky guy who finds a medieval or Roman treasure on a field or in his back yard. Are you the next one?

One thing all commercial metal detectors have in common is their price within the range of 'extremely high' to 'unaffordable'. Even kitted versions that need to be assembled at home are not really cheap, and often result in large amounts of stress during the construction.

This situation was a big pain for the author. After some serious use of both the grey and white matter inside his skull, the following circuit took shape in his workshop: a cheap and extremely simple metal detector!

The circuit of the poor man's metal detector is built around one of the most trusted and familiar ICs in the world of electronics: the good old 555. Two resistors, two capacitors and a few pieces of 0.3 mm diameter enamelled copper wire complete the whole. Apart from that, you'll also need a portable AM radio, which should lie somewhere in the junk box of any electronics enthusiast. If not, find one at the next car boor sale in your area.

The IC is used as an inverter in this particular circuit, which feeds back the voltage on pins 6 (threshold) and 7 (discharge) through the search head coil L1 to the trigger input on pin 2. Due to the reactance (resistance for alternating current) of the inductor and the inevitable delay in the IC, the circuit will start to oscillate with a frequency close to 80 kHz, resulting in a square wave with this frequency on pin 3 of the IC.

Now, a reasonably high frequency square wave isn't very useful... yet. We found the following solution for that. Coil L2 is connected to the output of the 555, so it starts working as a transmitting antenna with a very small power output. If we place the transmitting antenna close to the antenna of the AM radio receiver, we'll hear a 'whistling' tone on countless places within the range of the receiver. This is a beat frequency which comes about when one of the harmonics of our 80 kHz square wave (a square wave contains loads of harmonics) is close to the frequency to which the receiver is tuned.

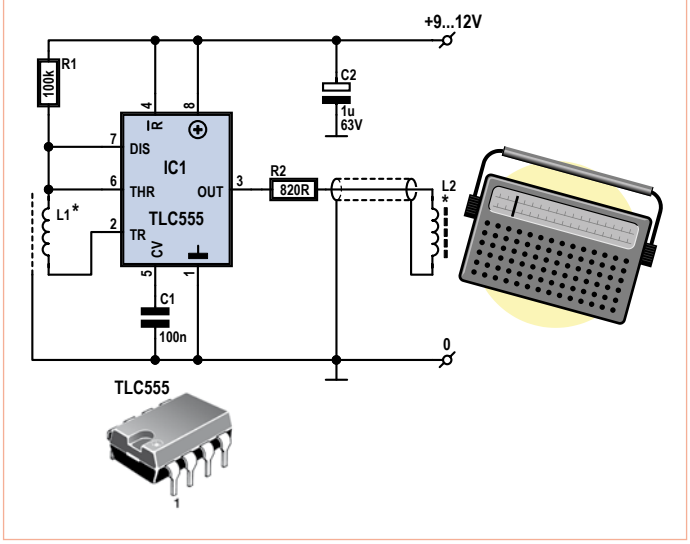
The workings of our circuit as a metal detector are now easily understandable. Assume for a moment that you have tuned the receiver in such a way, that the beat frequency has just disappeared. Normally, you won't hear a thing from the loudspeaker or headphone. But when L1 is placed in the vicinity of a piece of metal, the self-inductance (and therefore also the reactance) of the coil changes. This means that the frequency of the oscillator also changes, causing the AM receiver to pick up a beat frequency again. That could be your pot of gold...

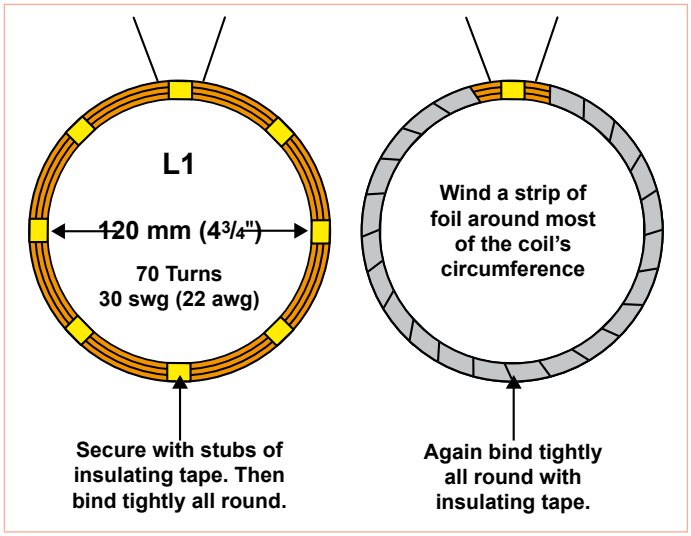
Practical issues

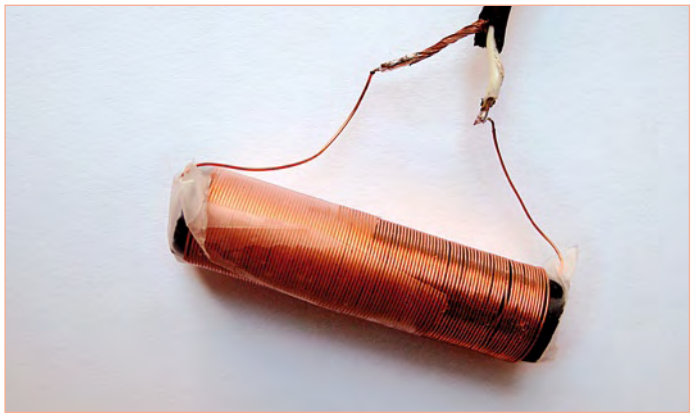
The circuit is built up in a no time at all on a piece of prototyping board (see picture). The biggest job is probably winding the coils, i.e. the search head coil L1 and the transmitting coil L2, but this isn't a complicated task.

You'll need a piece of PVC or cardboard tube with an outer diameter of approximately 120 mm (it doesn't matter if it's a bit more or less) to wind the search head coil L1 on. Neatly wind between 50 and 70 coils of 0.3 mm enamelled copper wire on the tube and carefully shove the coil off its former. Secure the coils with four of five pieces of tape. Finally wrap the whole thing in a layer of insulation tape or something similar.

The searching coil needs a 'Faraday protection', which is formed by a layer of aluminium foil. Keep in mind that a gap of about 10 mm wide needs to remain open. Do not cover the full circumference of the coil with foil. The protection needs to be connected to ground. This can be achieved by winding a piece of bare wire tightly around the foil and covering the whole with yet another layer of insulation tape. Nothing can really go wrong using the picture of our proto-







type and the construction drawing.
The connection wires of L1 are sensitive to disturbances and need to be kept as short as possible. We recommend fitting the PCB with the electronics on it as close as possible to the search coil.
The transmitter coil, L2, is made from 80 coils of the same copper wire around a short ferrite rod. This coil needs to be connected to the rest of the circuit through a piece of protected coaxial cable, as shown in the photo. Again, the protection needs to be connected to ground. As already noted, the antenna needs to be placed very close to the antenna of the AM radio. If the signal still is too weak, R2 can be lowered to 680 Ω or even 560 Ω.
The best power supply for the circuit is a set of batteries supplying between 9 and 12 V. Because the TLC version of the 555 is used, the power consumption remains modest at around 10 mA so the batteries can be used for a long time.
Although this is a very rudimentary design (so don't quit your daytime job to search for treasures just yet!), the sensitivity is quite okay. Through air, a coin with a diameter of about 1 inch (25 mm) can be detected at a distance of 10 cm or more!

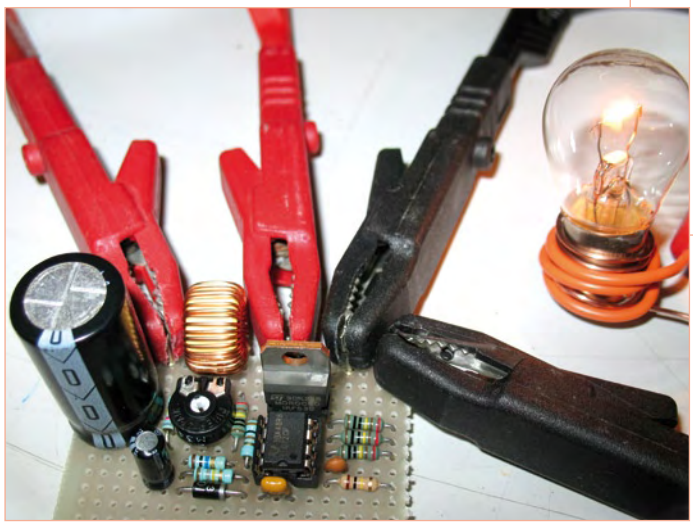
(i-00797))

Efficient camping dimmer

By Ton Giesberts (Elektor Labs)

Especially when you're forced to be sparing with electric power, like for example when you're camping and you're depending upon the limited energy supply of your car battery to light up your little tent, it is really important to let as little energy as possible go to waste. For one, the lights don't have to be on at full force all the time. Switching lamps all the time to adjust the lighting to the situation, is just inconvenient. But if you want to dim the lights, then do it in an energy-efficient way!
Controlling the lights at home is usually a matter of using electronic dimmer circuits. The advantage of such a dimmer is that very little energy is lost as heat in the dimmer itself. However, to regulate the brightness of a lamp that's connected to a direct current source (like a campsite or vehicle battery) these alternating current regulators aren't suitable. With a handful of parts from the junk box you can build your own efficient dimmer for use on the campsite — next year. We do want to mention: this dimmer is only suited for 12 volt incandescent light bulbs.
The principle of an energy efficient dimmer (also the alternating current type for use at home) is based on the complete turning on and off of a light bulb at a high frequency our eyes won't be able to discern. The slowness of the bulb makes extra sure that our eyes appear to perceive a steadily burning lamp instead of a flickering one. The fast turning on and off is done with an electronic switch. Theoretically no energy is lost in the switch, because when it is closed there is no electrical voltage on it and when it is open, there is no current. The product of voltage and current(= power) is therefore is always zero watts. (Usually there is some residual voltage across the switch and on top of that the switch isn't switching infinitely fast; so there is always some energy lost in the form of heat.)
If you want the bulb to burn brighter, simply increase the time the switch is closed and shorten the time it is open. That way the frequency of switching will stay the same. This relation between closed (lamp on) and open (lamp off) is called the duty cycle, or, formally, the duty factor.
In the accompanying schematic you can see the switch in the form of power MOSFET T1. This electronic switch is controlled by the part of the circuit on the left of it.
Around IC1A an oscillator was made that supplies a triangular output voltage. Sure, the shape of the triangle isn't perfect, but that doesn't matter in this particular case. This triangular voltage is compared to a reference level set on P1, by an opamp (IC1B) wired up as a comparator. If the triangular voltage level is below this reference voltage, the output of the comparator swings to 12 volts. The MOSFET will now conduct fully and lets a current flow through the lamp. If the triangular voltage rises above the reference voltage, then the voltage on output IC1B becomes zero volts, which causes the MOSFET to turn off. The current flowing through the lamp will now be interrupted. This switching goes on at an 'invisible' frequency of 12.5 kHz.

If we set a higher reference voltage with P1, a larger part of the triangular voltage will drop below this voltage and the MOSFET will therefore be conducting for a longer time (and blocking for a shorter time). The result is that the lamp burns brighter. With the given values of R5, R6, R7 and P1 a regulation of 0-100% can be achieved. Mostly because of the tolerance of P1, in reality there is a chance that 100% span can't be fully reached. If necessary, adjust



the values a little and make sure that the sum of P1 and R6 roughly equals R5+R7.

In series with the lamp there is an inductor (good for at least 2 ampères) with a inductance of 80 millihenries or thereabouts, 60 or 100 is okay too. The function of this component is to limit the switch currents and to suppress the electromagnetic interference caused by the switching.

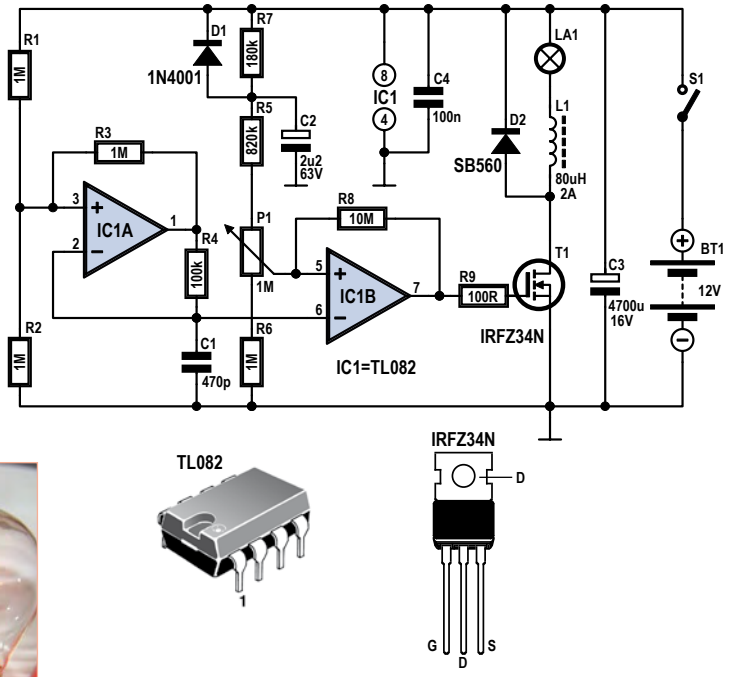
If the dimmer is switched on, capacitor C2 ensures that the brightness of the lamp will slowly increase up to the value set with P1 This will greatly improve the lifetime of your light bulb!

Just a few more practical tips: Limit the power of the lamp to about 24 watts (with a battery voltage of 12 volts the maximum current will be about 2 ampères). For switch S1 use a type that can handle at least 2 ampères and connect the circuit through a fuse (2 ampères time lag / slow-blow) to the battery just to be sure. If the lamp is dimmed to 0% the battery current will be about 4 mA; that may not be much, but shutting the dimmer off with switch S1 will save you even that bit of energy.

In our prototype (see picture) we used a preset; a potentiometer with a spindle and control knob would be way more practical of course.

To make sure that after your day out camping your car will still be able to start, the next thing you'll want to build is a battery monitor — suitable designs have been published in Elektor over the past few years, especially in the Summer Circuits editions, and of course the 30x book series.

(i-00843)



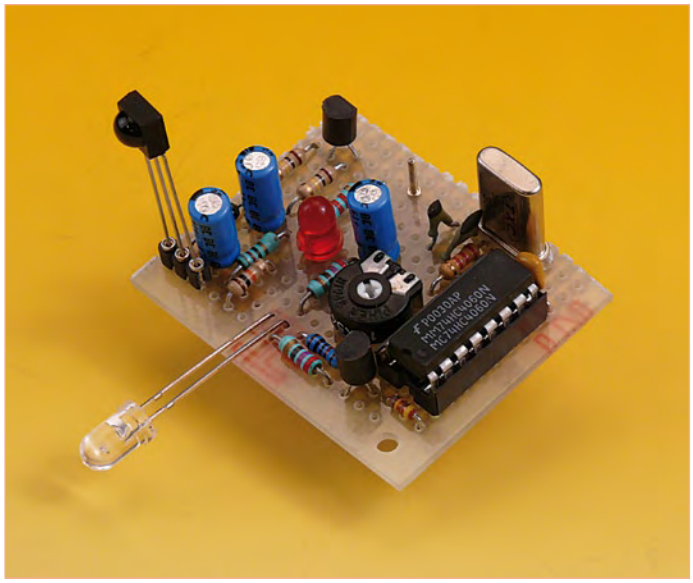
Touchless switch

By Ton Giesberts (Elektor Labs)

To the untrained eye, it may seem like magic: an engineer makes rapid Harry Potteresque gestures through the air and suddenly the light goes on or music starts to play... Luckily for you, the Elektor electronics lab isn't Hogwarts School of Witchcraft and Wizardry, even though it may seem so sometimes; everything conceived and built in our laboratory is firmly anchored in reality and can be understood and constructed by everyone!

There are a few different approaches you can take when building a switch that's operated without any physical contact. For example, you could brush up on Maxwell's equations and go for a capacitive or inductive approach. Although switches have been made using those principles, such a solution would require more electronics than what you're used to of i-TRIXX or Summer Circuits. That's why the engineers at the Elektor lab chose to take a radically different direction. Their solution is, for the largest part, comprised of components which you'll probably still have lying around. The principle is simple: An infrared LED transmits an invisible signal, which does not reach the infrared receiver in normal circumstances. As soon as you place your hand in the vicinity of the switch though, the signal gets reflected enough to activate the receiver, which in turn controls a relay used to switch something on or off.

The circuit is comprised of two parts: the transmitter and the receiver. To keep the construction simple, a standard infrared receiver-module (IC2) is used, which is normally used in conjunction with infrared remote controls. This 'three-pin device type SFH5110-36 contains just about everything you need to detect the presence of the signal, although there are a few peculiarities you'll need to pay attention to. This IC is probably one of the two components



you won't have lying around on your workbench in the junkbox, or in a drawer.

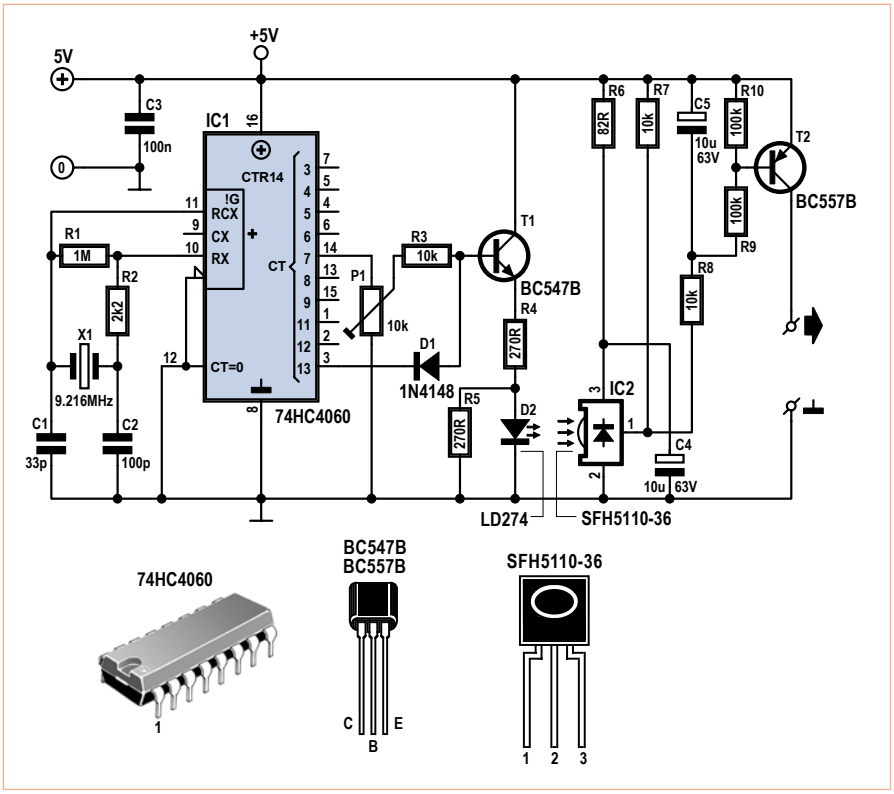
The core of the transmitter is formed by the fast HC version of the trusty old 4060 (IC1). This chip combines an oscillator circuit and a 14-stage binary counter (of which the highest ten are bonded out to pins) in a 16-pin package. To prevent calibration problems, we designed a crystal oscillator circuit using the oscillator section of IC1 and crystal X1. Because of the high frequency produced by X1 (9.216 MHz), you really have to use the HC version of the 4060.

On IC1s output Q8 (pin 14), you'll find the oscillator frequency divided by 28 (256), which amounts to a signal of exactly 36 kHz. IC2, the receiver, is tuned to receive exactly that frequency. Bear in mind that the SFH5110 is also available for use with other frequencies, so make sure you really get a hold of the SFH5110-36. This frequency is used to make a normal infrared LED (D2) flash. Potentiometer P1 is added to control the sensitivity of the circuit as a whole. This is done at the transmitter because SFH5110 doesn't contain any calibration options.

Now the only unanswered question remaining is just what diode D1 is doing in the circuit. It connects the base of T1 to the output Q14 (pin 3) of the 4060. Well, this is where the peculiarity of IC2 comes in. Because the module was built to receive information from remote controls, it ignores continuous, unmodulated carrier waves. An unmodulated signal, which can not contain any information, is therefore interpreted as 'no signal' and gets dealt with accordingly. Thanks to D1, T1 is switched on and off at the signal frequency at pin 3 of IC1 (which is 9.216 MHz divided by 214, or 562.5 Hz). This results in a perfect 50% modulated signal, which doesn't get ignored, therefore allowing us to detect the presence of an infrared signal.

As soon as the receiver module sees the reflected signal from D2, a square wave appears on its output with a frequency of approximately 563 Hz. Components R8 and C5 act as a filter and create a neat switching signal which drives the transistor T2 through the voltage divider R9/R10. The voltage divider prevents the circuit from reacting too enthusiastically on signals from regular remote controls.

A PNP transistor was chosen for T2, because the output of the infrared module IC2 is high in quiescent state (when no infrared signal is received). When a signal is received, the transistor will conduct and switch on anything connected to its output.



For testing purposes, you can wire up a low-current LED from the output of the circuit to ground through a 1 kΩ resistor. If you want to control TTL or CMOS logic, you could connect T2's collector to the ground through a 10 kΩ resistor and use the potential across the resistor to drive your circuit. A relay generally draws more current (20 to 30 mA) than T2 is able to supply, so you'll need a buffer to get things working.

Assembling the circuit won't be a problem we reckon. It's recommended to use a socket for IC1 and for X1 if necessary. Make sure you mount all oscillator components as close together as possible. The infrared LED D2 and the receiver module IC2 should not be allowed to be in visual range of each other, so place a screen between the two.

P1 controls the range of the circuit. When using the indicated component values, it's about 20 cm. If desired, the range can be increased by lowering the value of R4.

Now all that's left is to wish you a happy build!

(i-00870)

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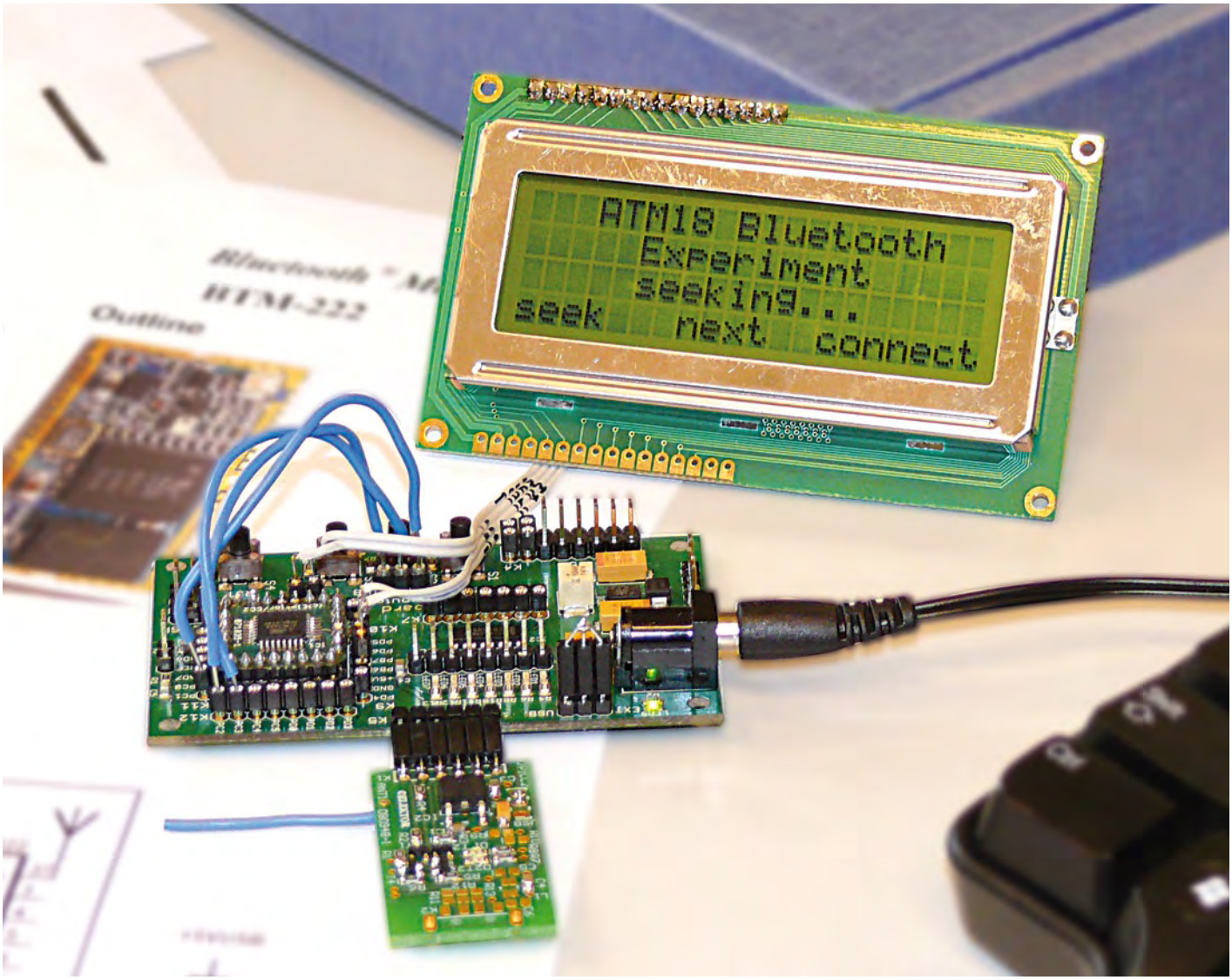
The Vikings Are Coming!
Bluetooth with the ATM18



By Wolfgang Rudolph and Detlev Tietjen (Germany)

Since its introduction in 2001, Bluetooth has developed into an essential standard for wireless links between devices. Using an inexpensive serial module, we can add Bluetooth functionality to our ATM18 board. Naturally, the example software written in C can also be adapted for use with other ATmega boards.

The unusual name 'Bluetooth' is a homage to the Danish Viking King Harald (in Danish, Harald Blåtand), who was born in 911 and died on 1 November 987. He united 960 large regions of Scandinavia, and he was known for his communication skills. Harald Blåtand also introduced Christianity to the majority of Denmark. The choice of name is connected with the participation of Ericsson in the development of the Bluetooth standard under the leadership of Dr Sven Mattisson, a Swede. As the objective of this

BTM-222 Bluetooth module features

- Certified for Bluetooth Version 2.0 and EDR
- Direct line-of-sight range with lambda/4 antenna (31 mm): 80–150 m (depending on weather conditions)
- Transmit power (Class 1): 18 dBm max.(63.1 mW into 50 Ω)
- Low power consumption (hold, sniff, park, and deep sleep mode)
- Supply voltage: 3.0–3.6 V
- Full Bluetooth data rate via UART
- Supports up to seven ACL links and three SCO links
- Supports enhanced data rate (EDR) for both modulation modes (2 Mbps and 3 Mbps)
- SPP firmware with AT commands
- Dimensions (mm): 28.2 x 15.0 x 2.8

Figure 1. The Bluetooth logo consists of the runic symbols for 'H' and 'B' against a blue background.

technology is to unite all modern devices and allow them to communicate with each other, the developers (including Professor Jaap Haartsen, a Dutchman) agreed on the name 'Bluetooth'. The Bluetooth logo consists of the runic symbols for 'H' and 'B' on top of a blue background (**Figure 1**).
In a project published in the January 2009 issue of Elektor [1], we interfaced a radio module with the ATM18 board to give it wireless data communication capability. Although Bluetooth is also a wireless data transmission interface, it operates in a different ISM frequency band (2.4 GHz) and uses a considerably more complex protocol. The Bluetooth standard has been described extensively in an Elektor article [2], and of course you can find descriptions of this standard on many websites, so we do not need to describe it in detail here. With a Bluetooth interface, the ATM18 board can establish a connection not only to a PC or another ATM18 board, but also to any other device equipped with a Bluetooth interface. To make this all possible, we first have to integrate a Bluetooth module with the ATM18 board.

Module selection

Although commonly available Bluetooth adapters in the form of USB sticks have become exceptionally cheap now, they can only be used with a USB host device such as a PC. For connection to our microcontroller board, we need a Bluetooth module with a serial interface. Serial Bluetooth adapters of this sort are used primarily in industrial applications, and unlike Bluetooth USB sticks they are not consumer goods. Although quite a few types are available, most of them are not cheap. We found a module from Rayson, with type number BTM-222 (**Figure 2**), that is fairly inexpensive. It is a Class 1 device with an output power of 18 dBm. Class 1 devices (see **Table 1**) have the highest transmit power, with a range of more than 100 metres (300 ft.) in free space. The key features are listed in the 'Module features' inset. The data sheet is available on the Internet via a link on the Elektor web page for this article [3]. The module supports the Hayes modem command set, which makes it easy to operate from a PC with a terminal emulator program. After start-up, the module initially evaluates all characters received via the serial interface as commands. After a connection is established, the characters (data) are simply forwarded to the party at the other end.

Bluetooth profile

Profiles are used for data exchange over the Bluetooth interface. During link setup, the devices exchange information about their profiles and agree on the profile to be used. The BTM-222 module used here supports the serial port protocol (SPP). This means that the module acts like a COM port on one side and like a UART (with TxD and RxD signals) on the other side. This sort of connection is sometimes called a 'virtual cable'. From the perspective of the application software and the connected hardware, this wireless link behaves the same way as a serial link using a cable.

Bluetooth board

The BTM-222 module consists of a small PCB fitted with SMD components and covered by a protective metal shell. With dimen-

Figure 2. The BTM-222 Bluetooth wireless module transmits with high power (Class 1) and has a serial data interface. It is soldered to the PCB in Figure 4 like an SMD component.

Table 1. Bluetooth classes and operating ranges

Class	Max. power	Max. power	Free-air range
1	100 mW	20 dBm	approx. 100 m
2	2.5 mW	4 dBm	approx. 50 m
3	1 mW	0 dBm	approx. 10 m

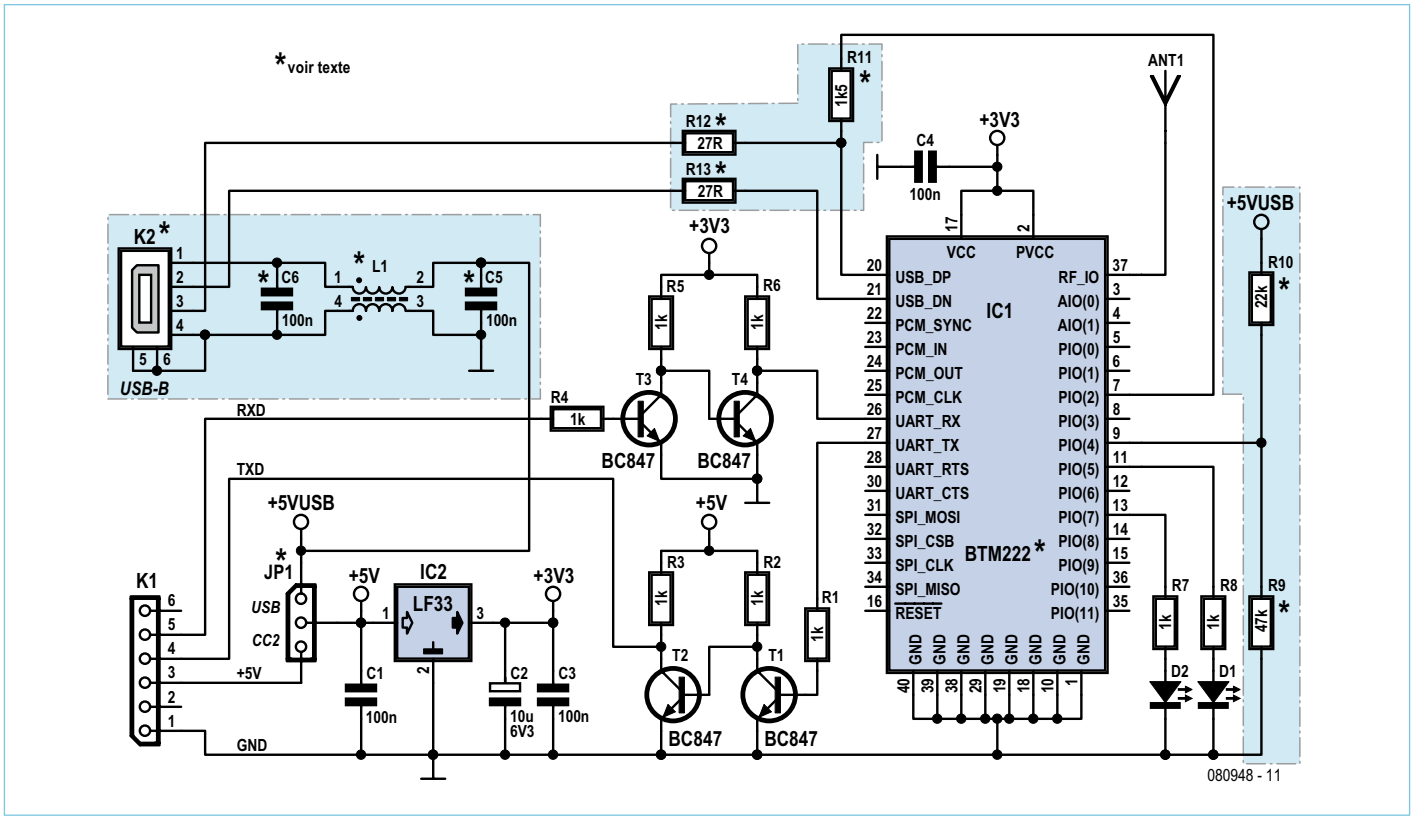


Figure 3. Circuit diagram of the Bluetooth PCB with the BTM-222 module. The components marked with an asterisk (*) are for the USB interface and are only necessary if the board is used with a BTM-220 module.

sions of 28 × 15 mm, it looks a bit like an overgrown 38-pin DIL SMD IC. It has stubby leads along the sides that can be used to solder the module to a circuit board in the same way as an SMD device. A circuit (**Figure 3**) and accompanying PCB (**Figure 4**) for the module have been designed in the Elektor labs.

The PCB is designed to accept the BTM-222 module (serial interface) as well as the BTM-220 module, which has an additional USB port. We used only the BTM-222 for our

COMPONENTS LIST

Resistors
R1–R8 = 1kΩ SMD 0805

Capacitors
C1,C3,C4 = 100nF SMD 0805
C2 = 10µF 10V SMD 1206

Semiconductors
D1 = LED, red, SMD 0805
D2 = LED, green, SMD 0805
T1–T4 = BC847, SMD (SOT-23)
IC1 = BTM-222, Bluetooth module, from Rayson Technology*
IC2 = LF33C or LF33CDT, DPAK-case, (e.g. Farnell # 1087187)

Miscellaneous
K1 = 6-way socket strip, right angled
JP1 = 3-pin header with jumper (or wire link)
PCB # 080948-1*

* available from the Elektor Shop or www.elektor-usa.com/080948

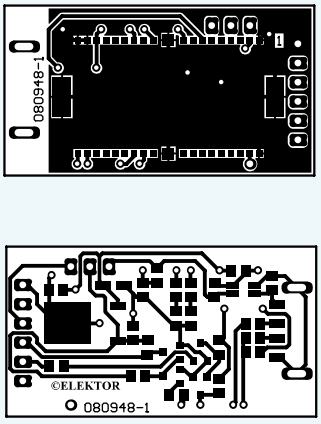


Figure 4. A few SMD components are fitted on the front side of the board, while only the BTM-222 module is fitted on the rear.

Addiional parts if IC1 = BTM-220 instead of BTM-222

Resistors
All SMD 0805
R9 = 47kΩ
R10 = 22kΩ
R11 = 1.5kΩ
R12,R13 = 27Ω

Capacitors
C5,C6 = 100nF SMD 0805

Inductor
L1 = 2200Ω @ 100MHz, e.g. Murata DL-W31SN222SQ2L (Farnell # 515599)

Miscellaneous
K2 = USB plug, type A, SMD, e.g. Lumberg 2410 07 (Farnell # 1308875)

application with the ATM18, which means that the components on the schematic diagram inside the highlighted boxes with dashed outlines are not fitted. The components that are only necessary for the BTM-220 are also shown separately in the components list.

The operating circuit for the BTM-222 module, as shown in Figure 3, consists of only a few components. K1 is a socket header for connection to the serial port of the ATM18 board. This connector in combination with jumper **JP1** (in position **CC2**) supplies the circuit with +5 V from the ATM18 board. Voltage regulator IC2 reduces this to the 3.3-V operating voltage of the wireless module. Level conversion for the serial interface (5 V ⇔ 3 V) is provided by transistors T1 and T2 for TxD and transistors T3 and T4 for RxD. Two LEDs are also connected to the wireless module. Diode D1 blinks red while data is being transferred over the serial interface, while D2 blinks green during wireless link setup and is constantly green while an active wireless link is present.
When assembling the PCB, pay particular attention to the correct orientation of the Bluetooth module. The dot-shaped marking on the protective cover **does not** mark pin 1. The correct orientation of the BTM-222 module is shown in **Figure 5**, with the marking next to the antenna connection.

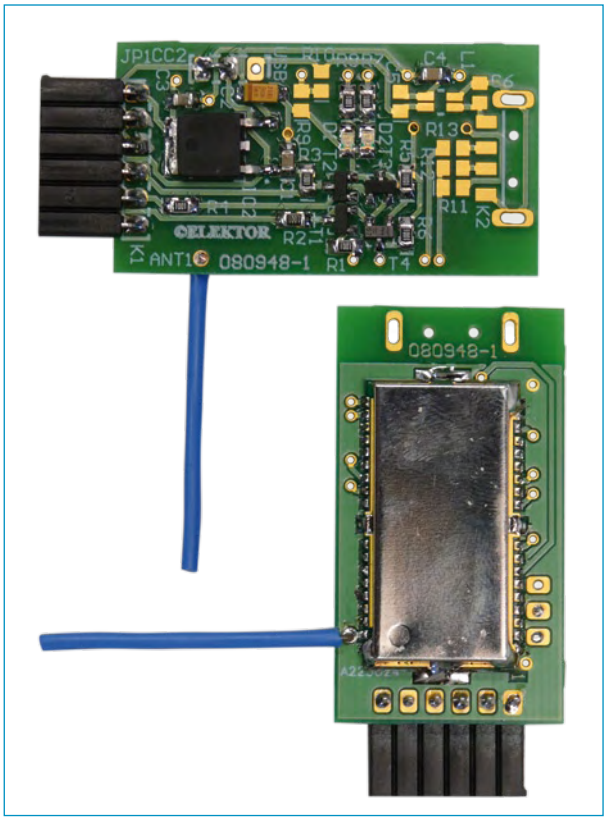


Figure 5. Both sides of the assembled PCB. A length of wire is soldered to one side to act as an antenna.

Connection to the ATM18 board

The module requires a wire antenna with a length of 31 mm (a quarter-wave antenna at 2.4 GHz). It must be soldered to the connection point marked ANT1 on the same side of the board as the BTM-222 module (see Figure 5). After this, you can plug the module board into connector K5 (serial port) of the ATM18 board (see **Figure 6** and the photos) with the component side facing up (module facing down) so you can see the LEDs. In addition, you must interconnect **all three JP1 pins** for supply voltage selection on the ATM18 board to provide a 5 V supply voltage to the Bluetooth board via K5. For testing, you can connect the Bluetooth board to a PC via a USB to serial interface adapter cable (such as item number 080313 in the Elektor Shop) and use a terminal emulator program to communicate with it. This can also be helpful if you have accidentally configured the module incorrectly, such as setting a data rate that is not supported by the ATM18 board.

Tricky communication

One of the shortcomings of the BTM-222 module is that it does not have a buffer for incoming characters. Consequently, you always have to wait for each character to be echoed before sending the next character. This means that after you send a command, you have to wait to see whether the module sends back 'OK' or 'ERROR', or perhaps doesn't send back anything at all, and if an error does occur you may have to repeat the command. This task is handled by the btm222_sendcmd() function of the btm222.h/.c software module. The parameter is the command, including the trailing <CR>. The return value is zero only if the module returns a response of 'OK', which indicates that it has accepted the command. A timeout ensures that the function will terminate even if no response is received from the module. The construction while(btm222_sendcmd(<CMD>)); ensures that the program waits until the module has accepted the command before proceeding. Defensive programmers may want to insert an additional timer to prevent the program from hanging here, which is possible because the command syntax is inherently error-prone.

Software module btm222.h/.c includes several other routines that make it easier to use the Bluetooth module. The btm222_setname() and btm222_setpin() routines construct the commands necessary to change the module's name and PIN code. The btm222_seek_devices() function initiates a search for other Bluetooth devices within range of the module (including mobile phones). This search may last up to one minute. The return value, which is also entered in btm_n_o_devices, is the number of devices found. Their names and IDs can be found in the btm222_devices field, so you can use freely configurable names to identify the other devices and are not forced to use their ID codes for this purpose. Here it should be noted that the names in this field are padded with blanks, so it is better to use the library function strstr() instead of strcmp() for comparisons.

You can use the ATA<nr><CR> command (where nr = 1...8) to establish a connection to the corresponding device. After a connection is established, the link acts the same as an RS232 connection with a cable. This means that the application program should evaluate the CONNECT <id> und DIS-

Table 2. Principal AT commands supported by the BTM-222 module	
A (Establish connection)	ATA<CR> establishes a connection to the device whose ID was previously set by an ATD=<ID><CR> command. ATA<no.><CR> establishes a connection to a device previously found in response to an ATF?<CR> command.
D (Set remote address)	ATD=<ID><CR> specifies the device that the module may connect to. In master mode, a connection can be initiated after this by issuing an ATA<CR> command. In slave mode, this can be used to prevent an unauthorized master from establishing a connection. The ATD0<CR> command allows connection to all available devices.
F (Search for Bluetooth devices)	ATF?<CR> initiates a search for other accessible devices. The found devices are output in a table. Before a search can be performed, the module must be put in master mode and autoconnect must be disabled.
N (Module name)	ATN=<name><CR> sets the name used as the module identifier. The allowed characters are 0–9, a–z, A–Z, blank and hyphen, but blanks and hyphens are not allowed as initial or final characters of the name. The maximum allowable size of the name is sixteen characters.
O (Autoconnect setting)	Configures a setting that determines whether the module should automatically establish connections with other devices. ATO0<CR> configures the module to automatically connect to any suitable device that it finds. After an ATO1<CR> command, each connection must be explicitly initiated by an ATA command.
P (Set PIN code)	Can be used to change the module's PIN code. Only modules with the same PIN code can connect to each other. This enhances security. The factory default PIN code is '1234'.
R (Master/slave)	ATR0<CR> configures the module as a master, while ATR1<CR> configures it as a slave.
Z (Warm start)	ATZ0<CR> restores the factory default settings.. However, this does not affect all the configuration settings. For instance, the name remains unchanged.

CONNECT <id> messages sent by the Bluetooth module to report link connection and disconnection, in order to avoid having the Bluetooth module interpret data intended for the other party as commands.

Before you can utilize these functions, you have to send the module an ATR0<CR> command to make it a master and an ATO1<CR> command to disable automatic connection. However, this is only possible if no suitable party is in the vicinity, as otherwise a connection will be established immediately.

The module configuration settings are retained after the supply voltage is removed, so you have to be careful with commands that change the serial interface settings. As you can see from the ATmega88 data sheet, the standard serial data rate of 57.6 kbps cannot be generated with adequate precision (error ≤ 1%) with a 16-MHz system clock. If you configure the BTM-222 module for a higher rate, you effectively lock out the ATM18.

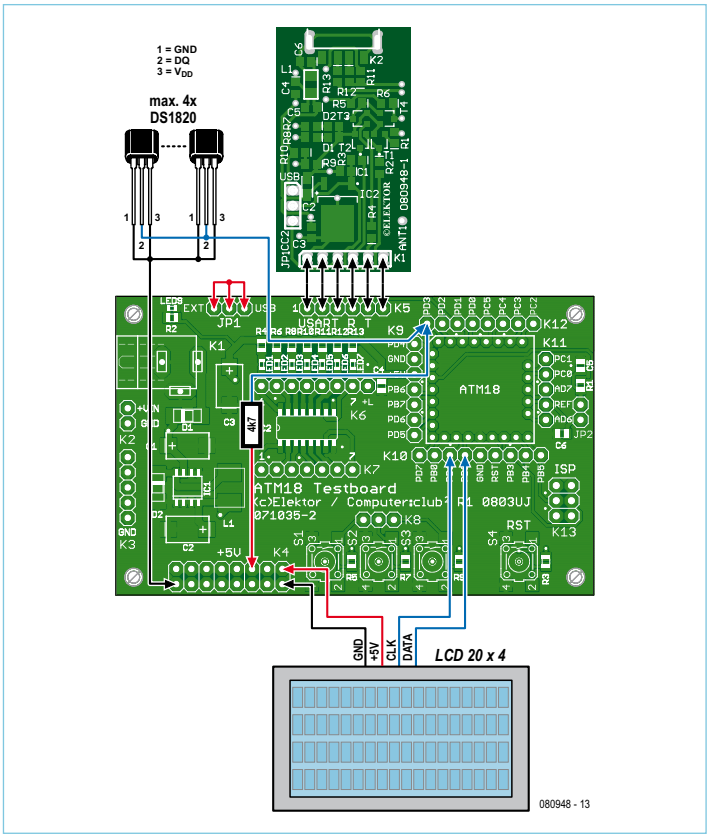


Figure 6. Several DS1820 temperature sensors can be connected to the ATM18 board as shown here. The attached Bluetooth module can transmit the temperature measurements over distances up to 100 m in free space.

The most important commands are listed in **Table 2**. The BTM-222 module data sheet [3] provides a more extensive list. Various undocumented commands can also be found on the Web, but they should be used with considerable caution, or better yet not at all, as you cannot be sure that they are supported by every version of the firmware.

Master and slave

We have programmed a sample application to illustrate what you can do with the BTM-222 module. It lets you use up to four DS1820 sensors (previously discussed in the ATM18 project article 'Another Brisk Day Today' in the March 2009 issue of Elektor) to measure temperatures. Pins PD4 to PD7 are driven as outputs and can be used to control a heating system or individual heaters, among other things. This arrangement could be used to implement remotely controlled temperature regulation. The sequence of the sensors is determined by their permanently configured

ROM addresses. The sensors are powered 'parasitically' via PD3, as shown by the wiring diagram in **Figure 6**.
The BTM-222 module is used here as a slave device. A new, not yet used module is most likely already configured as a slave, but to be on the safe side the ATM18 software first configures the module as a slave. This is necessary because the module retains its configuration settings after the supply voltage is removed, which means that it will still be a master if it was previously configured as a master for testing. As a precaution, the PIN code is also set to the default value (1234).
If you plug a Bluetooth USB stick into your PC and run a terminal emulator program on the PC, you can now establish a connection to the ATM18 board with the temperature sensors. It reports its status regularly to its master by sending the message

```
S<sensor_number> <temperature1>
<temperature2>...
<outputs><CR><LF>
```

The temperatures are coded as integers with a resolution of 0.01 °C. You can use `L<CR>` to query the current limits for all of the sensors, or

```
L<sensor_number> <lower_limit>
<upper_limit><CR>
```

to adjust the limits in order to set the desired temperatures. These limits are also stored in the EEPROM of the microcontroller, so they are directly available for use the next time. If you want to use this arrangement for a project such as monitoring and controlling temperatures in a greenhouse, you can add more sensors. Anything you can imagine, you can do!

Board to board

We also wrote a program to demonstrate a Bluetooth link between two ATM18 boards. It displays the status messages of the slave device on the LCD module. This lets you see the best way to use the BTM-222 module.
The program starts by sending the 'set master' and 'disable automatic connection' commands. They change the default configuration of the module as described above, so that the ATM18 can actively establish a connection. To ensure that the BTM-222 module is awake and ready for operation, the program waits until the module has accepted these commands.

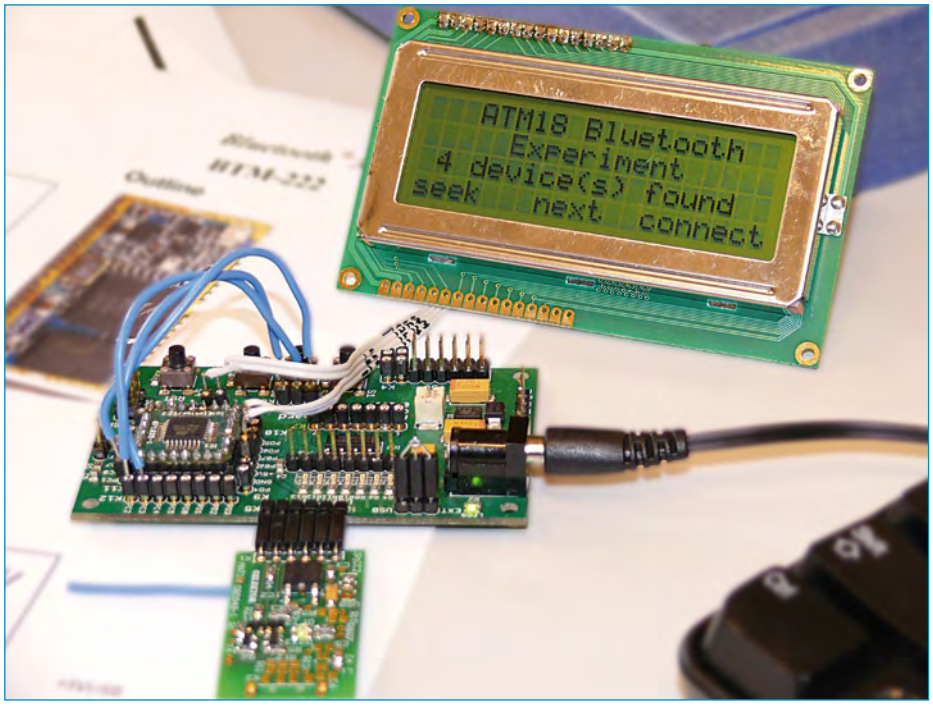


Figure 7. In each search cycle, the ATM18 board with attached Bluetooth module detects every Bluetooth device in its vicinity.

The operation of the program is controlled by three buttons (S1, S2 and S3) on the ATM18 board. Via K8, S1 is connected to PC1, S2 to PC2, and S3 to PC3. Pressing S1 starts a search for all available Bluetooth devices in the vicinity. After the search is completed, you can press S2 to display the names and IDs of the located devices (see **Figure 7**). By default, a BTM-222 module is shown as 'Serial Adaptor'.

Press S3 to establish a connection, after which the temperatures measured by the individual sensors and the states of the corresponding outputs will be displayed.

Downloads

The source text of the two programs has been written for use with the free GCC AV cross-compiler, which is available for many platforms. The software can be downloaded free of charge from the Elektor web page for the ATM18 Bluetooth project (www.elektor-usa.com/080948). The PCB layout of the Bluetooth board is also available on the same page for free download. A list of all previously published articles on the CC2 ATM18 system is available at www.elektor-usa.com/071137. On the Elektor forum everyone's invited to discuss the projects and articles published so far in the ATM18 / CC2 article series, as well as the closely related BASCOM AVR Course – see www.elektor.com/forum (all welcome).

(080948-I)

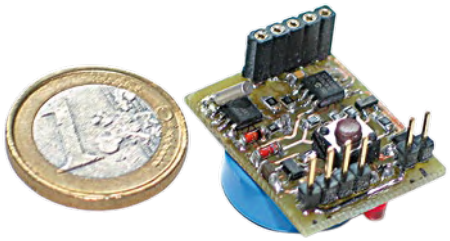
References and Links

[1] www.elektor-usa.com/080852
[2] 'Bluetooth: 2.4-GHz Data Radio instead of Computer Cables', Elektor January 2000
[3] www.elektor-usa.com/080948

Minimalistic Time Switch

A lot of features in a small package

By Fons Janssen and Mark Vermeulen (The Netherlands)



A time switch lets you save a considerable amount of energy by switching off equipment when it is not being used. However, time clocks from building merchants tend to be bulky and not especially easy to use. The circuit described here provides a distinctly larger set of features and is very compact, so it can easily be built into an existing piece of equipment.

The hardware (**Figure 1**) can certainly be dubbed 'minimalistic'. The circuit consists of only 24 components, including the connectors and pushbutton switch. It is built around a Maxim DS1337 (IC2), which is a compact real-time clock IC in an SOIC-18 package. This IC is designed to work with a 32.768-kHz crystal (X1). However, crystals that operate at this frequency are available in two different types. One type works with a 12.5-pF load capacitance, while the other works with a 6-pF load capacitance. The DS1337 only works properly with a 6-pF crystal. If a 12.5-pF type is used, the clock will be highly inaccurate.

For the microcontroller we chose Microchip's most powerful eight-pin type, the PIC12F683 (IC3), which also comes in an SOIC-8 package. Backup power in case of a power grid outage is provided by a 5.5-V GoldCap capacitor (C3), with a choice of capacitance values. Resistor R7 is included to keep the charging current of the capacitor within reasonable bounds. It ensures that the capacitor charging current never exceeds 30 mA, which is the maximum rated output current of the MAX1615 voltage regulator (IC1). In addition to these components, a small handful of SMD resistors and semiconductor devices are necessary for proper operation of the circuit.

The circuit employs an extremely minimalistic user interface in the form of a single pushbutton and a single 3-mm LED (D2). Nevertheless, the time clock is relatively easy to use. Setting the time and date is fairly intuitive, and programming the switching times for weekends and weekdays are just as easy.

A few extra components around the microcontroller are included to enable in-circuit programming. For instance, T1 and R5 are included to drive the LED. Here R5 provides sufficient isolation when pin 7 is used for the data signal during in-circuit programming. Resistor R6 is included for a similar reason; it allows the clock signal to be applied to pin 6 of IC3 during in-circuit programming. The programming voltage is supplied via the MCLR line (pin 4). Diode D1 allows power to be supplied to the microcontroller during in-circuit programming without powering the rest of the circuit at the same time.

As the circuit must be able to switch a fairly significant load (for example, a WiFi router can easily draw 1 A), we chose a type PMV45EN in an SOT23 package for the FET switch (T2). This MOSFET can handle well over 5 A, and it has a low on resistance (R_{DSon}). It can effectively switch a continuous current of around 2 A, which is more than adequate for most applications.

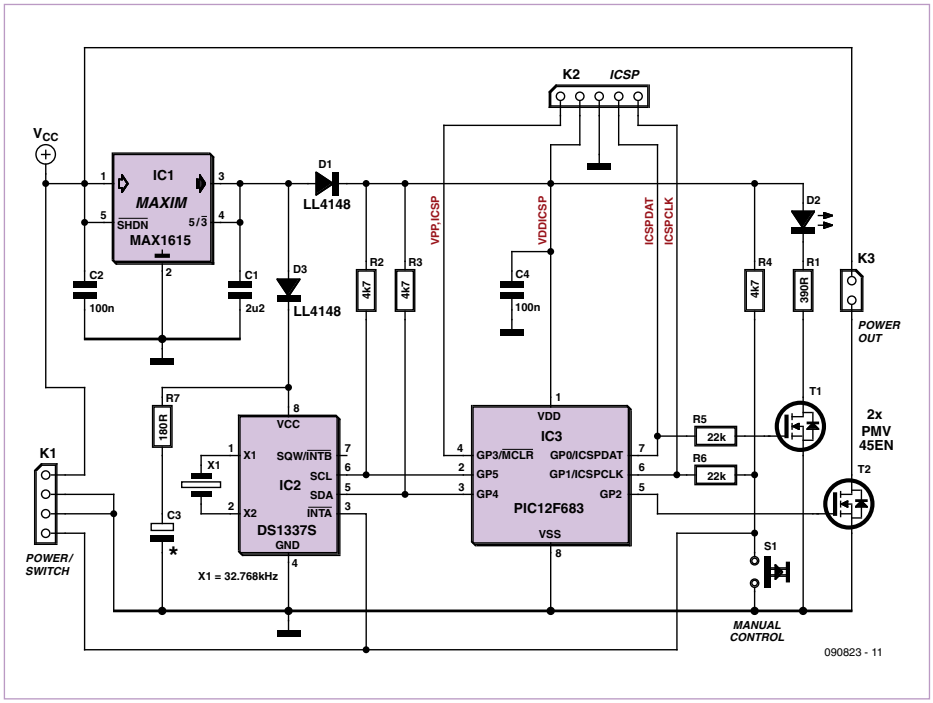


Figure 1. The entire circuit of the time clock consists of only 24 components, including the connectors and pushbutton switch.

Minimalistic software

Now let's have a look at how the time clock works.

Features of the minimalistic time switch

- 'Fit and forget' functionality
  - Automatic day of week determination
  - Automatic adjustment to summer and winter time
  - Long-term backup in case of power outage
- Easy to use
  - Manual override for 'always on' and 'always off' (regardless of the programmed switching times)
  - Single-button user interface (with a single LED for feedback) for all operating functions
  - Different switching times for weekdays and weekends (individual day of week programming possible if desired)
- Suitable for all DC-powered applications and battery-powered equipment
  - Input voltage range 6–28 V_{DC}
  - Very low current consumption (less than 10 µA)
  - Extremely compact design
  - Switches loads up to 2 A at 24 V_{DC}

Backup time

The circuit is designed to be used with a GoldCap capacitor rated at 1 F / 5.5 V. This capacitor must supply power to the DS1337 in the event of a power outage. With a supercapacitor of this type, the circuit can survive a power outage of more than three months. However, other types of capacitors can also be used. If you use a normal electrolytic capacitor rated at 470 µF / 6.3 V, the circuit will be able to handle a power outage with a duration of one hour.

Current consumption

The current consumption of the time clock is very low. The microcontroller is constantly in sleep mode under normal conditions, with a current consumption of only 350 nA. The corresponding current consumption of the DS1337 is somewhat larger at 600 nA. However, the current consumption of these two components is negligible compared with the current consumption of the voltage regulator. The MAX1615 used here has a maximum quiescent current of 8 µA, with the result that the maximum current consumption of the overall circuit is less than 10 µA.

Initial start-up

When you start up the clock the first time, the time setting is of course incorrect. This is indicated by the rapid blinking of the LED. You can set the time by first pressing the button within 30 seconds. If you don't do anything within this time, the clock automatically enters sleep mode. The only way to exit the sleep mode is to switch off power to the circuit. The circuit must be left without power for a few seconds to give the capacitors on the circuit board time to discharge, as otherwise the microcontroller will not reset.

Setting the time is relatively easy, despite the single-button user interface. A number from 0 to 9 can be entered by briefly pressing the button a corresponding number of times and then pressing it again for an extended length of time, which means holding the button pressed until the LED goes on. For example, you can enter the number '4' by pressing the button four times short and one time long.

The time clock expects you to enter ten numbers in the sequence DD–MM–YY–HH–MM (day, month, year, hours, minutes).

After a valid date and time have been entered, the time clock automatically determines the corresponding day of the week. This is important because you can set different switching times for weekends (Saturday and Sunday) and weekdays (Monday through Friday). Although the DS1337 has a register to store the day of the week, it is not able to determine the day of the week from the date, so this task is handled by the software. The entered information is stored in the registers of the DS1337.

Normal start-up

When the time clock starts up in normal use, it retrieves the date and time from the DS1337. Using this data, the software determines whether it is summer time or winter time. Based on the day of the week and the current time (both taken from the DS1337) as well as the switching times for the current day (taken from the internal EEPROM of the microcontroller), the software sets the output to the desired state. In addition, the software stores the next switching time in the ALM1 register of the DS1337. Once all of this has been done, the LED blinks once to indicate that the time clock has started up correctly and is ready for use.

After this, the microcontroller enables an interrupt on a change of signal level on pin 6 (GP1) and enters sleep mode. The microcontroller remains in this mode until the status of GP1 changes. When this happens, it carries on with execution of the program code. Consequently, there is no need for an interrupt service routine. Here the sleep mode is used as a low-power standby mode.

There are three possible sources of an interrupt via GP1: a button press, an interrupt signal from ALM1 (used for the switching times), or an interrupt signal from ALM2 (used for switching back and forth between summer time and winter time). As all three types of interrupts enter via GP1, the software must first determine the cause of the interrupt. It does this by reading the alarm flags of the DS1337. If one or both of the alarm flags is/are set, it or they is/are the cause of the interrupt. If no alarm flag is set, a button press is the cause of the interrupt. Here again, there are several options with the button:

- A **short** button press activates the override function.
- A **long** button press causes the time clock to enter switching time entry mode. In this mode, the time clock expects to receive the following data in the order listed:

  HH–MM (switch-on time, weekend)
  HH–MM (switch-off time, weekend)
  HH–MM (switch-on time, weekday)
  HH–MM (switch-off time, weekday)

The switching times are stored in the microcontroller's EEPROM. The switching times are stored separately for each day of the week, starting with Saturday and proceeding until Friday. This means that you can

COMPONENT LIST

Resistors
all SMD 0805
R1 = 390Ω
R2,R3,R4 = 4.7kΩ
R5,R6 = 22kΩ
R7 = 180Ω

Capacitors
C1 = 2.2µF, SMD 0805
C2,C4 = 100nF, SMD 0805
C3 = 470µF 6.3V, or GoldCap 0.1F or 1F 5.5 V (see text)

Semiconductors
all SMD, except D2
D1,D3 = LL4148
D2 = LED, red, 3mm
T1,T2 = PMV45EN
IC1 = MAX1615EUK+T
IC2 = DS1337S+
IC3 = PIC12F683-I/SN, programmed, Elektor Shop # 090823-41

Miscellaneous
X1 = 32.768kHz (CL = 6pF!, e.g. Farnell # 1216227)
S1 = pushbutton SPNO, 6mm (MCDTS6-5N)
K1 = 4-pin SIL pinheader
K2 = 5-way SIL socket
K3 = 2-pin SIL pinheader
PCB, # 090823-1
Project software # 090823-11.zip (source- and hex code files) from www.elektor-usa.com/090823

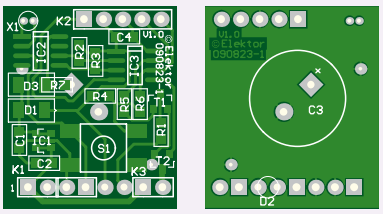


Figure 2. The accompanying PCB is also very compact. The largest component is the GoldCap capacitor on the bottom.

use a programmer to set different switching times for the individual days of the week if you so wish. We decided not to support this via manual entry because it would make setting the times significantly more complicated, and for the simple reason that there wasn't enough memory left to do so.

Override function
You can use this function to manually bypass the switching process. This works as follows:

- The first button press sets the output to **always on**.
- The second button press sets the output to **always off**.
- After the third button press, the output is again controlled by the programmed switching times.

The state of the override function is also stored in the microcontroller's EEPROM to ensure that the time clock continues to operate in the same way as before after a power outage.

Mini PCB

Figure 2 shows the printed circuit board for this minimalistic time clock. To keep everything as small as possible, SMDs are used almost everywhere. Most of the components are fitted on the copper side of the board, with only the backup capacitor and LED D2 fitted on the other side. Two headers (K1 and K3) provide the input and output connections, while K2 is the programming connector. Be sure to use the right type of crystal (6-pF capacitance) when assembling the board, as otherwise the clock IC will not work properly.
Readers who don't want to program the PIC themselves can order a pre-programmed microcontroller from the Elektor Shop (item number **090823-41**). The source code and hex code are available on the Elektor website.

External connections

The PCB has a pair of pin headers for connecting an AC powerline adapter and the switched equipment. In addition to the supply voltage pins, connector K1 has two spare pins that can be used if desired to connect a second push button. This button can be located in a more readily accessible location on the selected enclosure. The switched equipment is connected to connector K3 (see the wiring diagram in **Figure 3**).

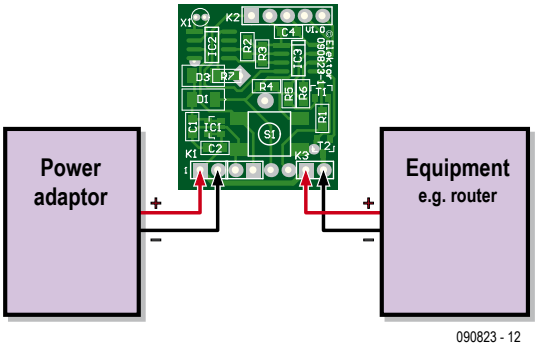


Figure 3. Follow this wiring diagram to ensure that you get the connections right.

The remaining connector on the PCB, K2, can be used for in-circuit programming of the microcontroller. It is intended to be used with a Velleman K8049 PIC programmer. Be sure to use the most recent version of the software for this programmer, as older versions do not support the PIC12F683.
The software is written in Pascal based on Mikropascal 8.0.0.1 from Mikroelektronika. This compiler is ideal for this application because the free version can be used to generate programs with code sizes up to 2 KB, which is exactly the amount of memory available in the PIC12F683.

Other applications

Switching a WiFi router on an off is of course only one example of the potential applications. Thanks to the extremely compact size of this time clock, there's virtually no limit to where it can be used. For example, you could use it to power equipment on and off in a caravan when you're camping, or use it as a time clock in combination with an inexpensive photo frame that doesn't have a built-in clock function. However, bear in mind that due to the choice of voltage regulator, the supply voltage from the switched equipment must lie in the range of 6 to 28 V_{DC}. The MOSFET selected for the switch limits the maximum switching current to 2 A continuous or 5.4 A peak. This is sufficient for practically all equipment that's powered by an AC power adapter.

(090823-I)

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Another two NC Headphones

Testing models from Creative and Bose

By Harry Baggen (Elektor Netherlands Editorial)

After wrapping up last month's tests we received another couple of very interesting NC (noise canceling) headphones: a model made by Creative and a brand new specimen from Bose. Certainly worth the effort of conducting a follow-up mini test.

The Creative Aurvana X-Fi headphones were originally requested for the test that was published in the previous issue, but it took quite a bit of effort to get the European head office of Creative to send a sample to us. When it did finally arrive at was too late as the article for the October 2009 issue was already finished. The second model that we describe here is the Bose QC15, and has only recently been introduced in Europe. We were allowed to test a sample even before it was officially introduced to the European press.
Here follow our findings.

Bose QuietComfort 15

These well-finished, on-ear headphones have bigger earcups than the QC3 model which we tested last month, these enclose the ears completely. The QC15 is supplied with a sturdy carrying case and several accessories such as an airline adaptor and a 6.3-mm adaptor plug. The power is supplied by a single AAA battery, so a special battery is no longer required, unlike the QC3. This is perhaps also the reason why the QC15 is $ 70 cheaper than the QC3 (which is supplied with two batteries and a charging adapter).
The QuietComfort 15 sits comfortably on the head thanks to the large earcups and soft cushions, even after using them for an extended period of time you will hardly notice them. The earcups exert very little pressure on the head, but without immediately compromising the sound isolation.

The connecting cable of the QC15 is easily removed so that you can use the headphones as a noise canceller only. The connecting plug of the cable also has a handy level switch built in, which can be used when the signal level of the source is too high. Unfortunately the QC15 (just as the QC3) produces sound only when a battery is fitted, you can therefore not use them passively.
The sound quality of the QC15 is very good, the total sound image is somewhat more balanced than that of the QC3, with a well-defined mid and high reproduction and a robust, tight low. Here too, the bass reproduction is a little too strong, but not as exaggerated as with the QC3.
Bose have used and entirely new system for the noise cancelation, where microphones are placed on the inside and on the outside of the earcups to generate the correction signals. This should result in a more effective noise cancelation than the QC3. In practice the cancelation of low frequencies was excellent, but because we did not have access to a QC3 any more we could not make a direct comparison. Voices can still be heard reasonably well, perhaps because of the acoustic openings in the earcups. But the most important acoustic noises such as the rumbling of a noisy server or the drone of a bus are almost completely eliminated.

Sound quality: 8.5
Noise cancellation: 8
Wear comfort: 8
RRP: about $425

Creative Aurvana X-Fi

These headphones are also well-finished but have somewhat bigger dimensions than the QC15. As a result the cushions of the earcups cover the ears easily. It is supplied with a carry case and the usual adaptors, with all the connectors gold plated. Power is provided by two AAA-batteries in the left earcup. In the right earcup there are the on/off switch, a volume control and three pushbuttons for activating the NC-system, X-Fi Crystalizer and X-Fi CMSS-3D.

The Aurvana X-Fi fits quite well, but the earcups press a little firmly against the head. While this provides very good acoustic damping it is not as comfortable as the QC15.
The sound quality of the Aurvana X-Fi is rather dependent on the selected settings. With the electronics switched off the sound image is quite average. After switching it on everything sounds a lot better

and the bass response is much fuller. If you turn the NC-system off with the pushbutton than the bass level drops back somewhat. You can improve the sound reproduction a little more by turning on the X-Fi Crystalizer. This X-Fi Crystalizer was originally intended just to improve the play-back of MP3 files, but it functions with any input signal and acts as a kind of equalizer. The third button on the X-Fi CMSS-3D generates a spatial effect. This seems to work quite well with some types of music, but with other kinds of music it creates more of a bathroom acoustic.
A potential negative point of these headphones is the fact that the headphones are not completely closed. A lot of sound leaks through the grills in the earcups so that a person sitting next to you can listen along quite well. This can be a drawback.
The noise cancellation system of the Aurvana X-Fi functions — certainly considering the price — very well. It is a fraction less than the QC15 from Bose, but the difference is minimal. The cancellation of low frequencies is also very good, but voice can still be perceived reasonably well. The difference between these two is too small to make a difference in the score for the noise cancellation function.

Sound quality: 8
Noise cancellation: 8
Wear comfort: 7
RRP: about $300

Conclusion

Both of the headphones tested here provide good noise cancelation, where the Bose QC15 works a little bit more effective than the Aurvana X-Fi. There is not much between them when it comes to sound quality either; the Bose supplies a little better illustrated bass and the Aurvana X-Fi is a little stronger in the reproduction of the mid range (with the correct settings). After an extended period of use, the Bose QC15 proves to be the more comfortable of these two.

Choosing between these two is quite difficult. They both have attractive features, but in the end your own preferences and size of your wallet will be decisive — the price difference is substantial!

(090809-I)

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Hexadoku

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The instructions for this puzzle are straightforward. 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.

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The closing date is 1 January 2010.

Prize winners

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The E-blocks Starter Kit Professional goes to: Kurt Kuehni (Switzerland).
An Elektor SHOP voucher goes to: Primož Prešern (Slovenia), Long Yang (USA), Ria Van Broeck (Belgium).
Congratulations everybody!

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

By Gerard Fonte (USA)

Keep It Simple Stupid or KISS is a fundamental and important concept. This is not to say that things can't or shouldn't be complex. That is often necessary. Rather, KISS is the idea that there is no reason to complicate things beyond what is required. Simple things are easy to fix, cheaper to make and very reliable. Unfortunately it is often overlooked, or else abandoned in an attempt to appear sophisticated and technically proficient.

Old School

In college, way back when, I learned a programming language called PL-1 (somewhat similar to C) which allowed nested function calls (a function that calls a function). I remember spending over an hour constructing a single statement that performed most of the program requirements. It was ridiculously complex. The single statement was several lines long and had multiple nested functions — one at least four nests deep. I got good marks for that because I impressed the professor. But that wasn't 'real-life' code. That was just an academic exercise in education. Unfortunately, what is good in school is not always good in a professional setting. I'd give it failing grade today in any practical application.

The reason is simple. It's way too complicated. If it took me over an hour with a reference book at my elbow. What would it take for someone else to change it when the need arose? Most likely the new person would gag on it, and after wasting hours trying to figure out my subtle musings, would decide to break down it down into a dozen or so separate statements. Then he would change the one or two that needed modification. In short, the single statement was simplified into something more manageable.

This is a key concept to KISS. Others will follow and change your work. Making your project easy to understand and revise saves time and money. That is appreciated by your boss and anyone who touches your software. While it may be personally satisfying to challenge yourself with complex intricacies, it isn't a useful practical approach. And, it's usually faster and easier to write a dozen simple statements than one convoluted one.

All for One

It would be nice if they had a college course in gestalt design. This is the total integration of the whole product right from the beginning. Hardware, software, PCB (printed circuit board) layout, parts selection, etc. It can have a dramatic effect on simplification.

For example, I had a client that needed a Retention Force Meter to fit in their special hand-held case. Since I was doing the whole product design and development by myself it was easy to use a gestalt approach. They defined the LCD display (40 pins). I chose an LCD driver that was also a microprocessor (68 pins). Therefore, I had substantial flexibility in defining the uC output pins. Before I did any programming, I routed the LCD and microprocessor (uC) on the PCB. With some effort I was able to route all the LCD lines without any crossings. That is, all the traces could be placed on a single layer (this included the 40 additional analog parts). The software was then written to match the PCB layout. This didn't really make things very difficult for the software since all the pins had to be controlled individually, anyway.

The client was very happy. He had an inexpensive, single-sided board with wide traces that was easy to fabricate and test. It didn't look sophisticated or high-tech or sexy. And substantial up-front consideration was needed right from the start. This may not be as practical if different people are doing the parts selection, hardware design, PCB layout and software coding. But for the hobbyist or one-man shop, it is an extremely useful strategy.

Invasion of the Creeping Complexities

An important part of KISS is the 'Keep' portion. It often happens that a design starts out very simple. But then an additional function is needed. And then another. And another. After a while the simple design has become a jumbled collection of small circuits that interact with each other in unpredictable ways. A simple working project has become a complicated and unstable structure.

This is especially common with hobbyists who build something that works. Then, later, they decide to enhance it by adding something new or improving its performance. While this is an excellent idea, problems can arise because the initial design didn't consider the added circuit(s). It often happens that the 'final' project either works poorly or consists of too many components.

The are a couple of solutions to this problem. The first is to define all of the functions from the start and then do the design. In this way, it usually becomes apparent if there are redundant parts. And it's easier to determine if the circuits dance well together if they are all designed at the same time. It's also not unusual to perceive a different solution to a problem when all of the pieces are seen together. But, of course, all of the requirements are not always defined from the start. So, stop and think before you start a project. Ask yourself, "If this works well, are there other things I would like to do with this?" If so, then consider those thoughts in your design.

The second solution is when you realize that the new-improved model isn't working the way you expected. You have to patch a fix and then add another circuit to correct something else and nothing seems to give you exactly what you want. This is the time to step back and take a long, hard look at the whole design. Is there a better way? This is hard to do because you've spent so much time on the current model. You don't want to throw away all that work and all those parts. But this is crucial. You will never see a simpler solution if you don't look for it.

Keeping things simple requires common sense and attention to detail. That's also what good engineering is about.

(090933-I)

The Z550M:
an unusual counter tube (ca. 1959)

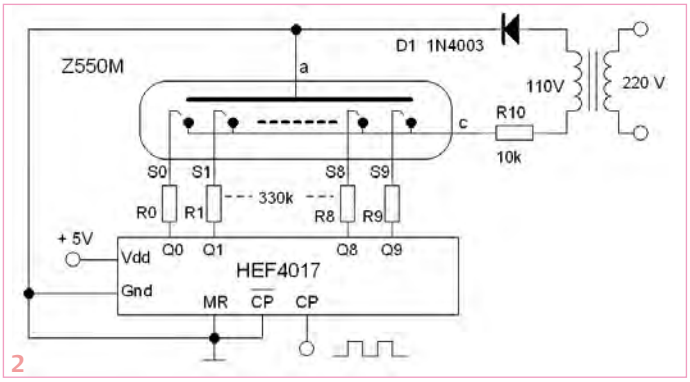
1

By Ronald Dekker
(The Netherlands)

The first version of the popular Nixie tubes launched by Burroughs in 1954 had the disadvantage that a transistor with a fairly high breakdown voltage was needed to drive the tube. Such transistors were very difficult to manufacture in the early day of transistor technology, when transistors were still made from germanium. To allow glow discharge tubes to be operated directly by low-voltage transistor circuits, a pair of researchers at the Philips Research Lab, Theo Botden and Martinus van Tol, developed the Z550M around 1959. A few examples with different markings are shown in **Figure 1**.

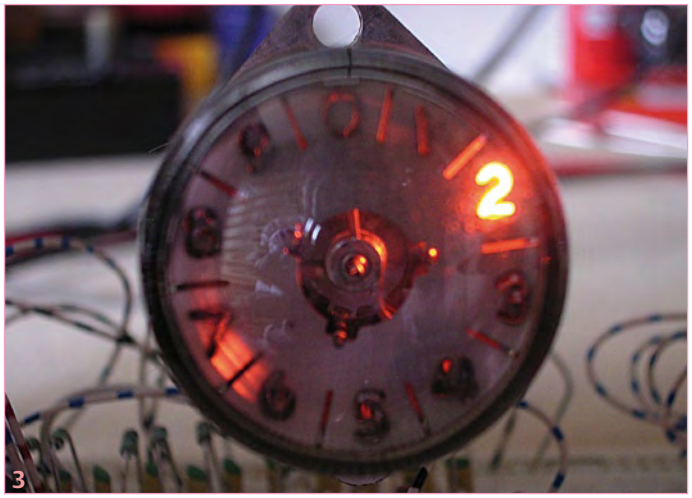
The Z550M consists of a small disc-shaped plate – the anode – with cutouts for the numerals 0 to 9. A set of ten interconnected cathodes is located behind the numerals. A starter electrode is located close to each cathode. A rectified AC voltage is applied between the anode and the cathodes (see the standard application diagram in **Figure 2**). It takes only 5 V on a starter electrode to initiate a glow discharge behind the desired numeral and cause the numeral to light up (**Figure 3**).

In order to understand the operation of the Z550M, you first need to know something about the characteristics of glow discharge tubes. A glow discharge tube has two electrodes, usually made from nickel or molybdenum, in an atmosphere of neon gas at a pressure of a few centimetres Hg. If the voltage between the two electrodes is less than the striking voltage, no current will flow. If the voltage is gradually increased, the gas will break down at a certain voltage. This striking voltage depends on many factors, such as the product of the pressure of the neon gas and the distance between the electrodes. The striking voltage is directly dependent on this product. Once the gas has broken down, a current will flow, and it is limited only by a resistor connected in series with the tube. As a result, the voltage across the tube decreases to the maintaining voltage.



2

If you ignore the starter electrodes in Figure 2, you can clearly see that if the supply voltage is gradually increased, at a certain point the gas between one of the cathodes and the anode will break down. The voltage across the tube will then drop immediately to the maintaining voltage, with the result that the other numerals remain dark. The numeral will remain lit until the next zero crossing of the supply voltage. The distance between the starter electrodes and the cathodes is much less than the distance between the cathodes and the anode, so the striking voltage of the starter electrodes is lower than the striking voltage between the cathodes and the anode. If a slightly elevated voltage (such as a voltage supplied by a transistor or a logic gate) is applied to one of the starter electrodes, the initial gas breakdown will occur there. The high resistance in series with the starter electrode limits the current that must be supplied by the drive circuit to a few tens of milliamperes. It turns out that this small discharge is able to initiate a larger discharge between the associated cathode and the anode.



3

Obviously, this principle can only work if the striking voltages of the various starter electrodes differ by less than 5 V. This proved to be not so easy to achieve. Fortunately, experience gained from decades of research on glow discharge tubes at the Philips Research Lab came in handy here. An extensive research programme focussing on glow discharges was initiated immediately after the lab was founded in 1914. Already before the Second World War, this resulted in several important new products such as fluorescent lamps, low-pressure sodium lamps for street lighting, and high-pressure mercury lamps for applications such as film projectors.

The largest contribution to the development of a fundamental understanding of glow discharges was provided by Frans Penning. In his research, Penning noticed that the striking voltage was strongly dependent on the surface contamination of the cathode. He developed a method for cleaning the cathode by operating the tube for a while with very high current density. The resulting bombardment

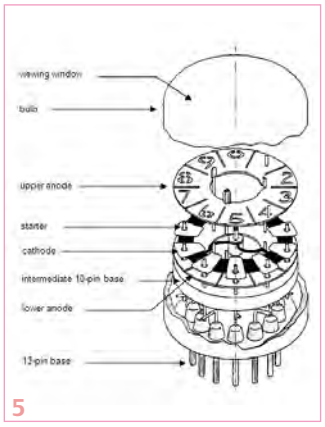
by gas ions cleaned the cathode in a process called 'sputtering'. A supplementary benefit is that the metal ions released from the cathode in this process bind impurities in the gas, which is called 'gettering'. Penning also discovered that if a tiny amount of argon is added to the neon gas, it is possible to not only reduce the striking voltage but also produce an operating region within which the striking voltage is nearly independent of the gas pressure and the electrode separation. Both techniques were applied to the Z550M, and after a bit of experimenting the desired tolerance range was achieved. **Figure 4** shows a picture of the electrode configuration ultimately determined in the lab.

After the feasibility of the Z550M concept had been demonstrated, the project was handed over to a development team in order to make the tube ready for production. The tube was assigned its type number at this time. The development team decided on a somewhat different construction with each starter electrode located in a small hole in the cathode. This made it easier to connect the starter electrodes to the pins of the tube (**Figure 5**). This arrangement also makes the average distance between the starter electrode and the cathode nearly independent of the exact positioning of the starter electrode, which further reduced the spread due to production tolerances. Finally, a small amount of tritium was added to the gas mixture to ensure fast and reliable initiation of the glow discharge. The author's website [1] provides extensive reading material on the history of the development of the Z550M and samples of original lab workbooks.

During this time, Pierre van Vlodrop in the glow discharge tube application lab also got his hands on a few samples of the Z550M. He used the Z550M to build a rather remarkable ring counter in which the starters were used as anodes, as illustrated in **Figure 6** [2]. Here he was able to make good use of the very well defined striking and maintaining voltages (105 V and 85 V, respectively). The operating principle of the ring counter is simple. When the supply voltage is applied, one of the numerals will be triggered at random (for example, 0). The resulting current causes a voltage drop across R10 that is sufficient to keep the other numerals dark. This current also causes a voltage drop of around 10 V over R0, which causes C0 to be charged to 10 V. A negative clock pulse on the base of T1 drives it into conduction, which pulls the supply voltage of the tube to zero and extinguishes the glow discharge. When the supply voltage subsequently rises, starter 1 will have a bias of 10 V relative to the other starters because C0 is the only capacitor with a charge, with the result that that a glow discharge will be initiated in the gas behind the '1' numeral. With each successive clock pulse, the next number in series will light up – simple but effective.

Despite the elegant principles underlying the design of this tube, it never achieved commercial success. Shortly after it was introduced, the BSX21 transistor was developed. With a breakdown voltage

4

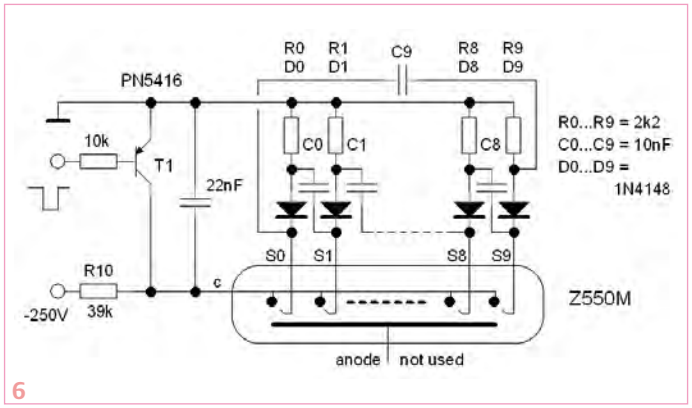


5

(BV_{ceo}) of 80 V, it could be used to drive a Nixie tube directly. In addition, the clockface display was regarded as inconvenient and outmoded, even inside Philips.

The fact that Z550M tubes can be found with Philips, Valvo and Mullard markings suggests that they were produced in large quantities in several Philips plants. In fact, the quantities were so small that they were only made in the pilot production plant on the Emmasingel in Eindhoven. The Eindhoven plant simply put different markings on the tubes according to the intended destination country in order to make them easier to sell.

Pro Electron was founded in Brussels in 1966 to coordinate the registration of European tube and semiconductor type numbers. The Pro Electron organization largely followed the Philips system, with the result that the Z550M was rechristened ZM1050.



6

Now in 2009, the tubes still work very well. However, they do not count as fast now, since the tritium added to the gas mixture to promote fast initiation of the glow discharge has a half-life of 12.5 years, and not much of it is left after 50 years.

(090653-I)

Internet Links

[1] http://www.dos4ever.com/ring/Z550M.html

[2] http://www.dos4ever.com/ring/ring.html

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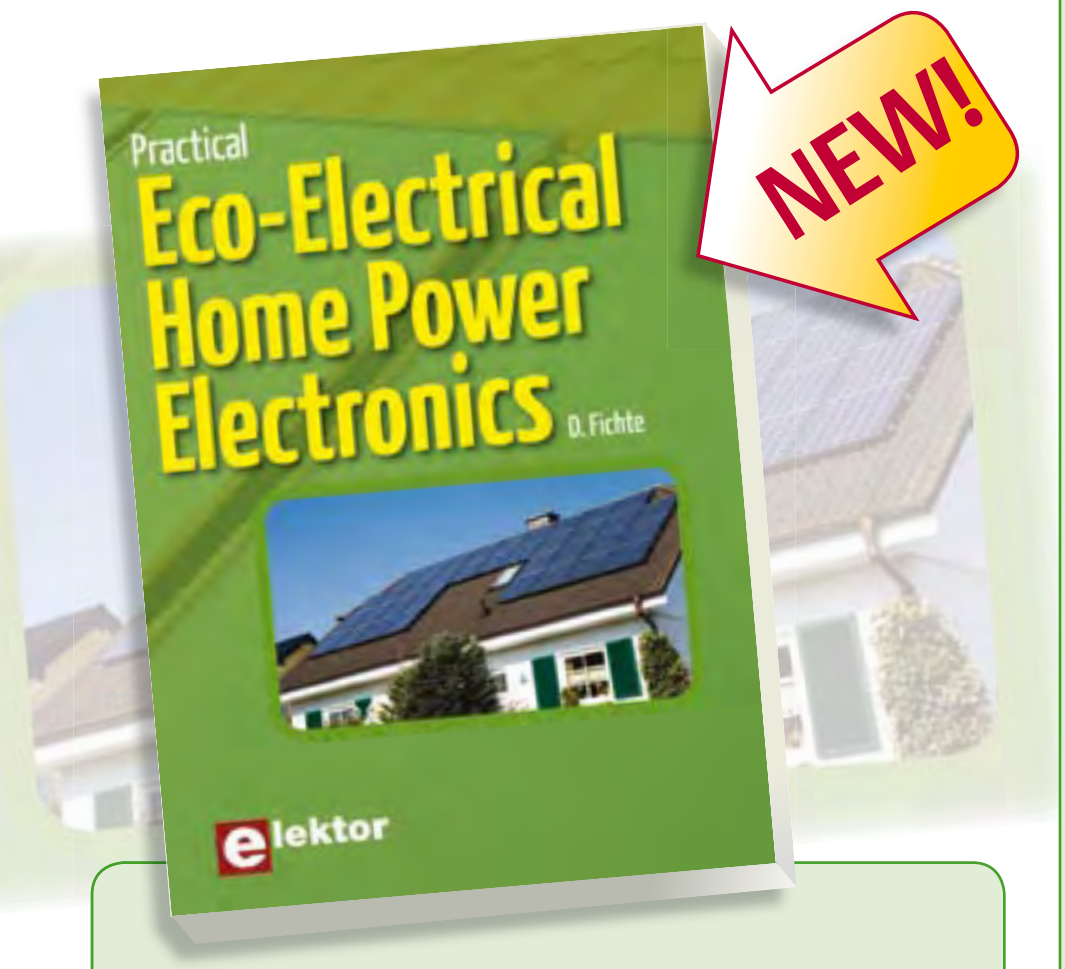

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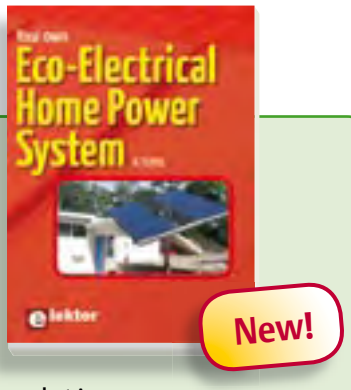

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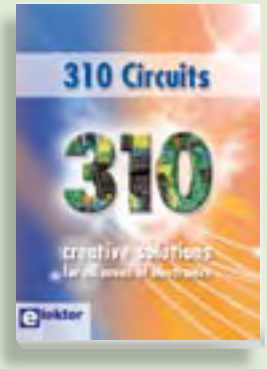

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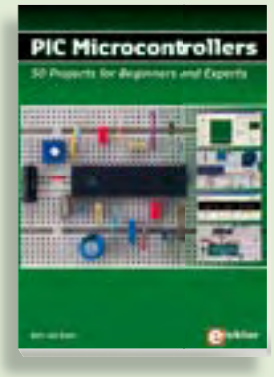

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C# 2008 and .NET programming for Electronic Engineers

This book is aimed at Engineers and Scientists who want to learn about the .NET environment and C# programming or who have an interest in interfacing hardware to a PC. The book covers the Visual Studio 2008 development environment, the .NET framework and C# programming language from data types and program flow to more advanced concepts including object oriented programming. It continues with program debugging, file handling, databases, internet communication and plotting before moving to hardware interfacing using serial and parallel ports and the USB port. It includes a hardware design for a simple oscilloscope using a parallel port and interfacing to analogue and digital I/O using the USB port. This book is complete with many program examples, self assessment exercises and references to supporting videos.

240 pages • ISBN 978-0-905705-81-1 • $44.50

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Elektor's Components Database 5

The program package consists of eight databanks covering ICs, germanium and silicon transistors, FETs, diodes, thyristors, triacs and optocouplers. A further eleven applications cover the calculation of, for example, LED series droppers, zener diode series resistors, voltage regulators and AMVs. A colour band decoder is included for determining resistor and inductor values. ECD 5 gives instant access to data on more than 69,000 components. All databank applications are fully interactive, allowing the user to add, edit and complete component data. This CD-ROM is a must-have for all electronics enthusiasts.

ISBN 978-90-5381-159-7 • $38.00

All articles published in 2008

DVD Elektor 2008

This DVD-ROM contains all editorial articles published in Volume 2008 of the English, Spanish, Dutch, French and German editions of Elektor magazine. Using Adobe Reader, articles are presented in the same layout as originally found in the magazine. The DVD is packed with features including a powerful search engine and the possibility to edit PCB layouts with a graphics program, or printing hard copy at printer resolution. Thanks to the use of an Internet browser program, the requirements for the PC are minimal.

ISBN 978-90-5381-235-8 • $35.00

CD/DVD-ROMs

110 issues, more than 2,100 articles

DVD Elektor 1990 through 1999

This DVD-ROM contains the full range of 1990-1999 volumes (all 110 issues) of Elektor Electronics magazine (PDF). The more than 2,100 separate articles have been classified chronologically by their dates of publication (month/year), but are also listed alphabetically by topic. A comprehensive index enables you to search the entire DVD. The DVD also contains (free of charge) the entire 'The Elektor Datasheet Collection 1...5' CD-ROM series, with the original full datasheets of semiconductors, memory ICs, microcontrollers, and much more.

ISBN 978-0-905705-76-7 • $99.00

See the light on Solid State Lighting

DVD LED Toolbox

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

ISBN 978-90-5381-245-7 • $54.00

R32C Application Board

This R32C Application Board sports pushbuttons, LEDs, an I2C interface, an OLED panel, an SD card interface and a socket for an Ethernet module. There is plenty of space on the board for further expansion.

Kit of parts incl. application board with SMD parts prefitted, plus all other components

Art.# 080082-71 • £112.50 • US $185.00

OBD2 Analyser NG

The compact OBD2 Analyzer in the June 2007 issue was an enormous success — not surprising for an affordable handheld on-board diagnostics device with automatic protocol recognition and error codes explained in plain language. Now enhanced with a graphical display, Cortex M3 processor and an Open Source user interface, the next generation of Elektor's standalone analyser sets new standards for a DIY OBD2 project. The key advantage of the OBD2 Analyser NG is that it's self-contained and can plug into any OBD diagnostic port.

Kit of parts including DXM Module, PCB SMD-prefitted, case, mounting materials and cable

Art.# 090451-71 • $135.00

Software Defined Radio

SD radio receivers use a bare minimum of hardware, relying instead on their software capabilities. The Elektor SDR project (by Burkhard Kainka) demonstrates what's achievable, in this case a multi-purpose receiver covering all bands from 150 kHz to 30 MHz. It's been optimised for receiving DRM and AM broadcasts but is also suitable for listening in to the world of amateur transmissions. The designer's aim for this project was to create a receiver displaying high linearity and phase accuracy. Development was focussed on the characteristics that were most important for a top-notch DRM receiver and the end result is a receiver with remarkable interference rejection characteristics!

Ready-populated and tested board

Art. # 070039-91 • $145.00

Experimenting with the MSP430

All the big electronics manufacturers supply microcontrollers offering a wide range of functions. Texas Instruments supplies handy USB evaluation sticks with related software for its low-cost MSP430 controllers. Unfortunately the I/O facilities are somewhat limited. These can be substantially enhanced with the help of the Elektor MSP430 board.

PCB, populated and tested

Art.# 080558-91 • $55.00

TI eZ430-F2013 Evaluation Kit

Art.# 080558-92 • $35.00

Kits & Modules

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December 2009 (No. 12) $

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November 2009 (No. 11)

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AVR-Max Chess Computer
081101-1 ....Printed circuit board 18.75
081101-41 ...Programmed controller ATmega88 ..... 16.50
081101-71 ...Kit of parts incl. PCB, programmed controller and components 44.00

R32C Web Server
080082-71 ...Application Board with SMD parts prefitted, plus all other components 185.00
080928-91 ...R32C Starter Kit: processor board populated and tested, Toolchain on CD 42.50
090607-71 ...PCB, populated and tested WIZ812MJ module with W5100 chip 25.00

October 2009 (No. 10)

Pocket Preamp
080278-71 ...Kit of parts 95.00

Digital Barometric Altimeter
080444-41 ...PIC18F2423, programmed 24.00

September 2009 (No. 9)

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080928-91 ...R32C Starterkit: Processor board populated and tested, Toolchain on CD 42.50

OBD Analyser NG
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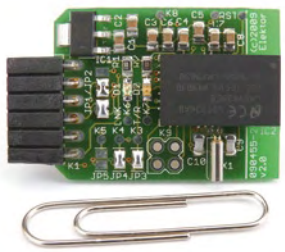
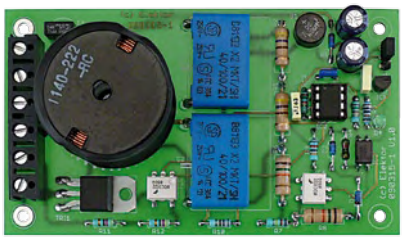
USB step by step

Many designers with otherwise fine ideas about connecting stuff to their PC resent the virtual disappearance of the trusted RS232 and Centronics ports that were sooo easy to write software for. The successor port called USB is a massive success commercially but feared by many for its complexity when it comes to being used as a gateway to homebrew circuits. In next month's article we present a step by step guide to getting USB-equipped peripherals to do the things you want to, guiding you through the hardware, a cheap Atmel AVR-USB development board, and software abstractions like libraries, DLLs and HIDs. For starters you will learn how to flash LEDs and read a miniature joystick, based on a library that's free to use by everyone.



Compact TTL-Bluetooth module

Laptops, mobile phones and PDAs — you mention it, these days it's bound to have a Bluetooth interface. USB Bluetooth dongles are available at low prices, which opens the way to using these wireless devices to link your own circuits to a PC. To do so, all you need is the compact TTL-Bluetooth dongle we'll describe in next month's edition. Besides the LMX9838 chip with its integrated radio transceiver the board contains just a handful of parts, including a connector for audio applications.



Microcontroller controlled dimmer

This dimmer employs an unusual method for brightness adjustment. The dimmer may be programmed by switching the lamp on and then right off again, whereupon the brightness is increased in small steps. As soon as the desired brightness is achieved, you press the switch again. The next time the lamp is switched on it will light at the desired brightness. This solution is also suitable for dimming a lamp via two switches in a staircase configuration.

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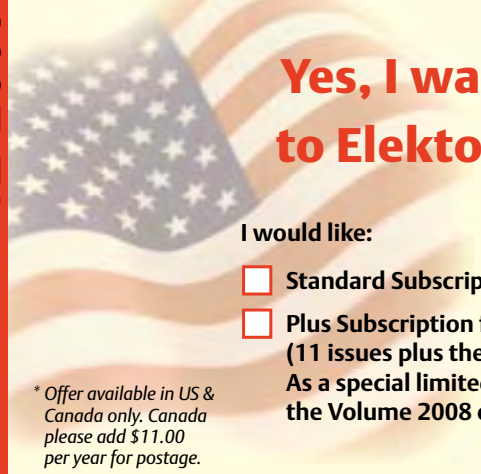

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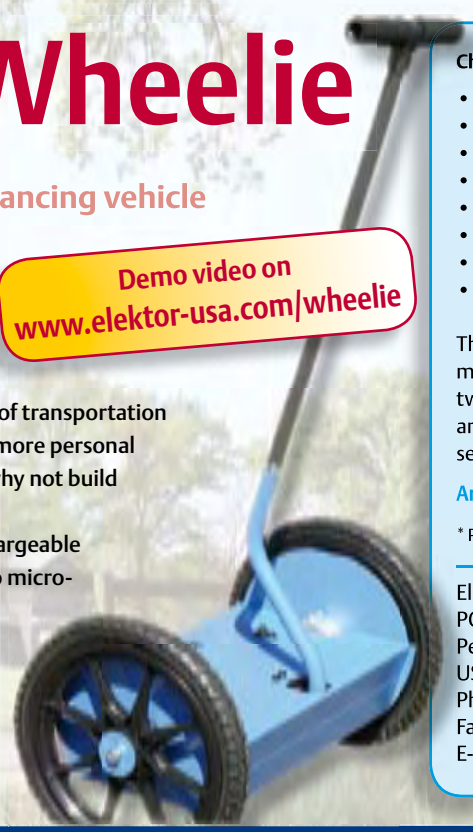
ElektorWheelie

Elektor's DIY self-balancing vehicle

Demo video on www.elektor-usa.com/wheelie

Everyone agrees that the internal combustion engine is coming to the end of its life cycle. However, you don't need to go to the expense of a Prius or Tesla to experience the future of transportation devices. If you would prefer something more personal (and don't mind turning a few heads), why not build the astonishing ElektorWheelie?
First take two electric motors, two rechargeable batteries and two sensors, then add two micro-controllers, and the ElektorWheelie is ready to transport you in style to your destination.



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- H-bridge PWM motor control up to 25 A
- Automatic power off on dismount
- Maximum speed approx. 11 mph (18 km/h)
- Range approx. 5 miles (8 km)
- Weight approx. 35 kg

The kit comprises two 500-watt DC drive motors, two 12-V lead-acid AGM batteries, two 16-inch ABS wheels, casing, control lever and assembled and tested control board with sensor board fitted on top.

Art.# 090248-71 • $2275.00*

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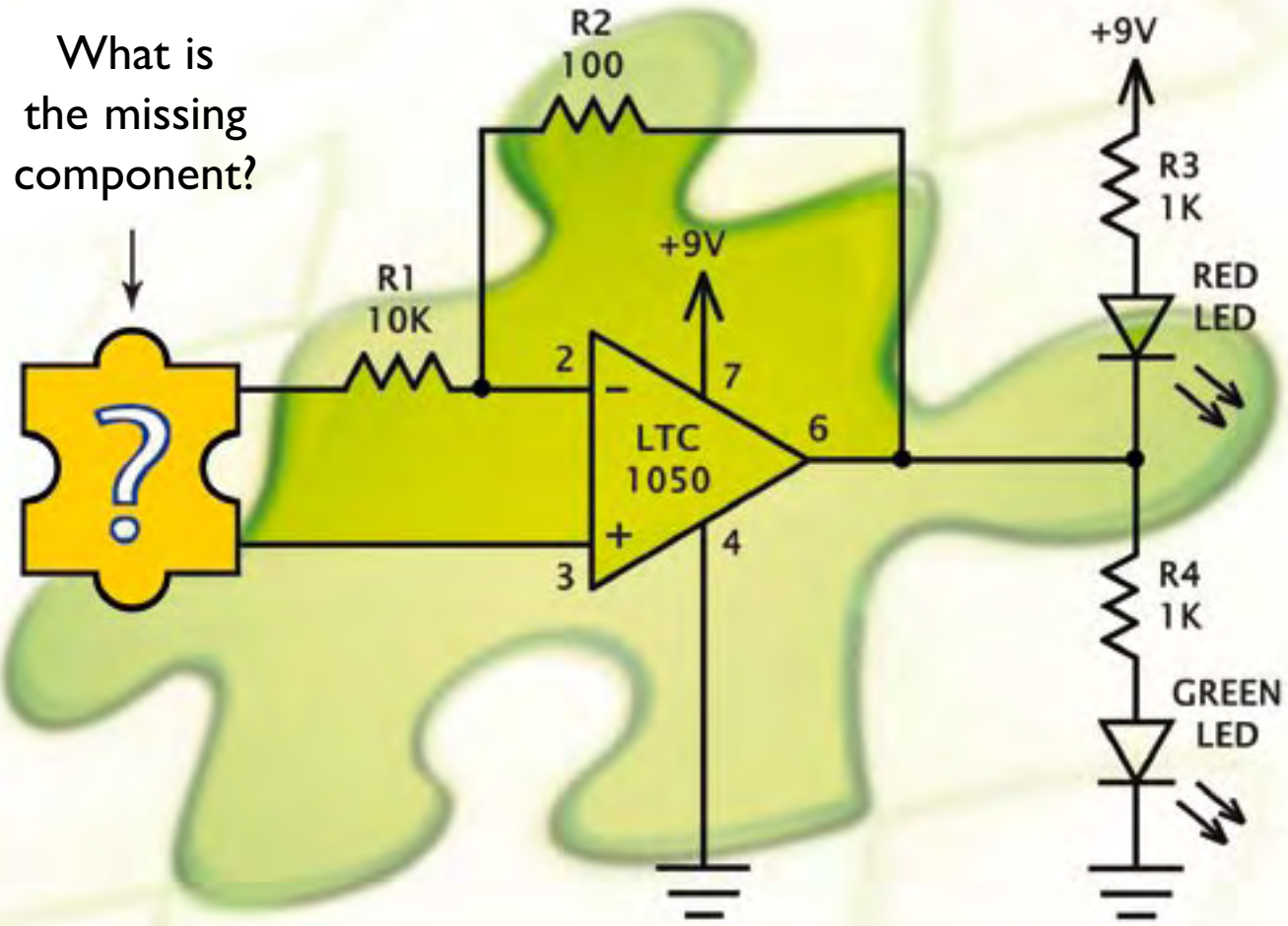

Industry guru Forrest M. Mims III has created a stumper. Video game designer Bob Wheels needed an inexpensive, counter-clockwise rotation detector for a radio-controlled car that could withstand the busy hands of a teenaged game player and endure lots of punishment. Can you figure out what's missing? Go to www.Jameco.com/unwrap to see if you are correct and while you are there, sign-up for our free full color catalog.

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