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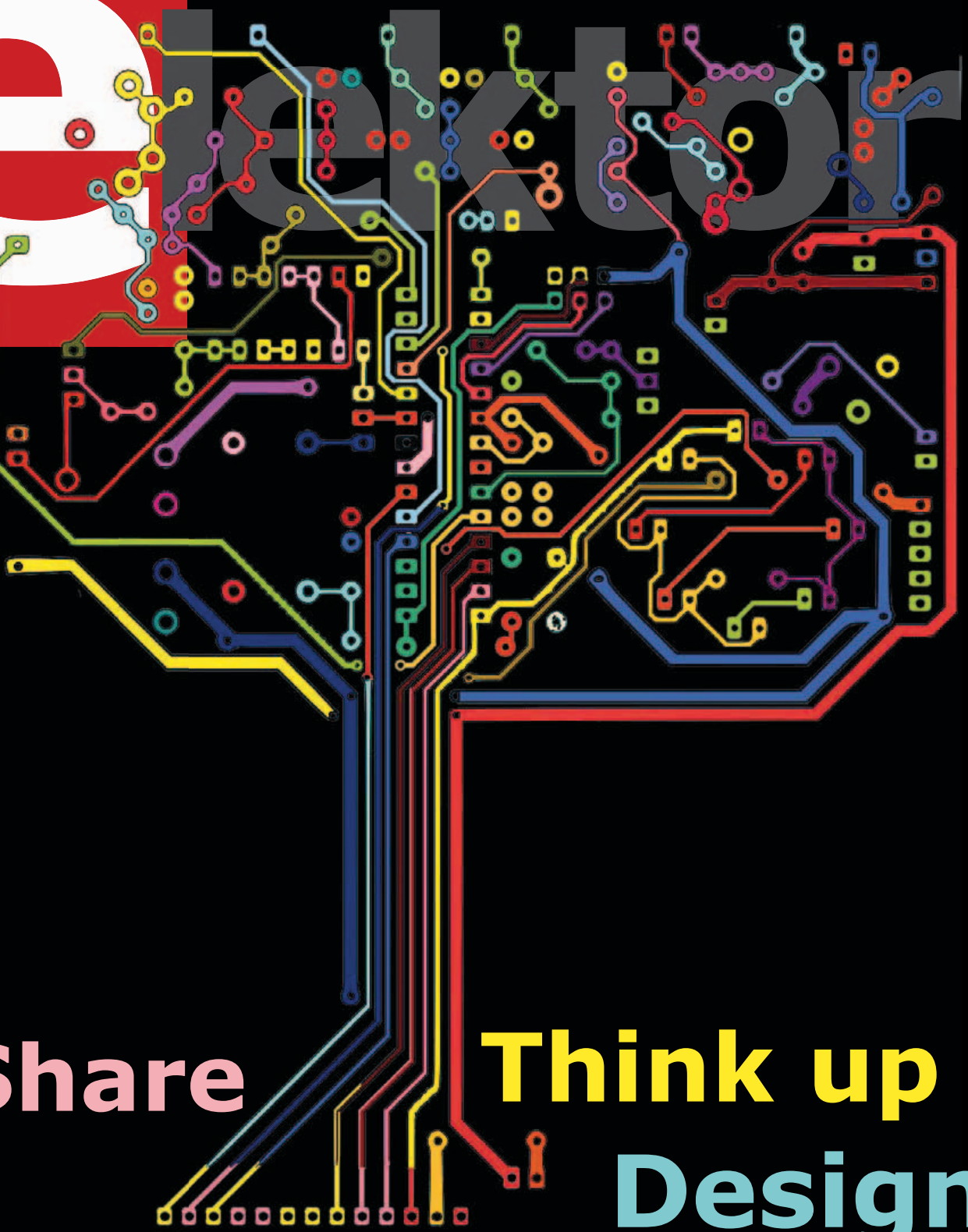

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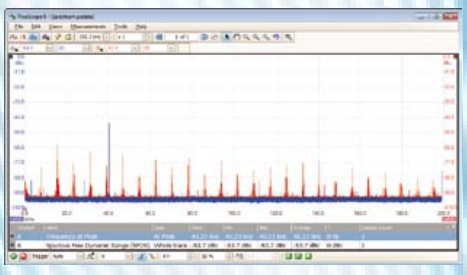
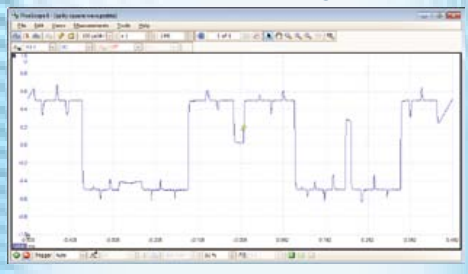


Spectrum analyzer

Serial decoding



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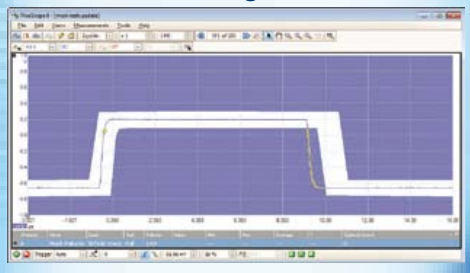

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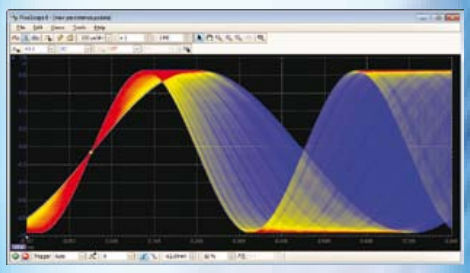

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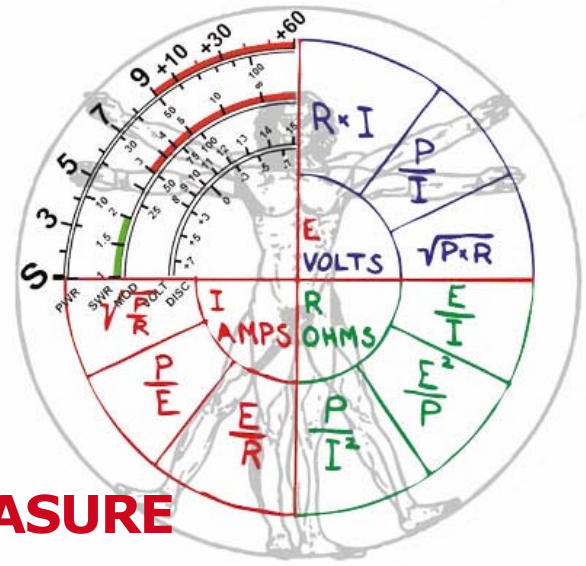

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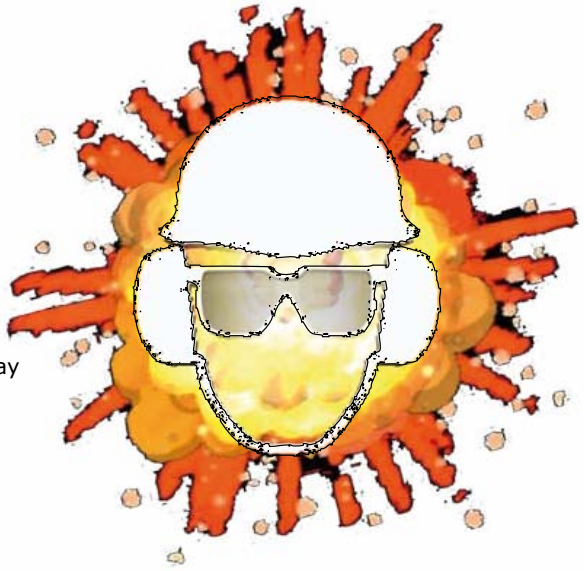

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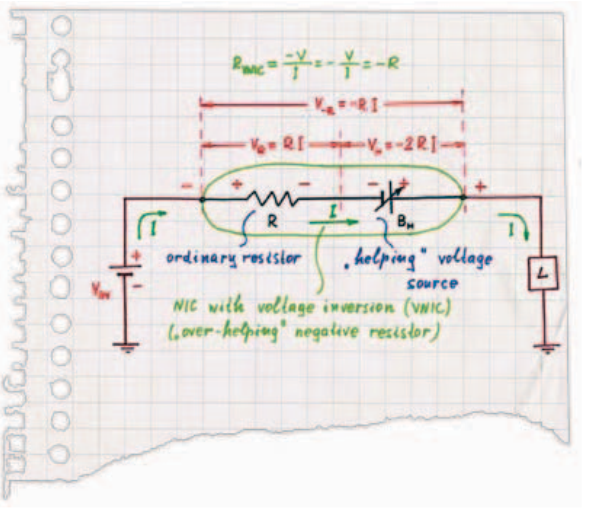

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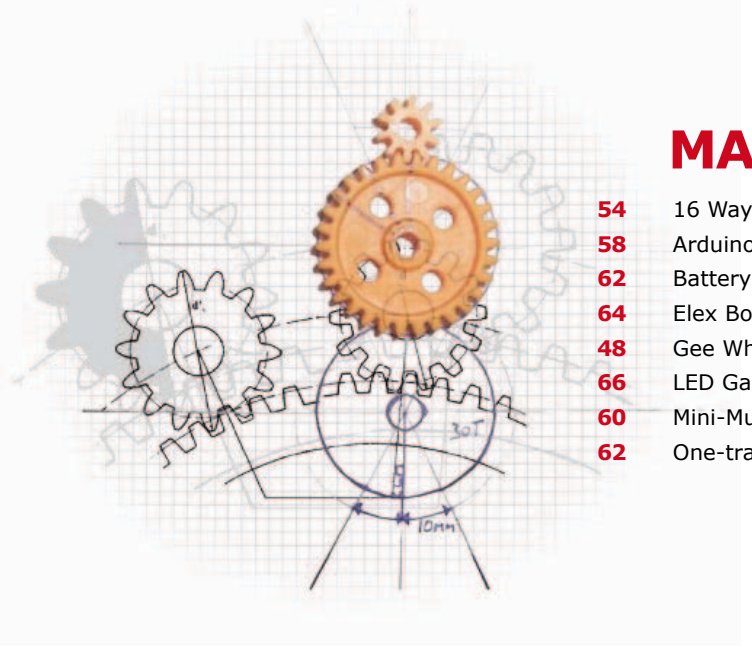

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No. 43-44, JULY-AUGUST 2012 ISSN 1947-3753

Elektor (ISSN 1947-3753) is published monthly (except for one issue in July/August) at $40 per year, Canada add $15 per year;
by Elektor International Media LLC,
4 Park Street, Vernon, CT 06066, USA.
Phone: 860-875-2199, Fax: 860-871-0411.
www.elektor.com

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

Subscriptions:
Elektor USA, P.O. Box 462228, Escondido, CA 92046.
Phone: 800-269-6301
E-mail: elektor@pcspublink.com
Internet: www.elektor.com

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

US Advertising:
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GET ELEKTORIZED

The first time I got electrified happened when working on the high tension (HT) section of a junked TV set. I was young and wet behind the ears and I had heard that any TV could be turned into a simple oscilloscope simply by rotating the CRT deflection yokes — it turned out to be a shocking experience!

Sure, from time to time I got jolts from the AC domestic grid, too. However I was awe-struck by the explosive short circuit I caused by dropping a spanner between the terminals of a car battery. The spanner virtually disappeared and my hand was temporarily paralyzed. Low tension – massive amps with ditto blast forces released!

From then on the word 'tension' to me had a different meaning altogether ... you get it, the real life.

My memories of electrifying events were prompted by association by some exciting things happening in the Elektor scene. We recently soft-launched a new website for our Plus members and contributors-by-invitation'. The site, www.elektor-projects.com, is a kind of 'live' version of the magazine. On it, we haul projects from the first vague ideas right up to where a working prototype is available, all using the motto: *Get Elektorized*. We hope to see our members get Elektorized, that is: start a new project, try a new technology, start and finish a project assisted by Elektor, participate in a game or challenge — we have the plans on our desks.

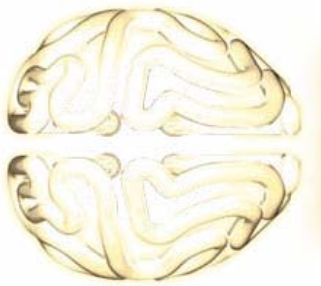
Get Elektorized also means sharing your project proposal with others. If the Elektor editors and lab workers favor your proposal, they will get in touch with you on opportunities for publishing the project in the magazine. In this way, your ideas and projects can actually generate money.

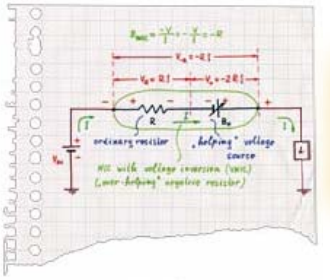
We view the current July & August double edition as a golden opportunity to inundate you with projects and ideas. And because we know that many of you like to preserve, archive and even Ebay-off our summer editions, this time we have done our best to put in as much quality as we could.

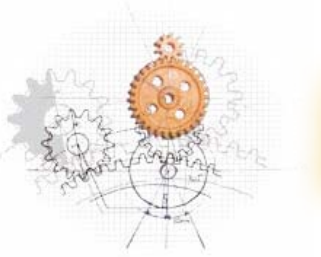
Have fun and ... Get Elektorized

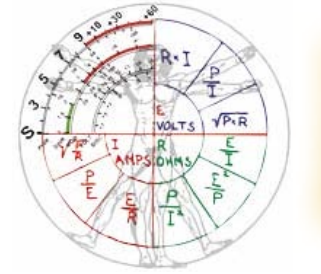
Wisse Hettinga

PS
The last time I was electrified happened during a recording for the June 2012 edition. Every month I do a short video presentation on the main topics in the brand new edition, and yes this time in my enthusiasm managed to touch the 160 V plate voltage of a Nixie tube! You can see (and hear) it happen at www.youtube.com/elektorim.









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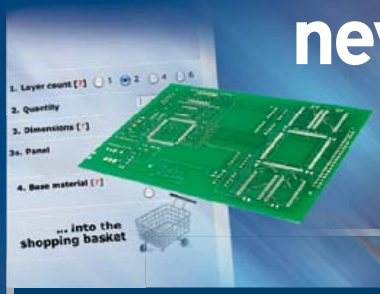

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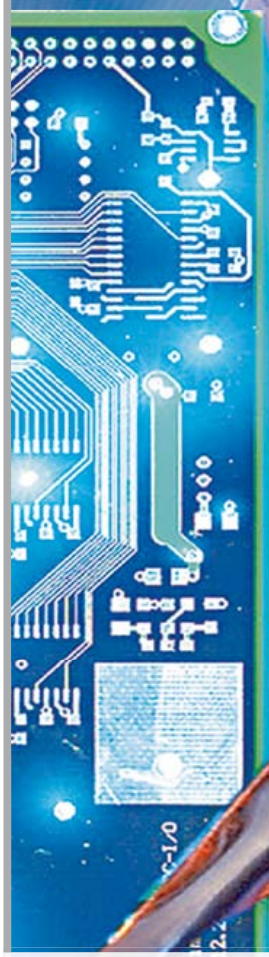

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The award ranks the top companies in the industry based on five key areas; innovative element of the product, leverage of leading-edge technology, value-added features & benefits, increased customer ROI (return on investment) and customer acquisition potential. The WiPry products scored the highest in three key areas: innovative elements, value-added features, and increased customer ROI. WiPry products are more than just the emerging standard in handheld RF test equipment for cellular communication planners, RF engineers, wireless network technicians and avid electronics hobbyists; it is a proven tool for success.

"The unique value proposition found with Oscium's WiPry family of products is the complete redesign of the interface experience with test equipment… Among the additional benefits that customers experience upon adopting Oscium's product is the fact that the WiPry is modular. This factor gives the company an important competitive advantage over similar industry solutions, as it lowers operational costs in comparison with other products used," said Mariano Kimbara, Frost & Sullivan Measurement & Instrumentation Analyst.

"We are thrilled that Frost & Sullivan has recognized the WiPry family of products as leaders in their field," said Bryan Lee, President of Oscium. "This award is significant because it set us apart in the industry, and it quantifies our contribution as: #1 in leading innovation, #1 in creating customer value and #1 in providing the most features and benefits."

The WiPry family of products applications are available to download free in the Apple App Store. The WiPry family of products apps are compatible with all generations of iPhone, iPod touch, and iPad devices running iOS version 3.1.3 or higher. It is made for: iPod touch (1st, 2nd, 3rd, and 4th generation), iPhone 4S, iPhone 4, iPhone 3GS, iPhone 3G, iPhone, iPad 3, iPad 2, and iPad. WiPry hardware can be purchased from Oscium directly or from one of their partners.

www.oscium.com
(120419-I)

Pololu Zumo chassis kit

Pololu announces the release of the Zumo chassis, a small, low-profile tracked robot platform. The main body is composed of ABS plastic and features sockets for two micro metal gear motors and a compartment for four AA batteries (motors and batteries sold separately). The micro metal gear motors are available in a wide range of gear ratios, making it possible to select the ones that have the best blend of torque and speed for the particular Zumo application. The chassis ships as a kit and, along with the main body, includes two silicone tracks, two drive and two idler sprockets, an acrylic mounting plate, and mounting hardware.

With dimensions of 98x86mm, the Zumo can qualify for Mini Sumo competitions. For such applications, Pololu separately offers a basic stainless steel

sumo blade, which can be mounted to the front of the Zumo chassis to push around other objects, such as other Mini Sumo robots. The design file for the sumo blade is publicly available and can be used as a starting point for custom laser-cut blades.

The Zumo chassis (item #1418) is available for $19.95. A full list of the kit contents and assembly instructions is available at the Pololu website.

www.pololu.com/catalog/product/1418
(120419-II)

Lowest power consumption industrial 2.4GHz transceiver

Atmel® Corporation recently announced a new RF transceiver for battery-operated wireless applications. The Atmel AT86RF233 transceiver is

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optimized for industrial and consumer products that comply with ZigBee/IEEE 802.15.4, IPv6 over low-power wireless personal area networks (6LoWPAN) and high data rate 2.4GHz industrial, scientific and medical (ISM) band applications.

The AT86RF233 transceiver offers 60 percent lower power consumption than its closest competitors. At the same time, the transceiver improves the superior RF performance for which Atmel's RF products are widely renowned, making it an ideal solution for products such as gas and water meters, monitoring and control systems, and energy-harvesting equipment.

Since target applications in these segments call for years of battery life without maintenance, a low-power, high-performance transceiver such as the AT86RF233 fits the bill. The AT86RF233 provides transceiver current consumption of 14 mA, receiver current consumption of 6mA and sleep current consumption of 0.02 µA. For a complete solution, design engineers can use a low-power, high-performance Atmel AVR® or an Atmel ARM® processor-based microcontroller (MCU) — two of the world's most popular MCU architectures — as a companion chip. Together, the AT86RF233 transceiver and an AVR XMEGA® MCU can deliver a low-power, cost-optimized solution to meet the operational requirements of applications that spend most of their time in low-power sleep mode and need fast wake-up times and short, active cycles.

As a highly integrated solution, the AT86RF233 requires minimal external components. Design engineers can, therefore, lower their bill of material (BOM) costs and also reduce system board space. With support for antenna diversity, the AT86RF233 enhances RF performance and link reliability. On-board Advanced Encryption Standard (AES) ensures secure wireless end-to-end communication.

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nication stacks, the AT86RF233 transceiver can be integrated into any design with efficiency. Designers who pair the transceiver with an AVR XMEGA MCU can further optimize their design environment with Atmel Studio 6, the newest integrated development environment. Supporting both AVR MCUs as well as Atmel ARM Cortex™-M processor-based devices, Atmel Studio 6 comes with 1,000 project examples with source code that eliminate most of the low-level coding in a design.
The AT86RF233 transceiver is available with the REB233SMAD-EK evaluation kit, which includes two AT86RF233 radio evaluation boards paired with the AVR XMEGA ATxmega256A3 MCU. Atmel also provides, free of charge, a variety of network software and programming examples, including the BitCloud® ZigBee PRO and the BitCloud Public Profile Suite.

www.atmel.com
(120304-VII)

Stereo spatial audio experience for smartphones and tablets

Texas Instruments recently introduced an integrated circuit (IC) that converts a smartphone or tablet computer's narrow soundstage into a much wider and exciting audio experience for consumers. The stereo spatial array IC and companion software tool enable mobile device designers to overcome the limited soundstage of closely spaced speakers by manipulating sounds in 3D space to create a bigger, more immersive cinematic experience. The LM48903 stereo Class D spatial array joins a family of innovative spatial audio ICs designed for space-constrained applications from smartphones to ultra-slim flatscreen TVs.

Key features and benefits of the LM48903 include

Complete audio solution: IC integrates a spatial processing DSP, two Class D amplifiers, 18-bit stereo analogue-to-digital converter (ADC), phase-locked loop (PLL), and I2S and I2C interfaces.
Simplified audio effect programming: Easy-to-use software tool speeds development by eliminating the customer's need for algorithm tuning and in-house DSP experts.
Immersive audio effect: Enables differentiated products that defy physical system size to provide an expanded soundstage superior to competitive solutions.

Integrated 2-watt speaker drivers: Two Class D speaker drivers deliver 2 W per channel of continuous output power into a 4 ohm load with less than 1 percent total harmonic distortion plus noise (THD+N) to simplify system design and reduce bill of materials.
The LM48903's web-based Speaker Array Designer tool includes an easy-to-use coefficient generator that creates unique spatial audio coefficients in a few easy steps. Also included are Android drivers and an evaluation board with graphical user interface.
The LM48903 is available today in a 30-bump, 2.7-mm x 3.2-mm micro SMD package.

www.ti.com/spatial2-preu
(120304-V)

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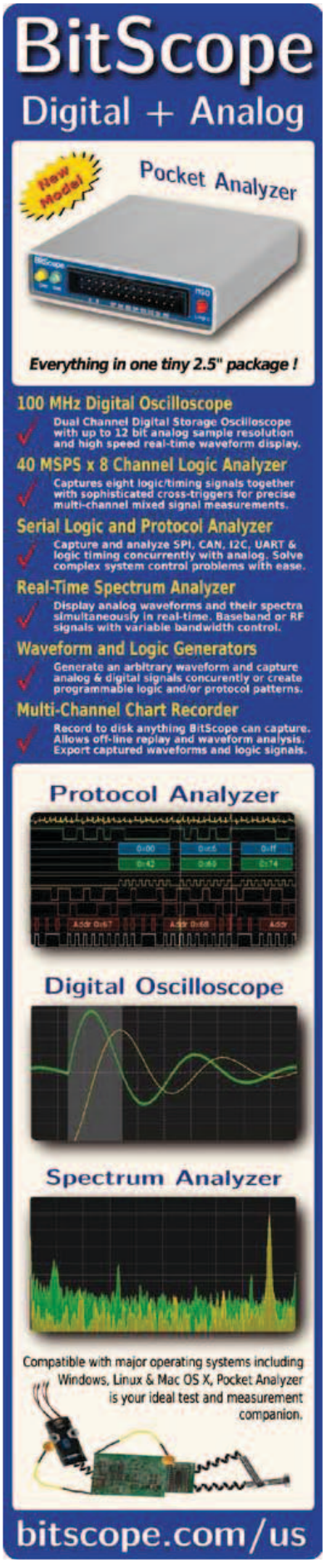

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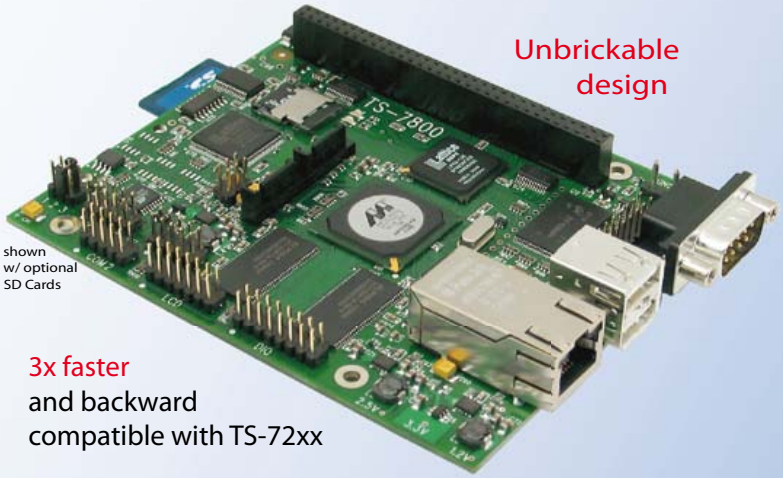

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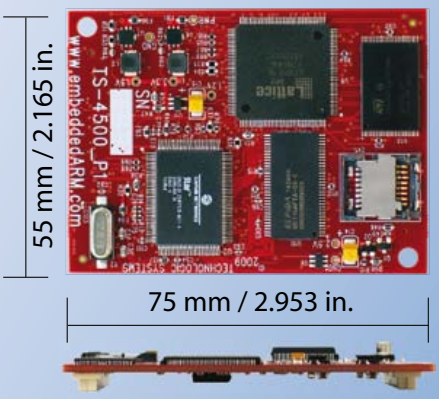

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elektor PROJECTS on the web

At the beginning of May Elektor discreetly launched its brand new online experience called *Elektor Projects*. This new website is pitched to be an electronics projects playground for you, the Elektor member. The site allows you to read about projects, vote for project proposals you like, and contribute to peer projects. But that's not all. *Elektor Projects* is also set up to stage activities for you, like games, design challenges and community projects in which you too can participate. And it doesn't stop here either, no sir, we go all the way by offering you a chance to make money from your passion!

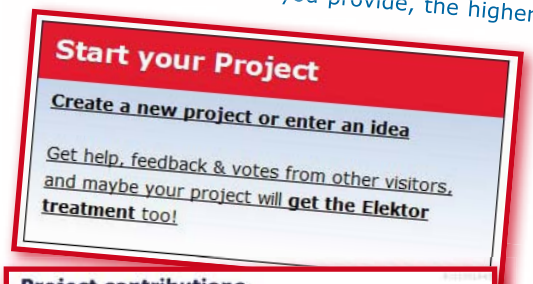
Go with the flow

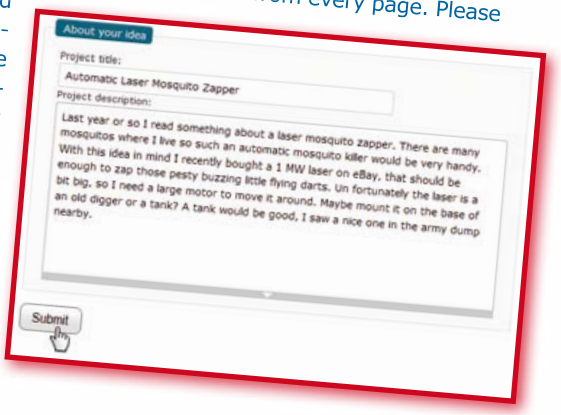
Proposals ➡ In Progress ➡ Finished

The work flow on *Elektor Projects* is simple. It all starts by entering a project or a proposal that's subject to voting by other members. If an entry attracts many votes or if Elektor tech staffers consider the subject of particular interest, the proposal is promoted to *In Progress*, meaning it's a registered project from then on. The goal of registered projects is to reach completion, to get published in Elektor magazine and/or to culminate in a product that can be sold in the Elektor's online shop. Once a project is finished it gets transferred to our *Finished Projects* archive where it will remain available for future reference.

Create and share

To enter a project or a proposal, simply click the red Start-your-Project box that's accessible from every page. Please provide a clear title enabling other members to quickly understand what it is about. The description box allows you to supply a short description but you can also enter a finished project report. The more information you provide, the higher your chances of getting others interested. After clicking the Submit button your entry is validated and other members can start voting for it. You can edit it by opening its newly created project page.





Participate and get noticed

You can contribute to projects in all phases: *Proposal*, *In Progress* or *Finished*. Simply click the Create Contribution link at the bottom of a project page. Adding a comment to a contribution is also possible. This way we keep related information nicely grouped together without cluttering the main project page. When you join a project you will receive notification messages whenever the project is updated. Of course you can always unjoin.

Vote and get elected

Another good way to actively participate on *Elektor Projects* is by voting for any project entries you like. To vote you either go to the Home page or to the Proposals list page. You can also unvote an entry when you think it's a poor show. Every member can vote or unvote only once per entry, so it is not possible to overrate your own proposal by putting hundreds of votes on it. On the other hand, it is possible to create a buzz on a project using the usual social media.

Elektor Labs will back you up

Once a project has been promoted to *In Progress* it is time to get going. Note that it is crucial to upload a good header picture for your project. Without one it will never appear in the gallery on the Home page. If you run into problems you can ask other members for help, you can even ask the Elektor Labs for support. If your project attracts many followers Elektor may back you up if needed to improve your chances of finishing the project in a successful way.

Get more out of your passion, get Elektorized!

Elektor Projects is more than simply "doing projects". If your project is advancing well, we may offer you a contract to write about it in Elektor magazine. That's right, you can become a paid author. Another possibility is putting the fruits of your work up for sale in the Elektor Shops and make money from your hobby. And there's more. We at Elektor are always on the lookout for talented people. Show off your skills and knowledge in projects, contributions or challenges and get noticed. Be an expert and we will reward you!

The Renesas RL78 Ecosystem

Design with the power of partnership

Time to market is everything. Most any micro can move bits around, contains timers, serial I/O, and other peripherals. Industry surveys continue to show engineers want software, solutions, and support as well as silicon. That's why at Renesas we work hard to bring you a well-rounded Ecosystem in addition to cutting edge MCUs.

By Rob Dautel (USA)

Remember the 80's? Big hair, bright, pastel clothing, and electronic music. How about MCU development? Reading physical databooks and software manuals, working with cumbersome command line tools, and using as much as 4 K of memory? If you were working on a high end system, you may have been lucky enough to work with that new technology called DRAM.
Perhaps you're too young to remember MCU work in the 80's. It was pioneering and driven. Every byte counted, you had to know what the bits did, and if you needed a function, you wrote it. Fortunately, the 80's are gone save for a few bands that have hung on, but that's a topic for another time.

Today's engineers want solutions, reuse, and quick turn around on designs. A microcontroller company cannot afford to just dump off a few books, wish the design team good luck, and stop back in a few months for production orders. An MCU vendor must provide an ecosystem for the controllers they offer and that ecosystem must be robust and agile enough to hold up to the demands of customers large and small. At Renesas, that's exactly what we've done.

The RL78 has an extensive ecosystem from training to support to partners. In the following few paragraphs, I'll touch on a few key points of the Renesas ecosystem which supports not only the RL78, but all Renesas MCUs.

Training. No one wants to read a thousand page databook right? Ok, perhaps if you're trying to cure a case of insomnia. Renesas provides a range of options for getting started with the RL78. Our first stop is www.RenesasInteractive.com which is our eLearning site. Operating 24/7, RenesasInteractive holds hundreds of courses on technology, microcontrollers, and tools. This is a great way to get a quick overview on an MCU, a brush up on some technology, or a deep dive into how a peripheral works. If you prefer the more hands on approach, Renesas and our distributors offer local and on site trainings constantly, and these in person trainings can be tailored to your specific needs. Need even more? Every two years, Renesas hosts its developer's conference, or DevCon. The next one is coming in October 2012, in Orange County, California, USA. This 3 and half day event features more than 120 technical sessions and labs from Renesas and our partners along with expert panels, discussions, and an exhibits floor. You can learn more about DevCon 2012 at www.RenesasDevCon.com.

Support. When you need it, we've got it. Renesas provides support from factory FAEs, distribution FAEs trained on Renesas products, an Applications Center, global support emails, and several online services such as our community support forums www.RenesasRulz.com which host thousands of threads and conversations, and great blogs such as our Dr. Micro who serves up interesting tech bits on a regular basis. There's also the RenesasPresents YouTube channel, www.youtube.com/RenesasPresents, with dozens of videos on a variety of topics.

Partners. The RL78/G13 RDK used in the RL78 Green Energy Challenge is the culmination of many Renesas Alliance

partners working tirelessly to support and offer solutions to ease the burden of evaluation, development, and aide in time to market. Alliance partners offer products and services ranging from software and stacks to design services, consulting, and full turn-key production. For an overview of the Alliance program and to see all of the partners, check out www.renesas.com/alliance

Representing just a fraction of the overall Renesas Alliance partners, several have taken an active role in the RL78 Green Energy Challenge. It is these partners who have helped to make the RL78 Green Energy Challenge fun and exciting with additional prizes and weekly giveaways. You can find out more about these partners at www.circuitcellar.com/contests/renesasRL78challenge/sponsors.html.

Although we've touched on a few, there are many other aspects to the Renesas ecosystem supporting the RL78 and other MCUs. I would invite you to take a look and make use of these services. Our vast ecosystem is here to serve you and we truly hope you enjoy participating in the RL78 Green Energy Challenge. We're excited to see the great designs that are being dreamt up for the RL78.

In closing, let's have a bit of fun, since I began with the 80's, I'll end with the 80's. Below is a line from my favorite 80's bands. Be one of the first 5 people to email me the band and title and I'll send you an RL78/G13 RDK.

Lyrics: "how can I explain, when there are few words I can choose?"

(120295)

The Elektor/Circuit Cellar/Renesas RL78 Green Energy Challenge is on at

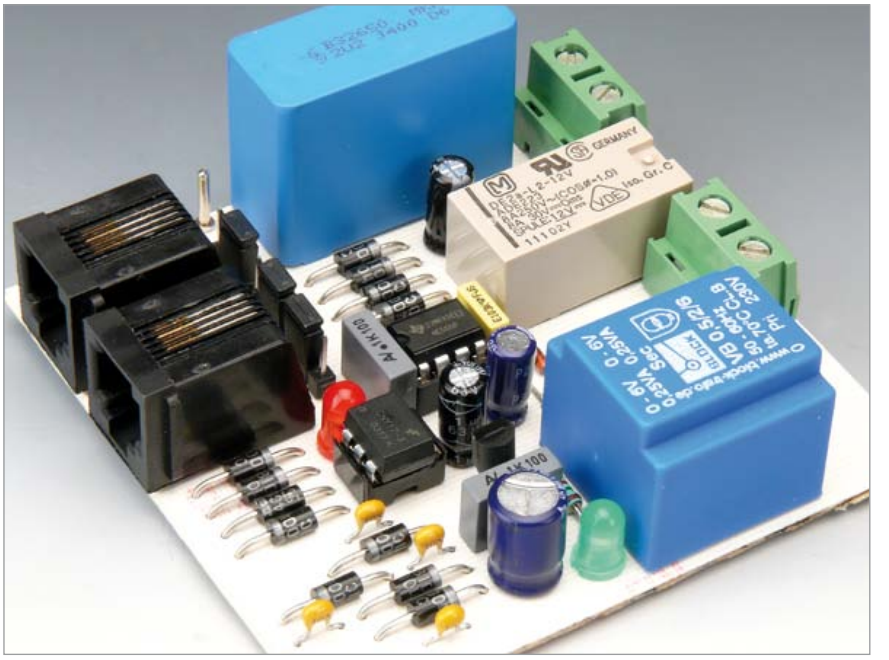
www.circuitcellar.com/contests/renesasRL78challenge

Rob Dautel, Sr. Manager of Ecosystems at Renesas Electronics America, has more than 24 years experience in hardware, software, and ASIC design. He is an expert in digital audio, industrial control, and development tools. He 'speaks' 22 different programming languages. (rob.dautel@renesas.com)

Advertisement

Goodbye Standby

By Uwe Reiser (Germany)



Energy saving has been a hot topic for some forty years now. In the early years the focus of public, political and specialist attention was on the large-scale users of energy, but now attention is also turning to the much more numerous smaller-scale users, on the principle that 'many a mickle makes a muckle'. After a series of bans imposed on ordinary incandescent light bulbs and the introduction of energy-saving bulbs in all shapes and sizes, the EU has recently started to take a look at the energy use of appliances in standby mode. Limits have been set that affect even small mains adaptors. However, one appliance, of which there are many millions in use in the country, and which wastes energy round the clock, has surprisingly somehow managed so far to avoid proper scrutiny: the humble fixed-line telephone.

The author, however, had not failed to notice this needless loss of energy. It had been a source of mild irritation for some time that even the most state-of-the-art fixed-line telephone is doing nothing most of the time except waiting for an incoming call, and yet needs a mains adaptor drawing power all day. It is perhaps worth knowing that most older telephones [1], [2], such as the type 706, draw no current at all when idle. This would be the ideal to which the author would aspire: a current draw in standby mode of zero. Furthermore, the energy-saving circuit itself should be as efficient as possible, preferably switching itself off completely as well.

Telephone without standby current

You will now no doubt be wondering how the author managed to satisfy these requirements. The fundamental question is how a circuit that draws no current can detect when it needs to come into operation. This is indeed possible and in fact not as problematic as it might appear. As is well known, the fixed-line network operator feeds an AC voltage of up to about 60 V down the analog line as a ringing signal; when the receiver is picked up to answer or place a call, a DC voltage appears on the line and a current flows.

Now to the circuit. The ringing voltage is passed via C1 to the bridge rectifier formed by diodes D1 to D4. The result is smoothed by C2 and pulls in bistable relay RE1. The mains voltage is then passed via the contacts of this relay to the telephone's mains adapter, which then leaps into action to power the telephone. Mains is also applied via this relay to the rest of the energy-saver circuit. The telephone will ring, and the call can be picked up and answered as usual. If the user wants to place a call, he first presses button S1, which causes the DC voltage across the 'a' and 'b' wires to pull in relay RE1. The number can now be dialled.

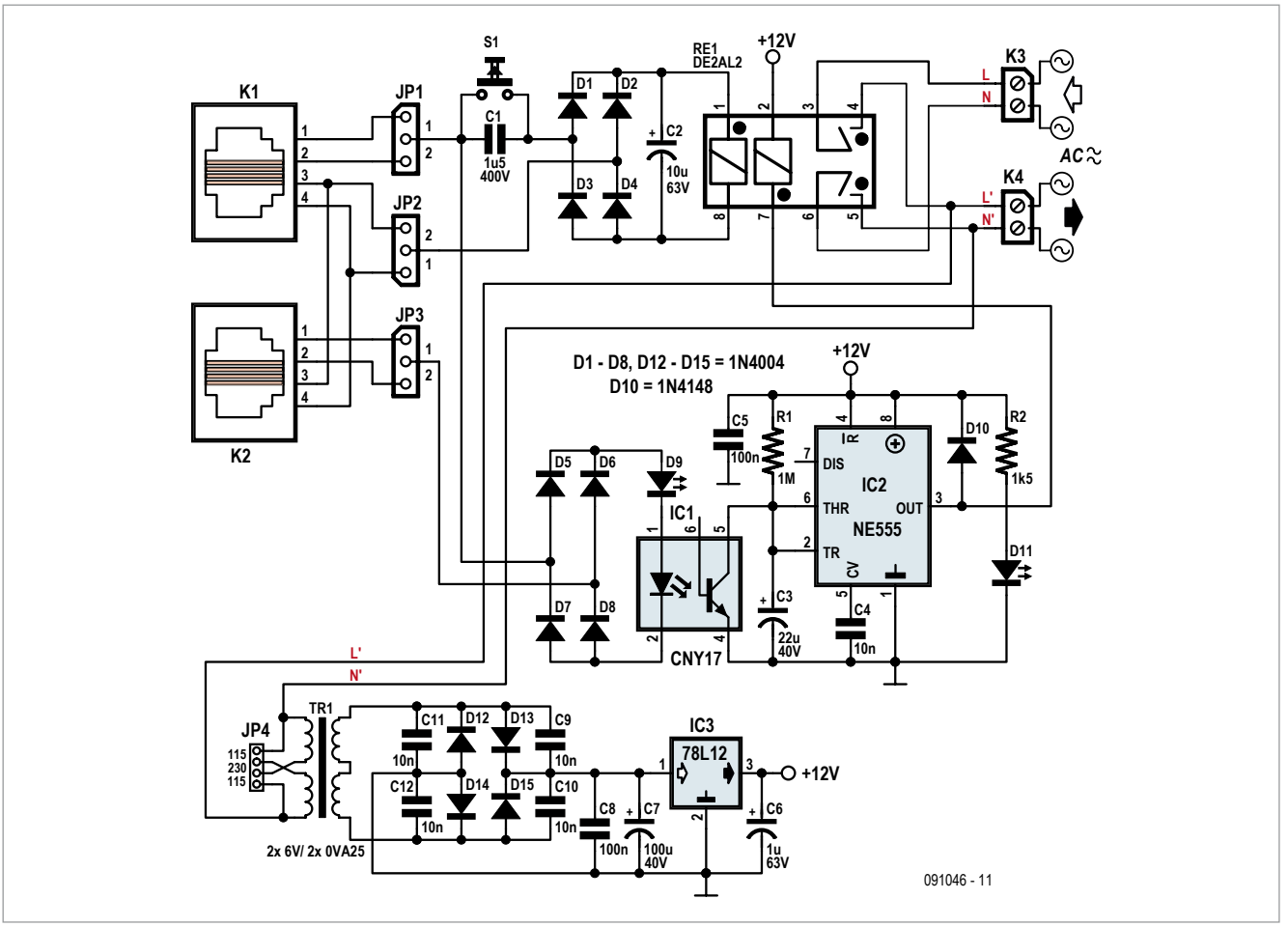
All that remains is to explain how the energy-saver circuit knows when the call is over, or, indeed, has not been picked up in the first place. This job is done by timer IC2 (a device almost as elderly as the type 706 telephone!), connected here as a monostable with a period set by R1 and C3 of 30 s. After this period has expired the second,

opposing, coil of RE1 is energized and the relay drops out. The telephone and energy-saver circuit are now without power. This behavior is perfect for the case where a call is not answered. However, calls often last longer than half a minute and it is not ideal to have to keep pressing S1 to retrigger the monostable.

That is where optocoupler IC1 comes in. It, together with an indicator LED, is driven via the bridge rectifier formed by diodes D5 to D8 which are in series with the telephone line. The loop current thus flows also through these LEDs as long as the receiver is lifted. This keeps the top end of C3 at ground potential throughout a call, holding the output of IC2 high. Thirty seconds after the receiver is replaced all the loads are disconnected.

The relay and the optocoupler serve to keep the low-voltage electronics and the telephone line isolated from the mains supply. The bistable relay used must be a type where the two coils are completely separate, and hence with a total of four coil connections. A red LED is best for D9, which lights while the receiver is lifted, because of its low forward voltage. The energy-saver circuit itself naturally consumes some power during a call. However, thanks to the 0.5 W transformer used and the simple, efficient electronics, it amounts to only a few milliwatts. This is small compared to the savings that can be expected when the unit is idle.

As you can see from the photograph of the prototype and from the component mounting plan, an Elektor printed circuit board has been designed for this project [3]. No SMDs are involved, and so populating the board should present no difficulties. Four- or six-way RJ11 sockets may be used. The board can be mounted in an enclosure that is fitted between the telephone and the wall plate. Jumpers J1 to J3 determine whether the circuit responds to the line wired to pins 1 and 4 or to pins 2 and 3. All three jumpers must be in the same position (position 1 or position 2). The transformer we have suggested has two 115 V primary windings and so can be configured using J4 for 115 V or 230 V operation. For 115 V operation

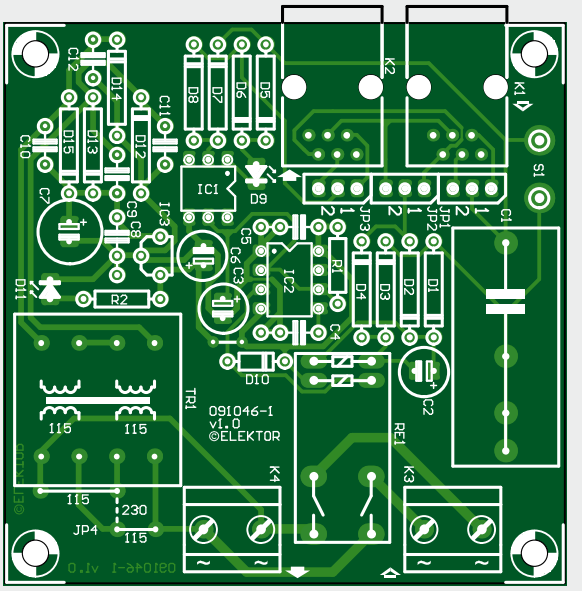


COMPONENT LIST

Resistors
R1 = 1MΩ
R2 = 1.5kΩ

Capacitors
C1 = 1.5µF 400V, MKT, pitch 15 or 22.5 or 27.5 mm
C2 = 10µF 63V, radial, pitch 2.5mm, diam. 6.3mm
C3 = 22µF 40V, radial, pitch 2.5mm, diam. 6.3mm
C4 = 10nF, pitch 5 or 7.5mm
C5,C8 = 100nF, pitch 5 or 7.5mm
C6 = 1µF 63V, radial, pitch 2.5mm, diam. 6.3mm
C7 = 100µF 40V, pitch 2.5mm, diam. 8.5mm
C9,C10,C11,C12 = 10nF, ceramic, pitch 5mm

Semiconductors
D1–D8,D12–D15 = 1N4004
D9 = LED, red
D10 = 1N4148
D11 = LED, green
IC1 = CNY17 (DIP6)
IC2 = NE555 (DIP8)
IC3 = LM78L12



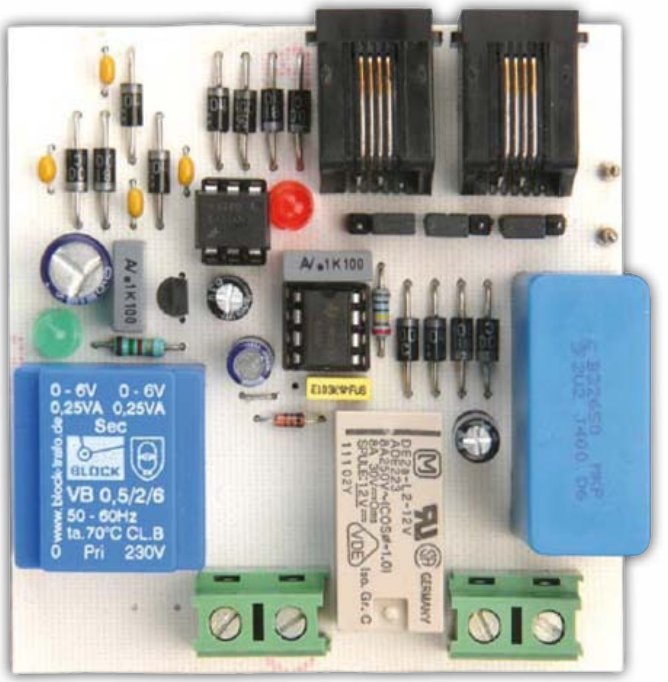
Miscellaneous
K1,K2 = RJ-11, PCB mount (4 or 6-pin)
K3,K4 = 2-way PCB screw terminal, pitch 7.5mm
JP1,JP2,JP3 = 3-pin pinheader, pitch 0.1 inch, w. jumper
JP4 = 1 wire link for 230VAC or 2 wire links for 115VAC (see text)
RE1 = Panasonic DE2a-L2-12V, 2 8 A/250 VAC contacts, 2 720 Ω/12 V coils, bistable
S1 = pushbutton, 1 make contact, 1 A
TR1 = power transformer, AVB0,5/2/6, 2x115 V primary, 2x6 V secondary, 0.5 VA
PCB # 091046 (see [3])

two links are fitted in the outer positions; for 230 V operation a single link is fitted in the middle position. The jumper arrangement precludes fitting all three links at once, which would have the unfortunate effect of short-circuiting the mains supply. If a transformer with a single appropriate primary winding is used, these links are not needed.

One final word on telephones. There are some models that are not ready for operation for ten to fifteen seconds after being powered up. These are not ideal for use with this circuit, as one or perhaps more rings will be lots when a call is received. Also, some telephones with integrated (non-cassette-based) answering machines either forget their stored messages or rapidly exhaust their back-up batteries when power is lost, and these also are not ideal.

Caution. Modification or home construction of circuits connected to the PSTN (public switched telephone network) is subject to local regulation and may not be legal.

(091046)

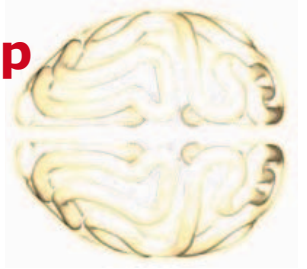


Internet Links:

[1] www.telephonesuk.co.uk/phones_pre1960.htm

[2] www.telephonesuk.co.uk/phones_1960-80.htm

[3] www.elektor.com/091046



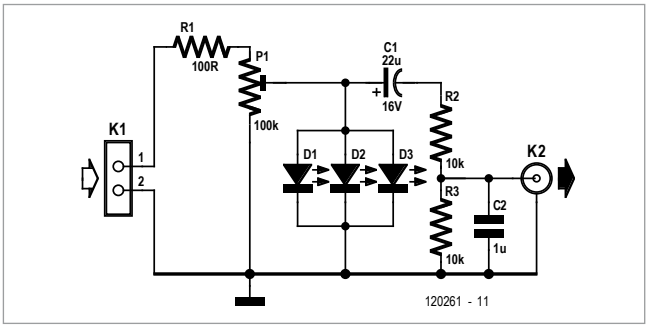
Noisy LEDs

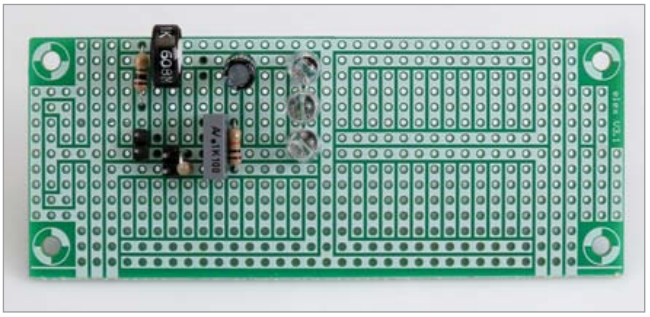
Simple generation of complex sound effects

By Ralph Willekes (Belgium)

These days there are many types of intelligent LEDs available. These LEDs flash or change their color, slowly or quickly and with different color combinations. Those LEDs that gradually change from color to color (so-called rainbow LEDs) were found to be particularly suitable for an alternative application. They happen to produce incredibly complex sounds when they are connected as shown in this circuit.

Potential divider R1/P1 limits the current through the LEDs and has a significant impact on the sound produced. The value can be set between roughly 100 Ω and 100 kΩ. In this circuit it was achieved using a resistor and a preset. If you want to keep things very simple you can get rid of the preset and experiment a bit with series resistor R1. The circuit works with a single LED, but the addition of more LEDs leads to more interesting sounds because the LEDs end up 'fighting' each other for the energy. C2 and resistor R2 form a low-pass filter. Start with a value of about 10 nF in order to hear the full range of sounds. For a 'heavier' sound you can increase C2 to about 1 µF or even 10 µF. C1 avoids the presence of any DC voltage at the output.





The supply voltage to the circuit can be anywhere between about 4 V and 10 V (depending on the value of R1 and the LEDs used).

Make sure that you turn the volume down fully on your amplifier before you connect this circuit, since level of the output signal can vary significantly.

(120261)

Internet Links

Demo film: http://youtu.be/z_aOeCGBZIk

Version using different LEDs and 4.7 µF for C2: http://youtu.be/vbITTveORRA

COMPONENT LIST

Resistors:

R1 = 100Ω
R2,R3 = 10kΩ
P1 = 100kΩ

Capacitors

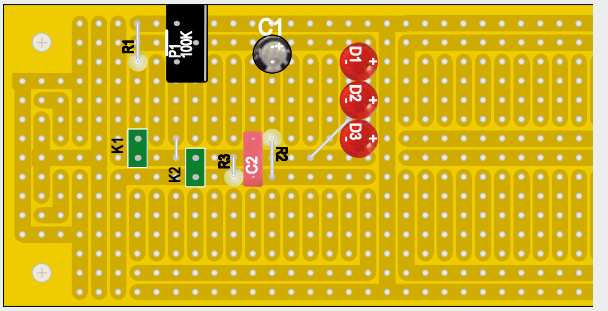
C1 = 22µF 16V
C2 = see text

Semiconductors

D1,D2,D3 = rainbow LED, preferably mixed types

Miscellaneous

'Elex' type experimenter's board



Bicycle Rear Light

one super LED and 10 components last 5 minutes

By Henri Dutoit (France)

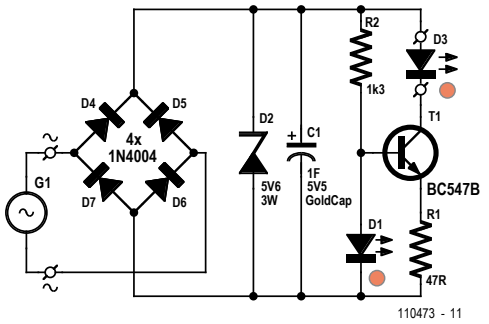
Fitting a bike with a rear light that stays on even when stationary is both useful and interesting – especially when it uses a circuit as simple as this.

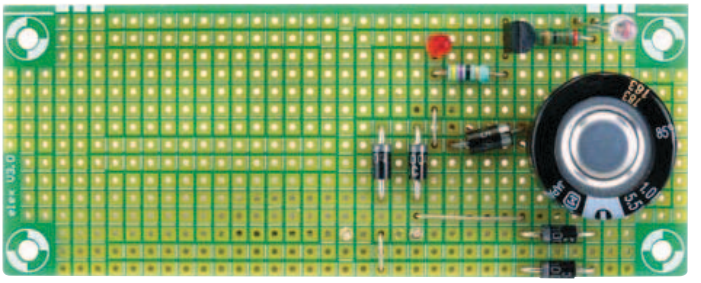
This project would stand a good chance of winning the prize for the smallest circuit in this edition. This is, moreover, the reason why it's been chosen here, as Elektor has already published at least two or three versions that are more elaborate, but not necessarily any better. This version is stripped right down to the bare essentials, but stays on for 5 minutes; it also provides an excellent pretext for trying to get young people interested in electronics, who maybe want nothing more than to get their hands on the soldering iron. If they want to, they'll discover here some fundamental notions like rectification, stabilization, the constant current source… but don't let's scare them away with all that for the moment.

The idea is clear, the solution illuminating: in essence, we have a rectifier, a very high capacitance buffer capacitor, and a high-brightness LED.

The alternating voltage from the dynamo (G1 on the circuit diagram) is rectified by 4 diodes, which works out cheaper than a single bridge-rectifier. Once it has been charged up by a few turns of the pedals, a single 1 farad supercapacitor, known as a GoldCap, is able to keep the LED D3 lit for a good five minutes when the bike is stationary. Before seeing how this LED works, let's take a look at the supercapacitor, on whose terminals the rectified voltage must not exceed the voltage stated by the manufacturer, i.e. 5.5 V. So we're going to be using a 5V6 zener diode to clip the peaks of the pulsing direct voltage. There's no risk that the current supplied by a bike dynamo is going to harm this device, which is capable of dissipating a power of 3 W. If you are a bit dubious, you can always go

The idea is clear, the solution illuminating.





for a capacitor with a higher voltage rating, for example the DK-6R3D105T from Elna America (available from Digi-Key) which, as its type number suggests, can handle 6.3 V. Another advantage of this device is its lower series resistance compared with the Panasonic type we tested (30 Ω instead of 50 Ω), which means that when fully charged, its voltage will be slightly higher.

With the GoldCap, using an AC voltage of 6 V @ 50 Hz, we measured a DC voltage of 4.8 V with 0.76 V residual ripple.

T1 and the two components associated with it, R2 and the LED D1, form a constant current source. Even when the supercapacitor discharges, these ensure that the brightness of the powerful LED D3 remains stable. It needs to be able to handle a continuous current of at least 20 mA.

This current is determined by the value of R1. The table gives an idea of the way the voltage across R1 changes with time once the bike has stopped. After six minutes, the voltage has dropped right off and the current in the LED is now only 5 % of its nominal value.

Stop	U_{R1}
0	1 V
2 min	0.5 V
3.5 min	0.25 V
4.5 min	0.1 V
6 min	0.05 V

To make the circuit easy to build, we suggest building it on prototyping board or breadboard. **Watch out!** Don't forget to make the break in the topmost track, otherwise T1 and D3 will receive the alternating voltage!

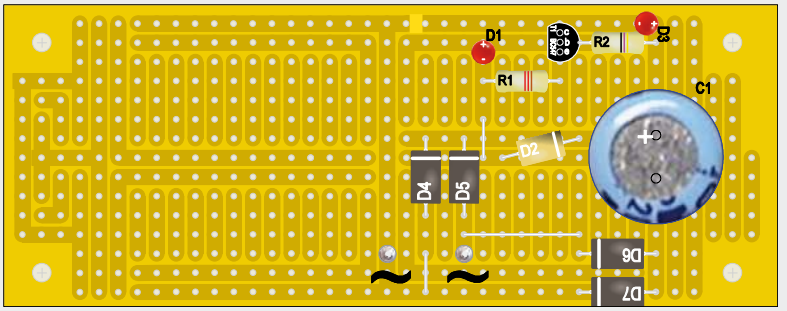
(110473)

COMPONENT LIST

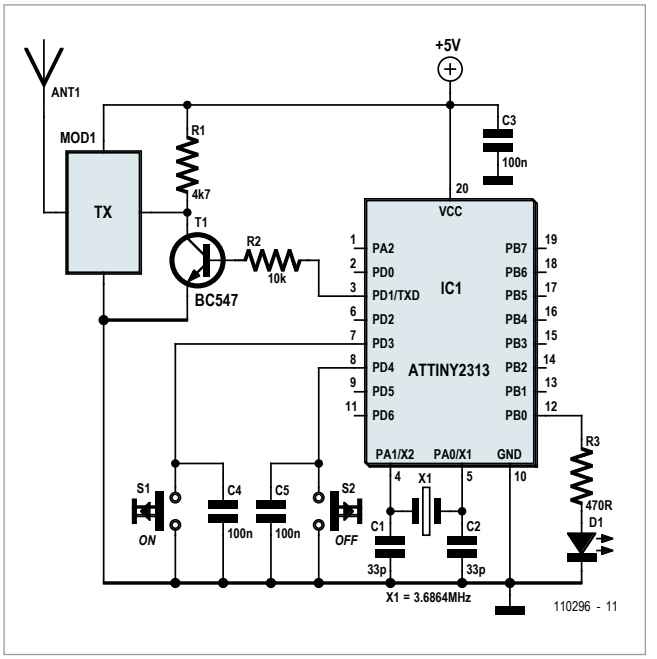
Resistors
R1 = 47Ω
R2 = 1.2kΩ

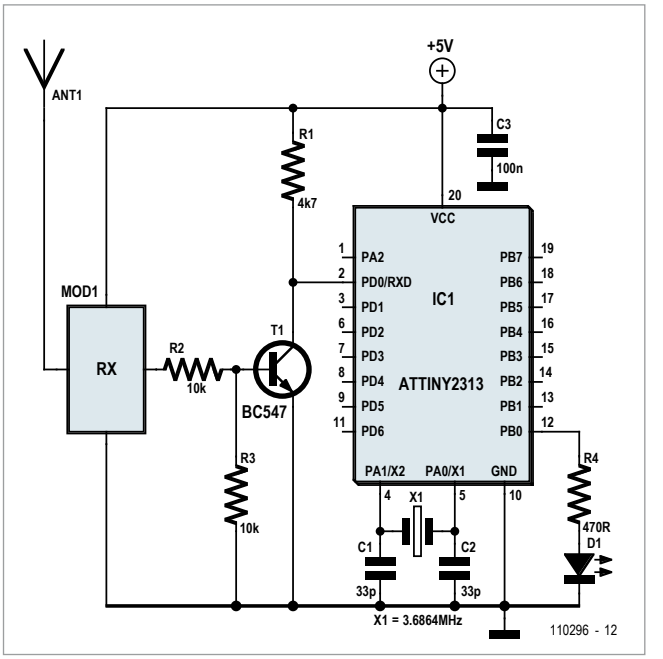
Capacitors
C1 = 1F 5.5V, e.g. Panasonic EECF5R5H105

Semiconductors
D1 = LED, red, standard (V_f = 1.7V)
D2 = zener 5.6V 3W
D3 = LED, red, high brightness, e.g. MCL034URC (I_{max} ≥ 20 mA)
D4–D7 = 1N4004
T1 = BC547B
Elex-1 (UPBS-1) prototyping board



ATtiny Goes Wireless





By Jürgen Stannieder (Germany)

In many application areas it can be very handy to be able to control something wirelessly. This circuit shows how an ATtiny microcontroller can be used to switch an appliance on and off remotely with a little help from wireless transmitter and receiver modules available from Conrad Electronic. If needed, it is very easy to extend the project to include additional commands.

To demonstrate the principle of operation we represent the appliance to be controlled by a red LED at the receiver end. At the transmitter end, buttons S1 and S2 are responsible for the 'on' and 'off' switching functions (see left-hand circuit diagram). When one of these buttons is pressed it pulls the corresponding input of the microcontroller (PD3 or PD4) to ground. The software running in the microcontroller recognizes the input and converts it into a command message. In this case the message consists of the single character 'E' to switch the appliance on and 'A' to switch it off. The command message is emitted at output PD1 (TXD) of the ATtiny, where it is inverted by T1 and then sent to the Conrad transmitter module. The inverter is needed here as the TXD output (as is conventional) returns high when no message is being sent. Without the inverter this would mean that the transmitter would always be active when no message was being sent: with the arrangement shown the transmitter is idle between messages. Crystal

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- Free software download

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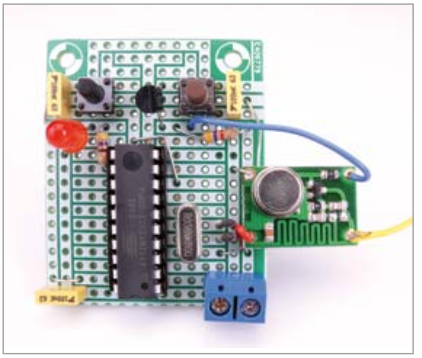


COMPONENT LIST

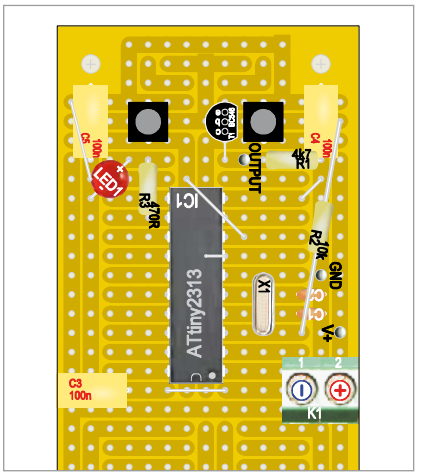
Transmitter

Resistors
R1 = 4.7kΩ
R2 = 10kΩ
R3 = 470Ω

Capacitors
C1,C2 = 33pF
C3,C4,C5 = 100nF MKT, 5mm

Semiconductors
LED1 = 5mm, red
T1 = BC547C, TO-92
IC1 = ATtiny2313 DIP-20, programmed, Elektor # 110296-42)

Miscellaneous
X1 = 3.6864 MHz quartz crystal, HS49/S case
S1,S2 = pushbutton, e.g. B3F-1000
TX = Transmitter module from 433 MHz AM transceiver set, Conrad Electronics # 130428
DIP20 socket
ELEX-1 (UPBS-1) board (1/2)



X1 produces the clock for the microcontroller, the 3.6864 MHz frequency used allowing easy generation of baud rates from 9600 baud to 76800 baud. We configure the microcontroller to run at 9600 baud, which gives reliable operation with the radio modules. LED D1 and its series resistor are present in the circuit to give feedback to the user when the microcontroller registers an input. The LED lights when either of the buttons is pressed.

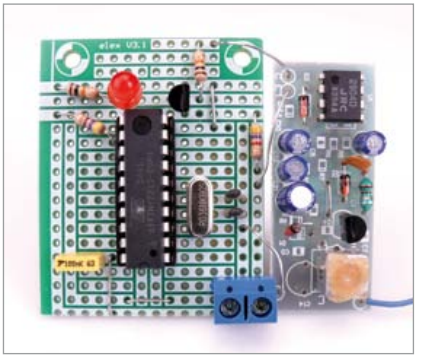
At the receiver end (see right-hand circuit diagram) the signal from the receiver module is passed to another microcontroller which then processes the received information. Because the signal was inverted prior to transmission, it must be returned to its uninverted form by inverter T1. The software in the microcontroller reads the signal in at its PD0 (RXD) input. Depending on whether its sees the letter 'E' or 'A', it turns LED D1 on or off. Again, the microcontroller receives its clock from crystal X1, with a frequency of 3.6864 MHz.

The 433 MHz radio transmitter and receiver modules used in this project are available as a set from Conrad [1]. Construction is relatively straightforward. It is worth noting that the antennas on the transmitter and receiver modules are tuned appropriately at the factory and should not need further adjustment. The circuit can conveniently be built on an Elektor Universal Prototyping Board Size-1 (UPBS-1, a.k.a.ELEX-1) cut into two halves (see photographs and mounting plans). The author managed to achieve reliable communication between the two modules within his house over a distance of 12 m (40 ft).

(110296)

Internet Link:

[1] www.conrad-uk.com/ce/en/product/130428/



COMPONENT LIST

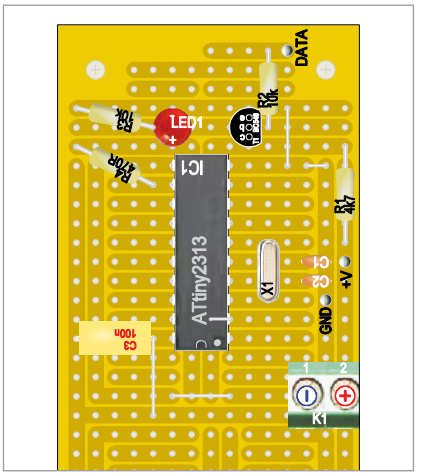
Receiver

Resistors
R1 = 4.7kΩ
R2,R3 = 10kΩ
R4 = 470Ω

Capacitors
C1,C2 = 33pF
C3 = 100nF MKT, 5mm

Semiconductors
LED1 = 5mm, red
T1 = BC547C, TO-92
IC1 = ATtiny2313 DIP-20, programmed, Elektor # 110296-41)

Miscellaneous
X1 = 3.6864 MHz quartz crystal, HS49/S case
RX = Receiver module from 433 MHz AM transceiver set, Conrad Electronics # 130428
DIP20 socket
ELEX-1 (UPBS-1) board (1/2)



A Zero Current Switch

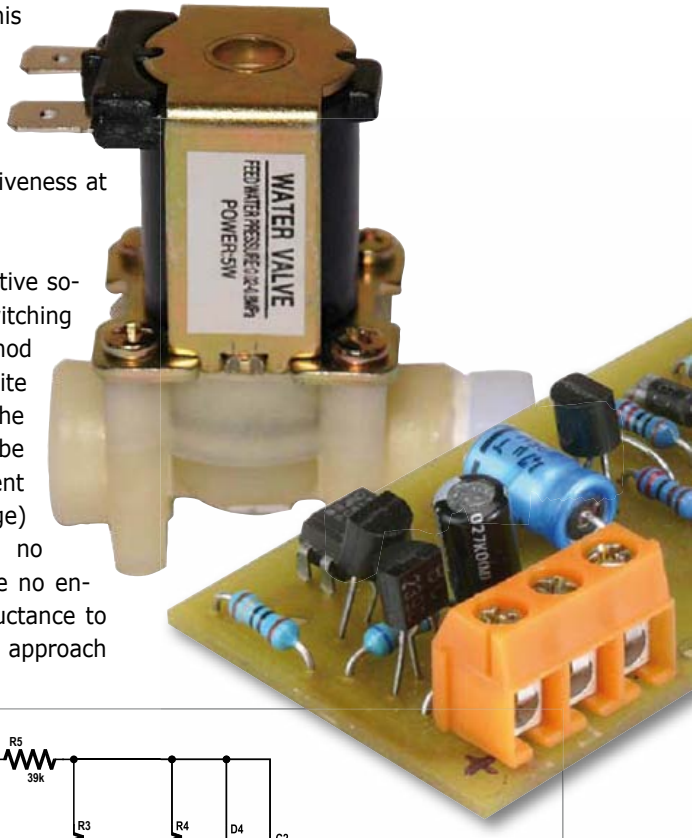
For inductive Loads

By Matthias Haselberger (Germany)

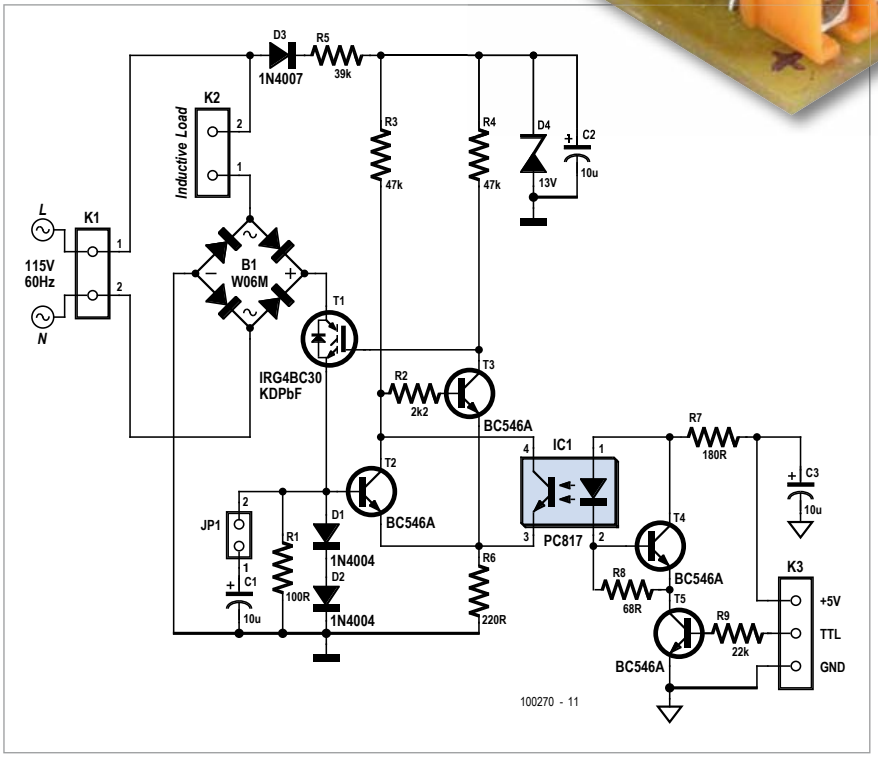
Relays or contactors are often used to switch mains powered inductive loads such as motors, valves or electro magnets. When the device is switched off an arc can form across the relay contacts as they open. This leads to premature relay failure if measures are not taken to suppress the spark. In addition to relay damage the high voltage spark causes interference and EMC issues. The most common method of suppressing the arc is to connect a snubber in parallel to the contacts. This device is a series resistor and capacitor network. Now when the contacts break, energy stored in the inductor has a path to dissipate through the snubber to generate a small amount of heat in the resistor. Typical values of the snubber components are R = 1 to 100 Ω and C = 10 to 1000 nF.

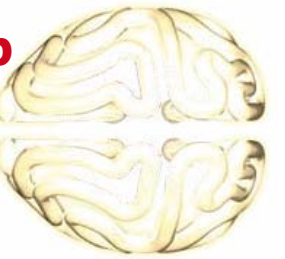
Relay contacts open at unpredictable times during the mains AC cycle; at the time of maximum current the induced 'back-EMF' and contact arcing problems mentioned above will be most severe. Semiconductor relays using thyristors or triacs will always turn off when the voltage across them passes through zero, for a load with a highly reactive power component the voltage and current will be phase shifted so that this point corresponds to the instant of maximum current. A snubber will be an essential component in this situation.

Snubbers are however not completely unproblematic; a small current will continually flow through the snubber RC network (and load) when the contacts are open. Not only is this wasteful but with a very light load such as a fan, it can often be enough to keep the fan running. Increasing the value of R reduces its effectiveness at suppressing arcs.



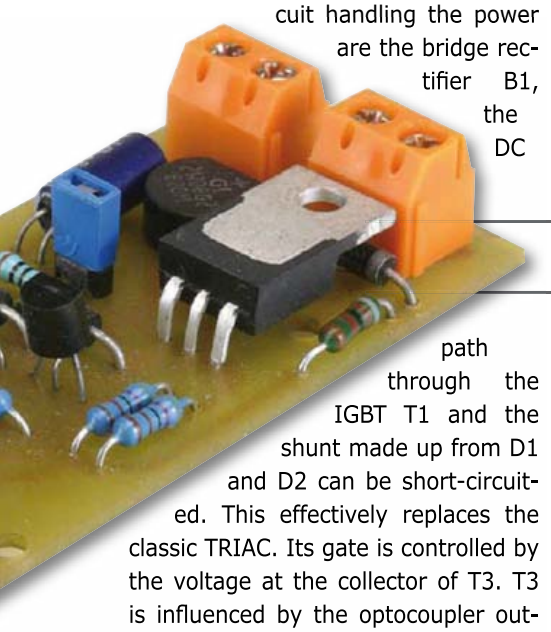
There is however an alternative solution to the problem of switching inductive loads. The method suggested here is really quite simple: make sure that the inductive load can only be switched off when the current waveform (not the voltage) passes through zero. With no current flowing there will be no energy stored in the load inductance to cause problems. Using this approach





it's possible to dispense with the snubber completely. This was the train of thought that passed through the authors mind and set him on the path to design this zero-current switching electronic relay.

So to the solution: The parts of the circuit handling the power are the bridge rectifier B1, the DC path through the IGBT T1 and the shunt made up from D1 and D2 can be short-circuited. This effectively replaces the classic TRIAC. Its gate is controlled by the voltage at the collector of T3. T3 is influenced by the optocoupler output and also the zero current detector made up from D1, D2 and T2.

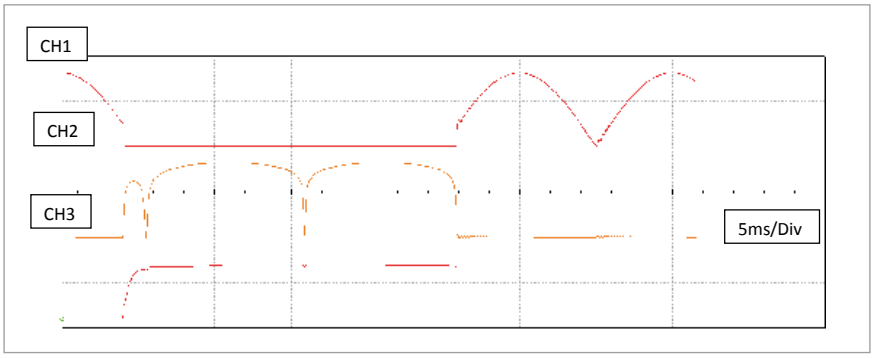


When the load is switched off there is no current flowing and T2 will be off, T3 will be conducting and T1 will be off. A high on the TTL input turns the photo transistor in IC1 on which shorts the base-emitter junction of T3, turning it off and bringing T1 into conduction thereby switching the load on.

To turn the load off the TTL input is brought low to turn off the photo transistor. T3 can now only be turned on when T2 turns off. T2 remains conducting until the load current passes through zero when the voltage across D1 and D2 drops to zero. So after the TTL input goes low, the load remains switched on until load current sinks to (almost) zero. Just what we wanted.

Snubber-free switching

The author simulated the circuit using the Multisim11 software from National Instruments (NI). The resulting diagrams confirmed the circuit function using inductive loads. CH1 shows the voltage at the collector of T1 and CH2 the voltage at the emitter of T1 and the base of T2 which corresponds to the absolute value of current flowing in the load. CH3 shows the control voltage applied to the gate of T1. A phase shift of 20 ° between the voltage and current waveform is used in this simulation. The author confirmed the simulation results with observations of the finished working circuit. Those of you interested in the simulation details can look at the 'Elektor3_10.ms11' file associated with this project which can be downloaded from the Elektor website



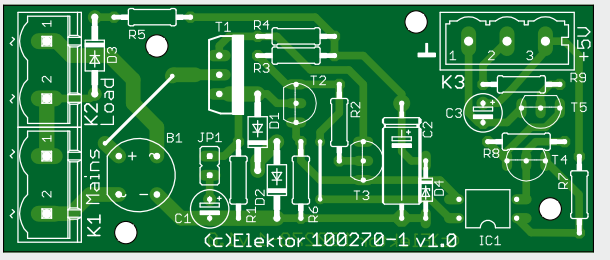
COMPONENT LIST

Resistors
R1 = 100 Ω
R2 = 2.2kΩ
R3,R4 = 47kΩ
R5 = 82kΩ 1%, 0.6W 350V (Vishay MRS25000C8202FCTOO)
R6 = 220Ω
R7 = 180Ω
R8 = 68Ω
R9 = 22kΩ

Capacitors
C1,C3 = 10µF 100V 20%, pitch 2.5mm, diam. 6.3mm
C2 = 10µF 63V, axial, 10 x 4.5mm

Semiconductors
D1,D2 = 1N4004
D3 = 1N4007
D4 = BZX79-C13 (13V 05W)
B1 = WO6M, 600V 1.5A
T1 = IRG4BC3OKDPbF
T2..T5 = BC546A
IC1 = PC817 (see text)

Miscellaneous
PCB # 100270 [1]



[1]. An evaluation version of the Multisim simulation software is available from NI [2].

A few more circuit details: R1 ensures that the voltage at the base of T2 really does go to zero when the current waveform passes through zero. D4 limits the V_{CE} of T2 and T3 and also the V_{GE} of T1 to a safe value. Capacitor C1 together with the jumper position JP1 allows the circuit to be used in situations where the AC load is lightly inductive. It allows some adjustment of the turn-off point of T2 (and T1) to the actual zero crossing point of current in the cycle. An IGBT type device has been used for T1 because the higher switching threshold of the gate voltage is more suited to this application than a high voltage MOSFET. Practically any optocoupler can be used for IC1, its switching speed is not critical.

A PCB is available for the project. The layout doesn't use any SMD's so assembly is very easy. The PCB can be obtained from the Elektor shop or the layout files in Eagle format can be downloaded free of charge [1] allowing you to produce your own. Be aware that the circuit is directly connected to the mains, some parts of the circuitry and PCB tracks carry lethal voltage levels. It is therefore vital to observe all the appropriate health and safety precautions. The use of 1N4004 diodes allows load currents up to 1 A, corresponding to a power rating of 230 VA. Transistor T1 does not need a heat sink at this power level. To make the design suitable to handle a higher current is not just a simple matter of swapping D1 and D2 for higher current versions. It will also be necessary to beef-up the PCB tracks handling the load current, B1 must also be replaced and T1 will require a heat sink.

(100270)

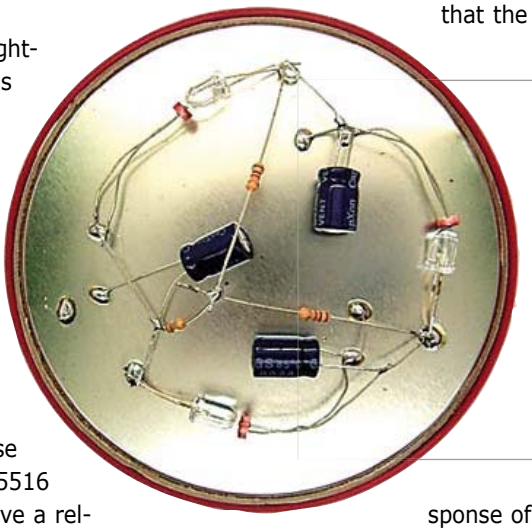
Internet Links

[1] www.elektor.com/100270

[2] www.ni.com/multisim

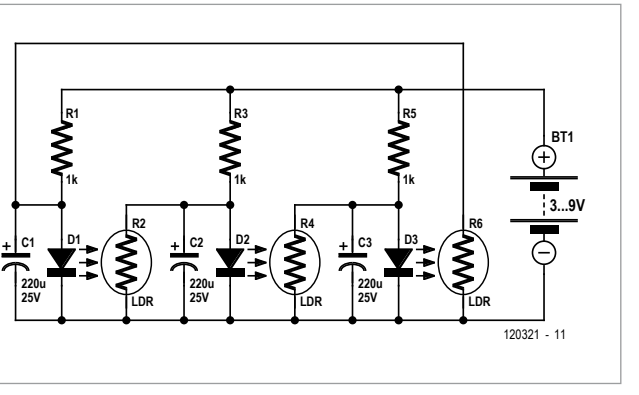
LED-LDR Ring Oscillator

By Burkhard Kainka (Germany)



Can high-brightness white LEDs and light-dependent resistors (LDRs) be used to make an oscillator? I decided to have a go. For the experiment I chose type PGM5516 LDRs which have a relatively low resistance (5 kΩ to 10 kΩ at 10 lux). A ring oscillator configuration was used, with each LED placed directly next to its neighboring LDR (see circuit).

The first test, without the capacitors, was unsuccessful. I had hoped that the natural slow response of the LDRs would be enough to start oscillation, but the oscilloscope proved me wrong.



Only by adding the 220 µF electrolytic capacitors could I get the oscillation to start, using a power supply of between 3 V and 9 V. The oscillation frequency rises with supply voltage. At 3 V the circuit must be kept in darkness (and the result is a very low-energy running light!). At 2.7 V the circuit draws 0.9 mA and is disturbed by even the smallest amount of ambient light.

(120321)

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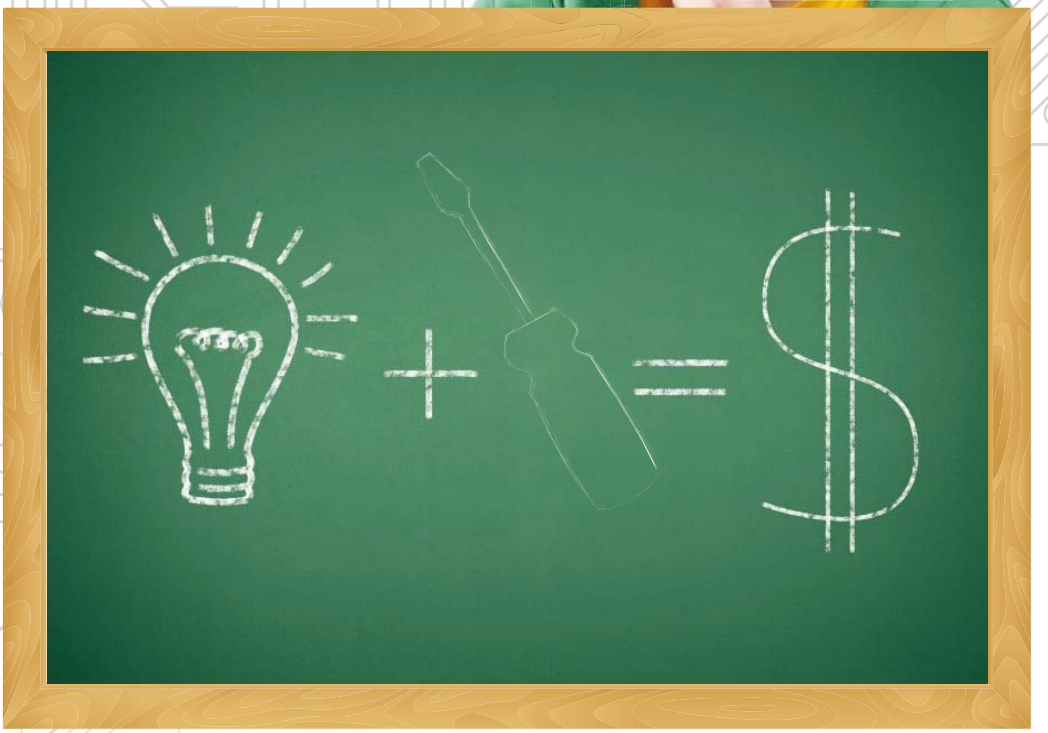

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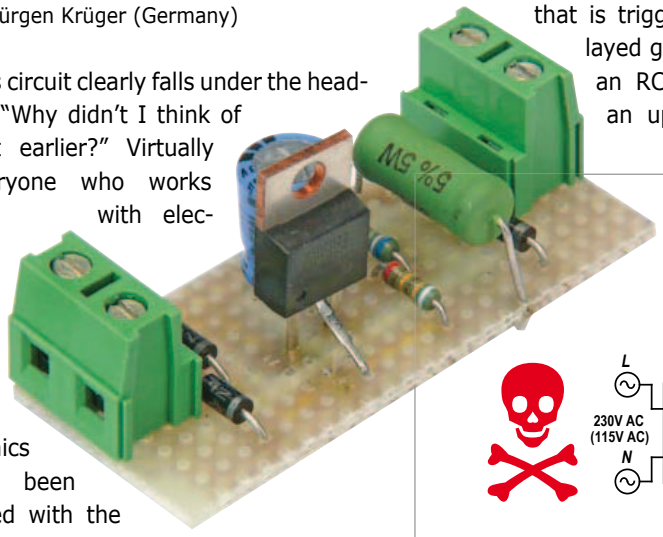
Soft AC Line Start

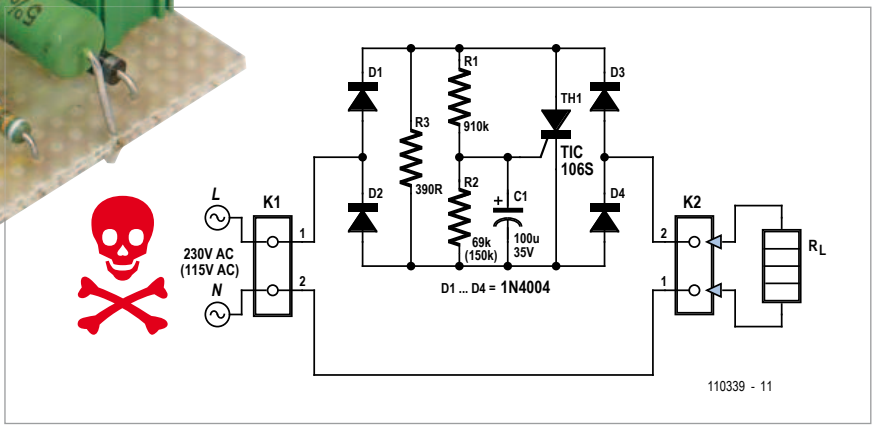
By Jürgen Krüger (Germany)



This circuit clearly falls under the heading "Why didn't I think of that earlier?" Virtually everyone who works with electronics has been faced with the need or desire to limit the inrush current of a large load. In the distant past this was achieved by placing a hefty resistor in series with the supply line and using a contactor (or a relay with a bit of additional electronics) to short out the resistor shortly after the load is switched on. Although this does the job, it's an electromechanical solution and therefore subject to wear, bulky and not especially elegant. Now you have the option of putting together a microcontroller circuit that uses an analog input to detect the presence of AC line voltage and an internal timer to generate a delayed trigger for a triac that shorts out the series resistor. This also does the job, but it's actually a bit of overkill.

Mr Krüger adopted a logical approach and came up with a minimalistic circuit that not only does the job, but does it with remarkable simplicity. Although the simplest solution would be a triac that is triggered by a delayed gate signal from an RC network with an upstream series diode, it suffers from the fact that triacs with unipolar triggering have different trigger sensitivities for positive and negative half-waves. This means that when the load is switched on, it is possible for one or more negative half-waves to get lost. This is not so nice with inductive loads such as transformers, since they may become saturated and as a result cause exactly what you are trying to avoid: a blown fuse or tripped circuit breaker.

For this reason, the author chose to implement a slightly more complicated version. The basic principle is the same as with the series triac, but with an SCR incorporated in the DC arm of a bridge rectifier instead. That's all there is to it. An SCR also has the advantage that the necessary trigger current can be significantly lower than with a triac. The proposed type (TIC106) typically triggers at a gate current of 60 µA. This allows resistors R1 and R1 to have relatively high values. These resistors in combination with C1 determine the trigger delay, which is dependent on the component tolerances and can be as much as several hundred milliseconds. A 5 W type should definitely be used for R3, since it has to dissipate a considerable amount of power during this brief interval.



The author has used series circuits of this type fairly often as soft-start circuits for incandescent lamps, which as is well known have low cold resistance. Particularly when you use an inverter to convert 12 V DC to 230 C AC for camping, high inrush currents with a 100-watt incandescent lamp can be enough to cause start-up problems with the inverter, even with a 300 watt rating, or fry the lamp. Relatively large transformers can also generate high peak currents during switch-on if they

Small Circuit, Big Effect

happen to be switched on exactly at the zero crossing point and become saturated due to inadequate core magnetization.

With the specified components and component values, the circuit can be used for loads up to 230 VA. Higher currents require heavier-duty diodes and an SCR with a higher current rating, as well as a heat sink for the SCR. With such modifications you should bear in mind that high-current SCRs require higher trigger currents, so the values of R1 and R2 should be reduced and the value of C1 should be increased. Another option would be to use separate drive logic, but that would detract from the elegant simplicity of the circuit. The value or R3 should be adapted to the intended use or desired inrush current level.

(110339)

Knitting Counter

By Marian van Hal (Netherlands)

Knitting always involves a lot of counting as you have to keep track how many rows you've knitted and how many should follow. This can of course be done with pen and paper, but it's more fun with an electronic variant using a microcontroller.

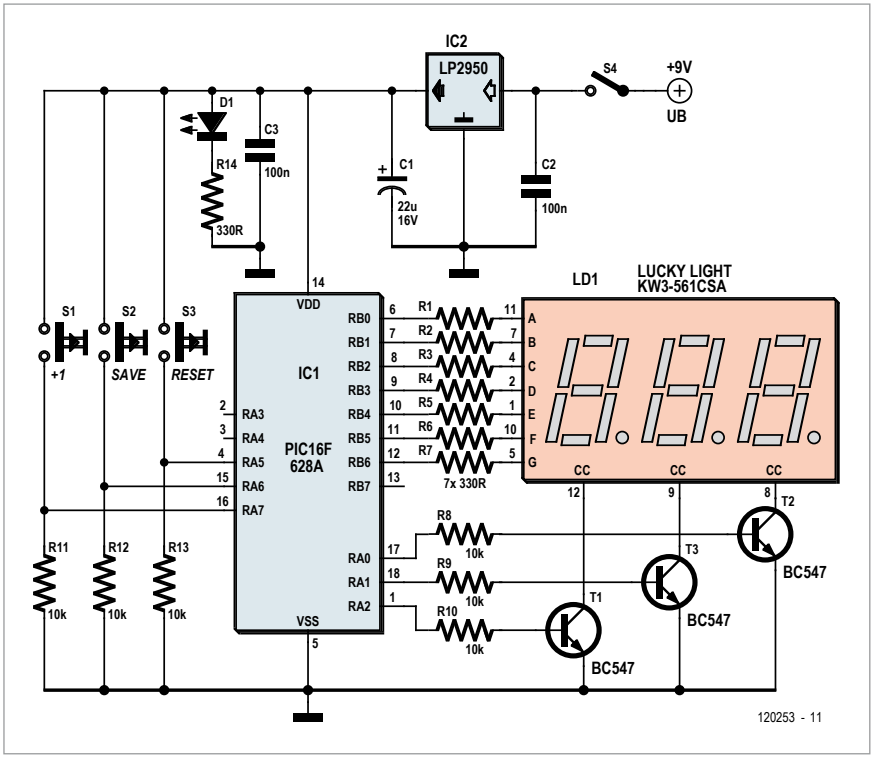
This counter has the following functions:

- Switch S1 increases the counter by one.
- Switch S2 saves the current count in the EPROM memory of the microcontroller.
- Switch S3 resets both the counter and internal memory to zero.

Switch S4 turns the device on and off. When it is turned on the display will show the value stored in the internal memory.

The display and counter function are turned off after about 5-10 seconds in order to improve the battery life. Pressing S1 turns the display and functions back on again. An LED shows when the circuit is switched on, even with the display blanked. A low dropout voltage regulator (LP2950) is used the get the maximum usage from a 9 V battery.

At the heart of the circuit is a PIC 16F628A. The three digits of the LED display (a common cathode type) are multiplexed via the PIC. The software is written in PICbasic from Proton and can easily be modified if required. Since the author has only recently started with programming microcontrollers, the software has not made use of timers or interrupts. Despite that, the display is still turned off after some time, but this is achieved solely by the software.



The circuit is built on a standard experimenter's board and the component layout was developed using the program Lochmaster from Abacom [1].

The basic, asm and hex files can be freely downloaded from [2].

(120253)

Internet Links

[1] www.abacom-online.de/uk/html/lochmaster.html

[2] www.elektor.com/120253

COMPONENT LIST

Resistors

R1–R7,R14 = 330Ω
R8–R13 = 10kΩ

Capacitors

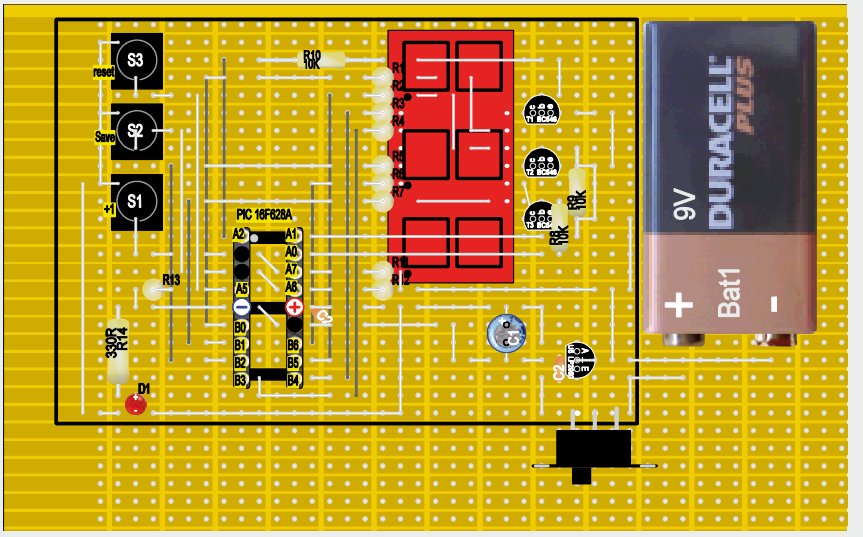
C1 = 47µF 16V
C2,C3 = 100nF

Semiconductors

D1 = LED, red, 5 mm
Display = KW3-561-CSA (Lucky Light) or 3 discrete 7-segment displays (CC)
T1,T2,T3 = BC547
IC1 = PIC16F628A, programmed

Miscellaneous

S1,S2,S3 = pushbutton with make contact
S4 = slide switch with make contact
9V battery with clip-on connector
Piece of experimenter's board



OHM's LAW

Three famous people brought together
in one equation… do you see any similarities?

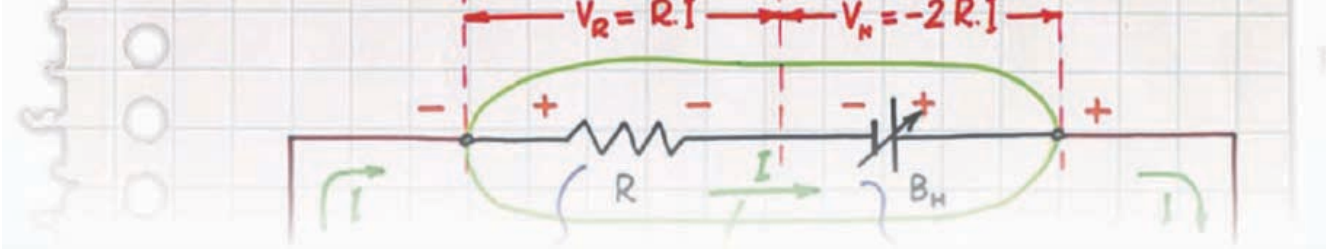
Alessandro Volta

=

André-Marie Ampère

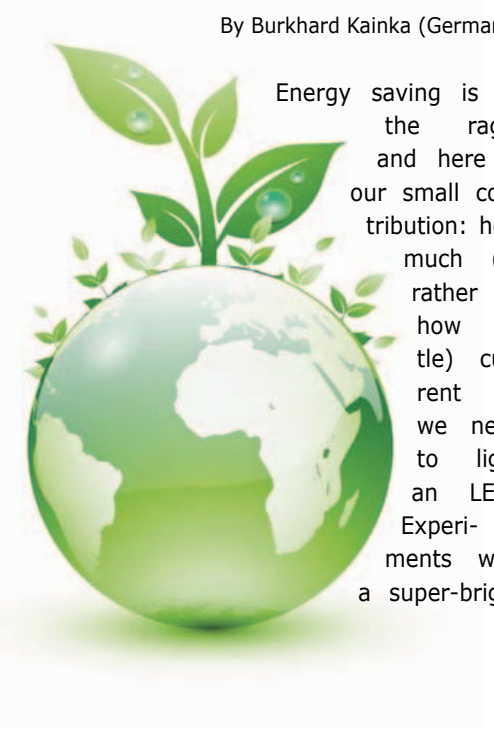
×

Georg Simon Ohm

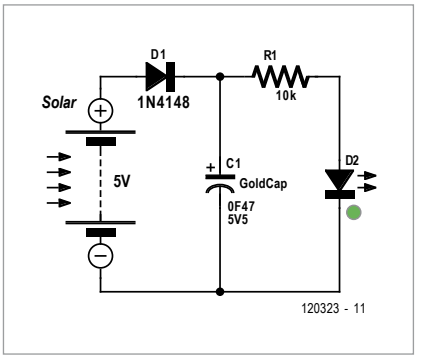


‘Green’ Solar Lamp

By Burkhard Kainka (Germany)



Energy saving is all the rage, and here is our small contribution: how much (or rather how little) current do we need to light an LED? Experiments with a super-bright 1 W green LED showed that even one microamp was enough to get some visible light from the device.



Rootling in the junk box produced a 0.47 F memory back-up capacitor with a maximum working voltage of 5.5 V. How long could this power the green LED? In other words, if discharged at one microamp, how long would the voltage take to drop by 1 V? A quick calculation gave the answer as 470 000 seconds, or about five days.

Not too bad: if we use the capacitor for energy storage in a solar-powered lamp we can probably allow a couple more microamps of current and still have the lamp on throughout the night and day. All we need to add is a suitable solar panel. The figure shows the circuit diagram of our (in every sense) green solar lamp.

(120323)

Power LED Driver

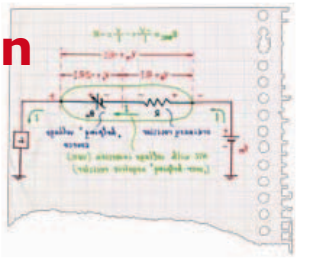
By Michael Hölzl (Germany)

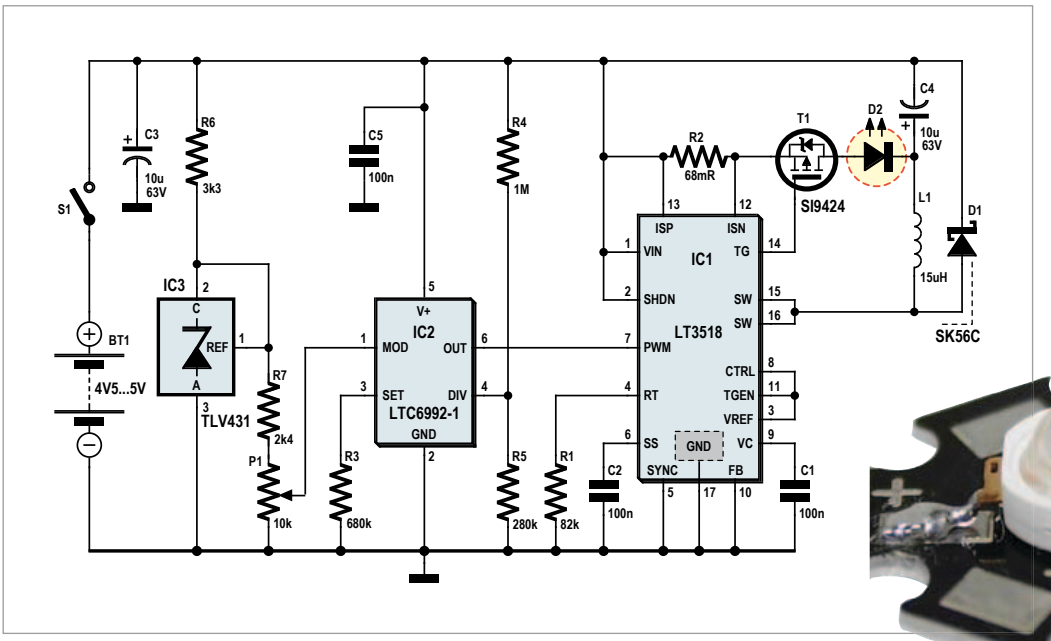
If you want to operate power LEDS with a truly constant current – which significantly prolongs the lifetime of the lamp – and avoid the power loss resulting from using a constant voltage supply with a series resistor, you need a suitable constant current source. However, the only way to achieve really good efficiency is to use a switching regulator. Altogether, this means that you need a switching regulator designed to generate a constant current instead of a constant voltage.

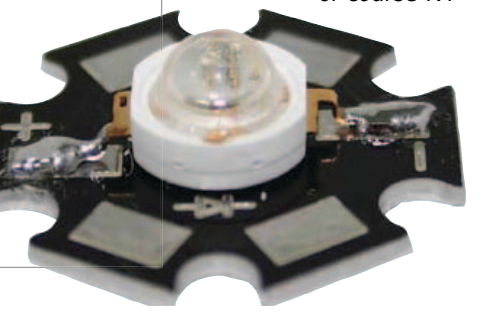
With this in mind, the author started working on the development of a LED pocket torch with especially high efficiency. Along with using high-capacity rechargeable batteries to maximize operating life, it’s worthwhile to be able to reduce the brightness, and therefore the operating current of the LEDs, when you don’t need full power. Accordingly, the author incorporated a dimming function in the design, based on operation in PWM mode in to reduce power losses to an absolute minimum.

As you can see from the circuit diagram, the author chose an LT3518 switching regulator IC, which is a buck/boost converter optimized for LED operation. Here it is used as a down converter (buck mode). This IC can achieve better than 90% efficiency in this mode, depending on the input voltage. According to the typical application circuit on the data sheet [1], its switching frequency can be set to approximately 170 kHz by selecting a value of 82 kΩ for R1. To maximize overall efficiency with this type of IC, the voltage drop over the sense resistor used to measure the current flowing through the LED should be as low as possible. This particular device operates with a voltage drop of 100 mV, corresponding to a current of just under 1.5 A with the specified value of 68 mΩ for R2. This value proved to be suitable for the Cree LED used by the author. At this current level, a diode with a power rating of at least 6 W should be used for D1.

IC1 has an additional property that is ideal for this application: the connected LED can be dimmed by applying







a PWM signal to pin 7 of the IC, with the brightness depending on the duty cycle. Obviously, the PWM frequency must be lower than the switching frequency. The PWM signal is provided by IC2, a special voltage-controlled PWM generator (type LTC6992 [2]). The duty cycle is controlled by the voltage applied to the MOD input on pin 1 (range 0–1 V). The resistor connected to pin 3 determines the internal clock frequency of the IC according to the formula f = 1 MHz × (50 kΩ/R3). This yields a frequency of approximately 73.5 kHz with R3 set to 680 kΩ, which is much too high for controlling IC1. However, the PWM IC has an internal frequency divider with a division factor controlled by the voltage applied to pin 4, which in this circuit is taken from voltage divider R4/R5. The division factor can be adjusted over the range of 1 to 16,384. The division factor with the specified component values is 64, resulting in a PWM frequency of around 1,150 Hz. If you want to be able to generate a PWM signal with an adjustable duty cycle over the full range of 0 to 100%, you must use the LTC6992-1 option. The -4 option, which provides a range from 5 to 100%, might be an acceptable alternative.

To prevent the duty cycle (and thus the brightness of the LED) from depending on the battery voltage, which gradually drops as the battery discharges, IC3 generates a stabilized 1.24 V control voltage for potentiometer P1. Series resistor R7 reduces the voltage over P1 to 1 V, which exactly matches the input voltage range of the LTC6992.

All capacitors should preferably be ceramic types, in particular due to their low effective series resistance (ESR) as well as other favorable characteristics. However, only capacitors with X5R or X7R dielectric should be used; capacitors with type Y dielectric have very poor temperature characteristics.

The supply voltage is limited to 5.5 V by the maximum rated supply voltage of IC2. The author used four NiMH rechargeable cells connected in series, which yields a voltage that is just within spec. With an operating voltage in the range of 4.5 V to 5.5 V, you must use an LED that can operate at less than 4 V. This eliminates devices with several chips connected in series on a carrier, which is very often the case with power LEDS rated at over 5 W. These devices require a correspondingly higher supply voltage, which means more cells connected in series. This is only possible if the supply voltage for IC2 is reduced by a 5 V voltage regulator or other means, and of course R4 must also be connected to this lower supply voltage.

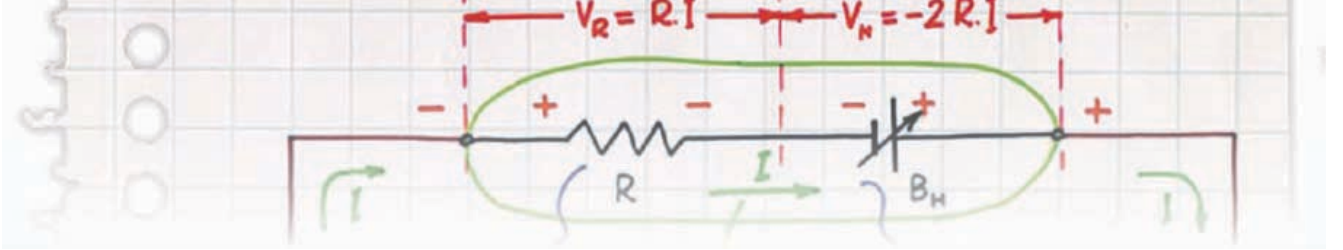
Finally, a few words about soldering. An exposed thermal pad must be provided on the PCB for the LT3518, and the rear face of the IC must be soldered to this pad. The author obtained good results by dimensioning the exposed pad large enough to extend beyond the outline of the IC. When assembling the board, first tin the pad and the rear face of the IC. Then heat the pad with a soldering iron. When the solder melts, withdraw the tip of the soldering iron to the edge of the pad and simultaneously place the IC on the pad and align it. After this the pins can be soldered.

The author produced a two-sided PCB, and the CAD layout data (Target) can be downloaded from the Elektor website [4].

(120201)

Internet Links

[1] www.linear.com/product/LT3518
[2] www.linear.com/product/LTC6992
[3] www.ti.com/product/tlv431
[4] www.elektor.com/120201



DC Protection for Speakers

By André Aguila (Burkina Faso)

I'm in the process of building myself a single-ended class A MOSFET amplifier consisting of two mono blocks, and I don't want to use a coupling capacitor between amplifier and the speaker. So I needed a circuit that would protect the speaker against DC voltages; I have given it a dual role:

- DC protection in the form of a device to disconnect the speaker in the presence of a DC voltage greater than ±1 V, using an LM358;
- speaker connection delayed by around 5 s after powering the amplifier, using a 555.

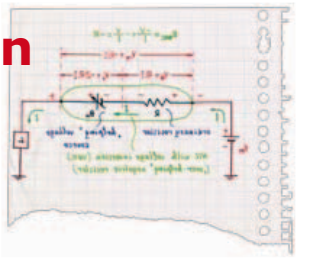
I've drawn inspiration from various ideas gleaned from the Internet, but I don't think this circuit actually exists anywhere in quite this form. Obviously, for a stereo system, you'll need a protection circuit for each channel.

The output signal from the audio amplifier without an output capacitor is applied to the normally-open contacts of relay Re1, and also to the input of the DC voltage detects formed by an RC integrating network and comparators, whose output drives the relay control stage and an LED indicator.

The network R6/C4 is a low-pass filter that heavily attenuates the audio signal but will allow any positive or negative DC component through to the inputs of dual comparators IC2a and IC2b, which are protected from excessive voltage by diodes D1 and D2.

IC2a output goes from +12 V to −12 V when the voltage on its negative input is higher than that on the positive input, while IC2b output goes from +12 V to −12 V when the voltage on its positive input is lower than that on the negative input. The values of resistors R7, R8, and R9 in the potential divider set the DC voltage detection thresholds to around +1 V for IC2a and –1 V for IC2b.

To disable the relay if a positive or negative DC voltage is detected, all that remains to be done is to combine the LM358 outputs. As these are not open-collector outputs, diodes D4 and D6 form a wired-OR gate to avoid short-circuiting them. If there is a positive DC voltage on the amplifier output, IC2a output will go from +12 V to −12 V and disable the relay by turning off T2, while IC2b output remains at +12 V. If a negative DC voltage is present at the input to our protection circuit, the roles of IC2a and IC2b outputs are reversed.



Transistor T1 inverts the output from the 555, wired as a monostable, which is high (here that means ground) for around 5 s after power is applied. T1 is then turned off, as its base is at the same voltage as its emitter, and thus holds T2 off: the relay remains de-energized. At the end of the time delay, the 555 output falls (−12 V), T1 conducts and the relay is energized via T2.

I've carried out a lot of testing and tried several types of relay, finally choosing a high-quality 24 V type designed for speakers, and I'm very pleased with the circuit. Preset P1 makes it possible to adjust the operating threshold of the relay chosen according to its coil resistance. The choice of a 2N1711 for T2 is justified by both its availability and its gain, higher than a BD139, for example. Don't worry if it gets hot, its junction can withstand up to 175 °C.

The protection circuit is mains powered via two symmetrical regulator (IC3 and IC4) which will need to be fitted with small heatsinks of the transformer secondary voltage is high. It should theoretically be between 12 and 25 V, but given the fluctuation in AC line voltage, it's wiser to limit it to a range of 15 to 22 V.

As the power drawn from the transformer is modest — around 3 VA is more than enough — it would be feasible to use quite a small transformer to allow the protection circuit to be fitted within the speaker being protected.

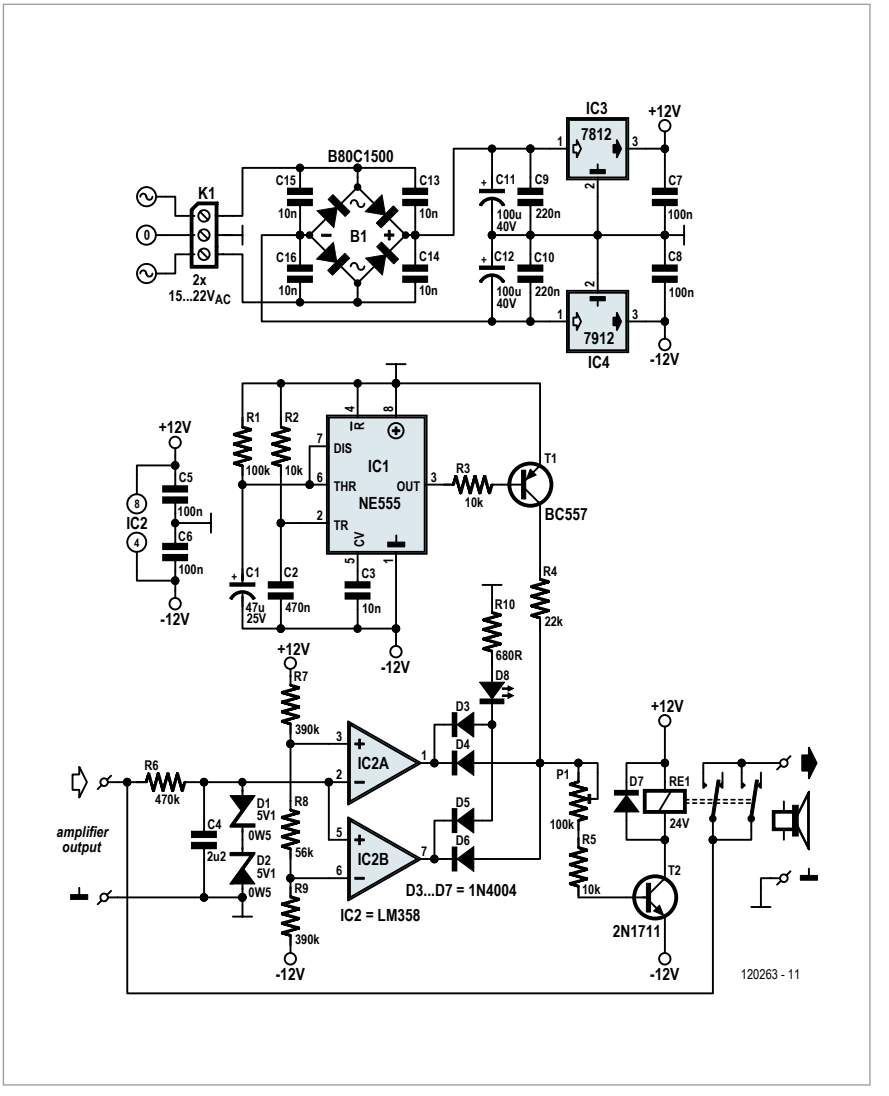
You will note that the 555 is powered between the center zero rail (which is its positive rail) and the −12 V rail.

Choosing a low-current LED for D8 will let you save a few tens of milliamps, at least when the diode is lit. In this case, the value of R10 will increase from 680 Ω to 4.7k so as to reduce the current to 2 mA instead of 15 mA!

When testing, bear in mind that when the protection circuit input is open-circuit, the two opamps receive no bias voltage. So to test their operation, you'll need to apply a DC voltage source.

(120263)

I've drawn inspiration from various ideas gleaned from the Internet, but I don't think this circuit actually exists anywhere in quite this form.



Bulb-2-LED Bicycle Light Conversion

By Anders Gustafsson (Finland)

Elektor is all over the globe, starting out from Holland. The same with bicycles, which are even older. All the way from Åland Islands N60 E20 (check that out), Anders Gustafsson wrote 2 us: "I just got so fed up with my bicycle light. I ride the bike to and from work every morning and with fresh batteries the light was acceptable. Problem was that the batteries wore down real fast so I was wondering what a LED could do. The original bulb, an Osram PR2 2.4 V 0.5 A should produce 10 lm. A Cree XP-E should produce 114 lm at 350 mA. I opted for a slightly lower current, or 320 mA, powering the LED from a constant-current switcher which will produce a constant current down to a battery voltage of 1.5 V. To get the output where I wanted, I used a Khatod KLCP 20CR lens with a 6-degree angle."

Besides a circuit diagram of a simple voltage step-up converter based on a Linear Technology LT1618 chip [1]. Anders kindly included a few photographs of his reworked bicycle light, which are reproduced here mainly as food for thought.

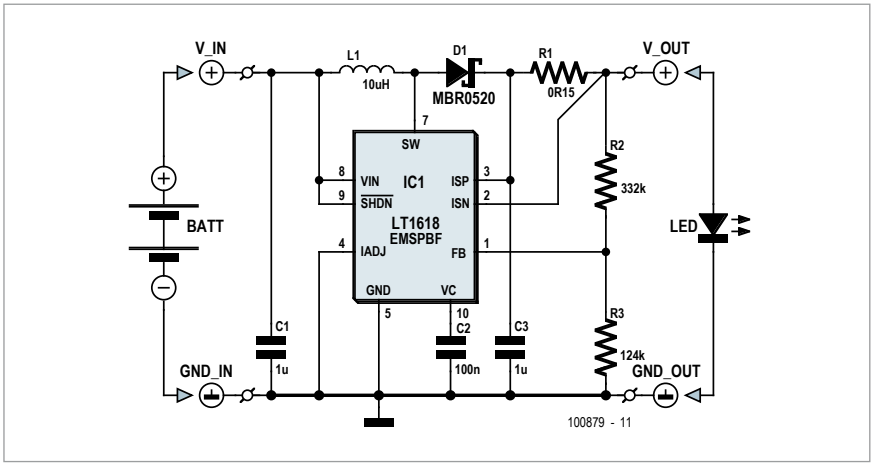
The great thing about the LT1618 is that it can operate as a constant-current, constant-voltage source. The fixed-frequency, current mode switcher is rated to operate from an input voltage between 1.6 V to 18 V. Its high switching frequency of 1.4 MHz permits the use of small inductors and capacitors.

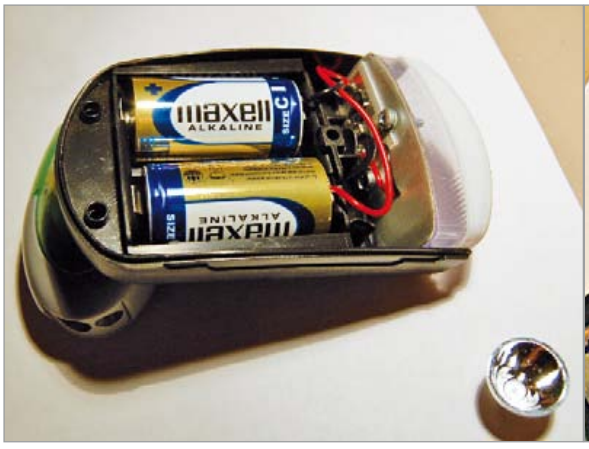
Here we use constant-current mode and power the converter from two (thick!) 1.5 V batteries to obtain a LED current that's remarkably steady around 320 mA.

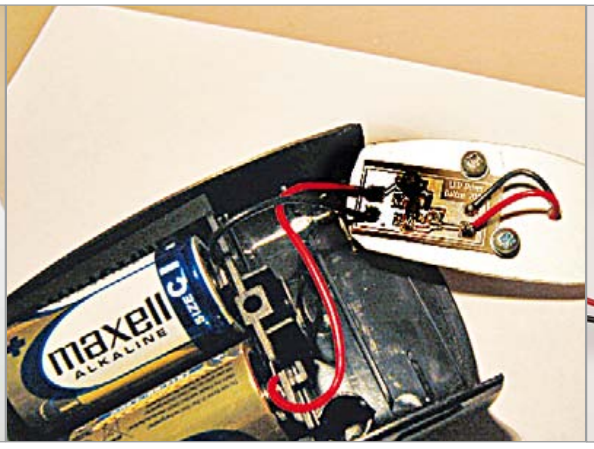
The values of R2 and R3 in the voltage at the output are set up for V_{out} = 4.64 V using

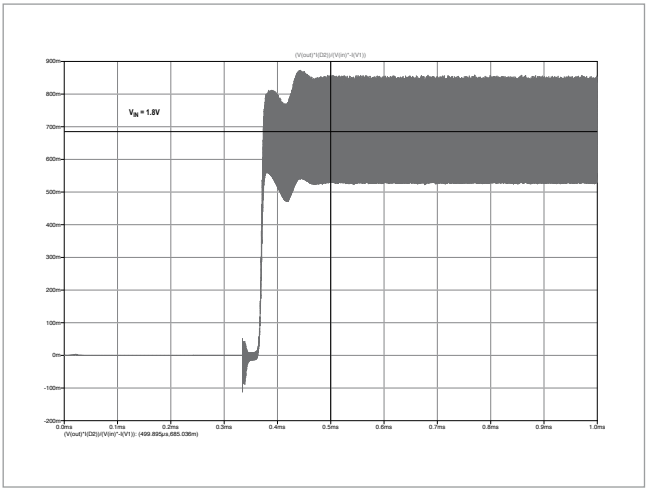
$$R2 = R3\left(\frac{V_{out}}{1.263} - 1\right)$$

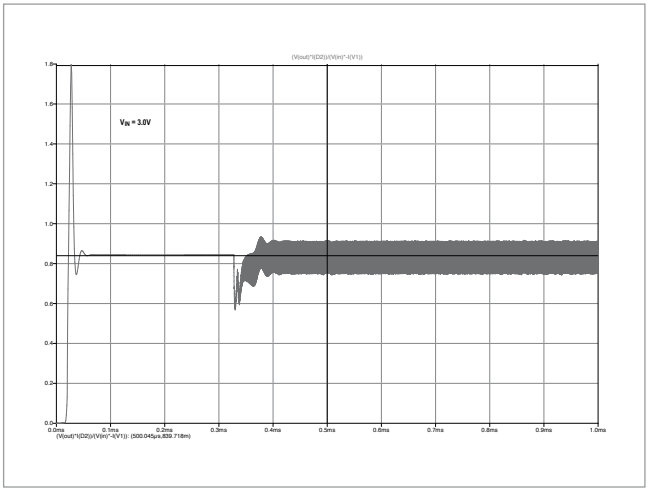
which is fairly arbitrary but bearing in mind that some absolute maximum has to be set. For sure the desired con-











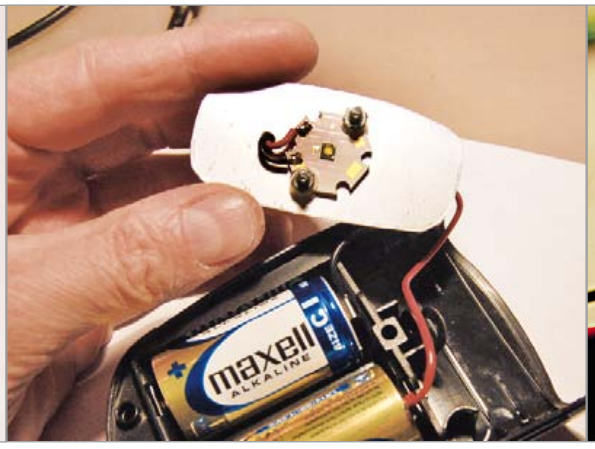
stant current of about 320 mA has priority as we aim to power an LED 'to the max'. With the IADJ pin (4) of the chip tied to ground the nominal current sensing voltage is 50 mV (appearing between the ISP and ISN pins). Here we have a constant current like

$$I = \frac{0.05V}{0.15\Omega} = 0.33A$$

which is just right to push that Cree LED into producing a very bright light beam in darkest Åland Islands and beyond, even if the batteries are juiced. Theoretically! So, Elektor Labs grilled the converter, measured its performance and drew up a table with selected results. In conclusion, the circuit does a good job both when powered from two dry cells (source = 3.0 V) or from two rechargeables (source = 2.4 V). The more mAh's proudly print-

Measured performance

Source [V]	Source [A]	V_{out} [V]	I_{out} [mA]	Efficiency (%)
1.3	0	1.3	-	
||				
1.7	0.45	2.89	-	
1.8	0.71	2.95	329	75.9
||				
2.3	0.62	3.03	323	68.9
||				
2.8	0.45	3.03	320	76.9
||				
3.2	0.38	3.03	321	80.0

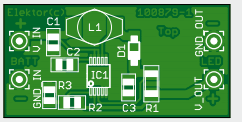


COMPONENT LIST

Resistors
R1 = 0.15Ω size 1206
R2 = 332kΩ size 0805
R3 = 124kΩ size 0805

Capacitors
C1,C3 = 1µF X5R, size 0805
C2 = 100nF X5R, size 0805

Inductor
L1 = 10µH, 7.3x5mm, e.g. TT Electronics HM7610100LFJTR



Semiconductors
D1 = MBR050
IC1 = LT1618EMS (Linear Technology)

Miscellaneous
PCB # 100879-1 from www.elektorpcbservice.com

ed on the batteries, the longer your LED headlight shines.
Next we decided to put the start-up response of the converter through an LTSpice simulation, specifically at the lower end of V_{in} (1.8 V) and the nominal value (3.0 V) as it is often found that these converters fail to start when the batteries are flat. The run-in behavior of the 1.4 MHz oscillator in the LT1618 can be seen in both images.
Space being at a premium in the bicycle headlight the choice of SMD parts rather than through hole should be obvious. Hence a very small circuit board was designed and printed here. If you experiment with the circuit on your workbench, do not forget to attach a heatsink to the LED as it is likely to die without one. Even a U-style finned heatsink for TO3 devices does a good job.

(100879)

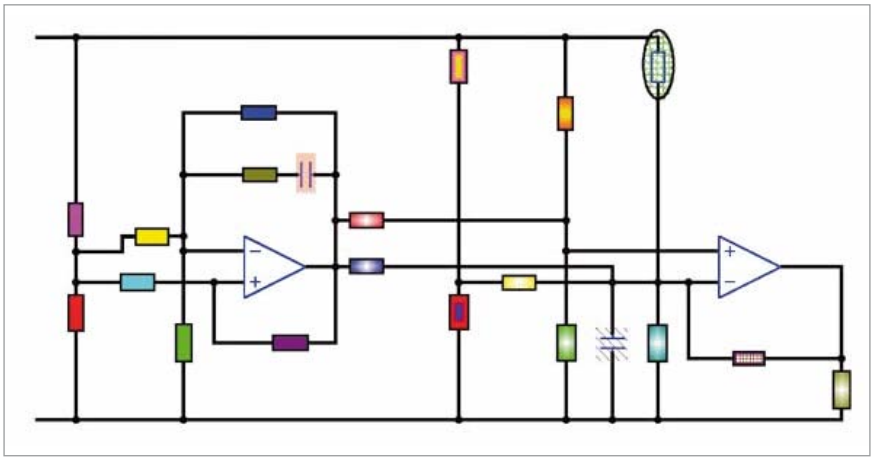
Internet Link

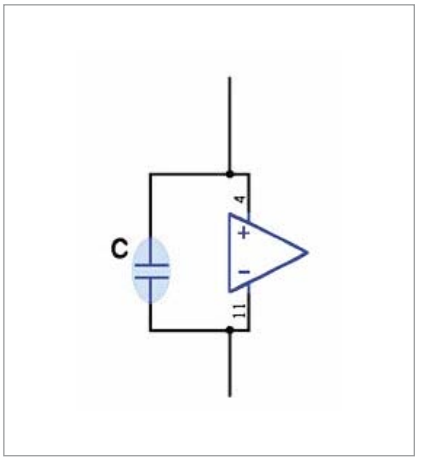
http://cds.linear.com/docs/Datasheet/1618fas.pdf

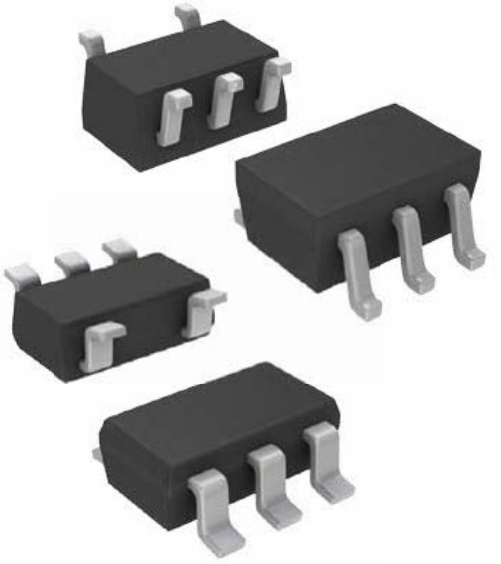
EZ-SMD OpAmp Tweaker Board

By Dietmar Schröder (Germany)

When working on electronics projects containing one or more operational amplifiers (opamps), the associated resistors and capacitors often have to be exchanged in order to change, optimize or generally adjust the circuit's behavior. Doing so is remarkably easy when using SMDs (surface mount devices) so these tiny components may be preferred over the 'good old' through-hole versions. Mini-MELF resistors are especially easy-going in this respect.







To be able to quickly assemble a circuit containing an opamp, a truly versatile and universal PCB was developed that's suitable for '1206' components. It was designed to be suited for a SOIC-14 quad opamp, like the ubiquitous TL074. It is laid out as a single-sided board and quite small, so it can easily be etched on a piece of circuit board idling somewhere in your workshop. A pdf file representing the track layout of the board can be downloaded free of charge from the Elektor website [1].
The board routing was designed such that hookup wire is rarely called for to complete the circuit you are putting together. There are some extra universal pads though for the more demanding cases. There are also several solder jumpers which can be conveniently shorted using a blob of solder, if necessary.

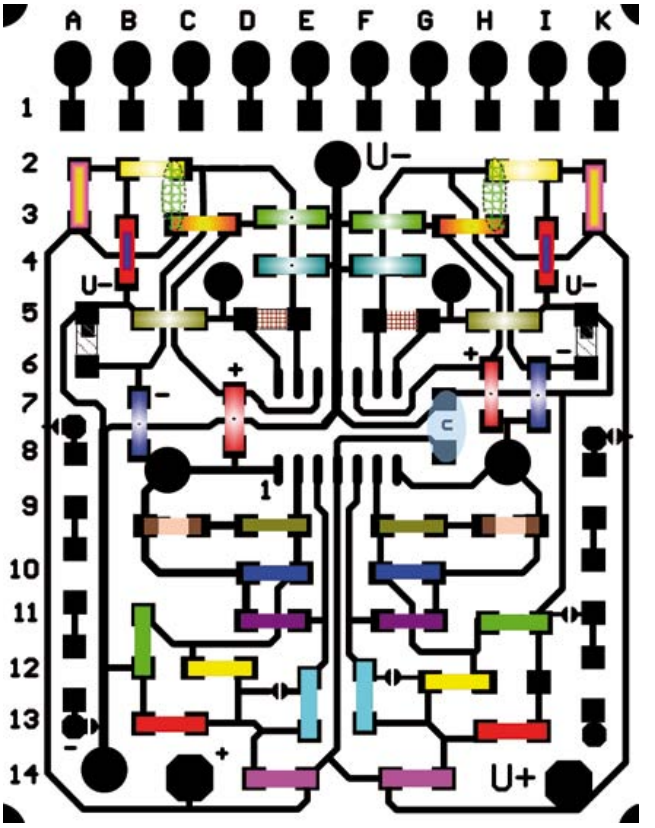
Looking at the PCB design, one half of the left side got copied and appears mirrored on the right with only a few alterations, hence the result is almost symmetrical, except for the supply voltage decoupling capacitor (marked 'C'). This is connected between the positive and negative supply rails (not from supply to ground, since this could inject supply ripple into the ground rail).

Putting it all to work, fill in the necessary components in the schematic and — using the colors in the illustrations printed here — populate the PCB accordingly using whatever components you need for your design. Note that the schematic printed here shows just two opamps, i.e. half the actual circuit. The schematic is also available for downloading at [1], so you can conveniently print it and fill in the component values as many times as you like, keeping your documentation up to date as you proceed to Fame & Glory with your project.

There's nothing tricky with, or difficult about, this universal 'prototyping tool', so feel free to give it a try and personally verify that it works a treat when developing circuits hands-on.

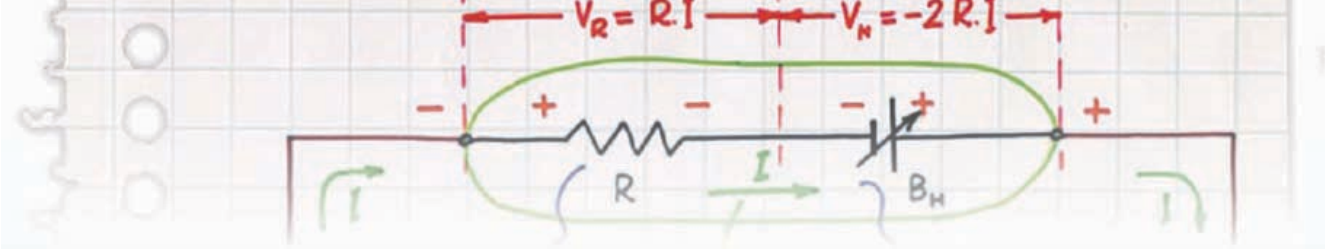
(110737)

There's nothing tricky with, or difficult about, this universal 'prototyping tool'.



Internet Link

[1] www.elektor.com/110737

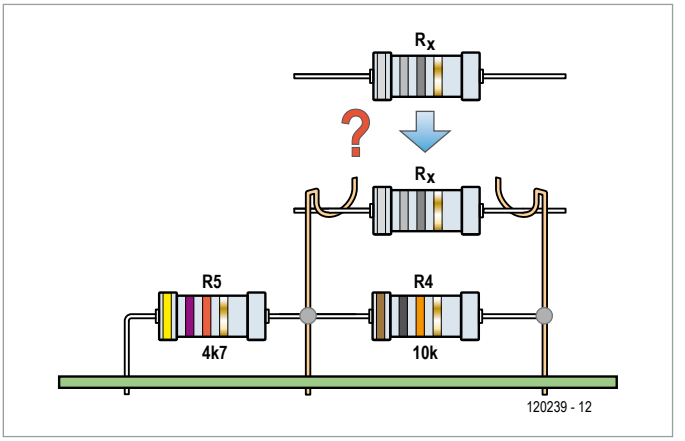


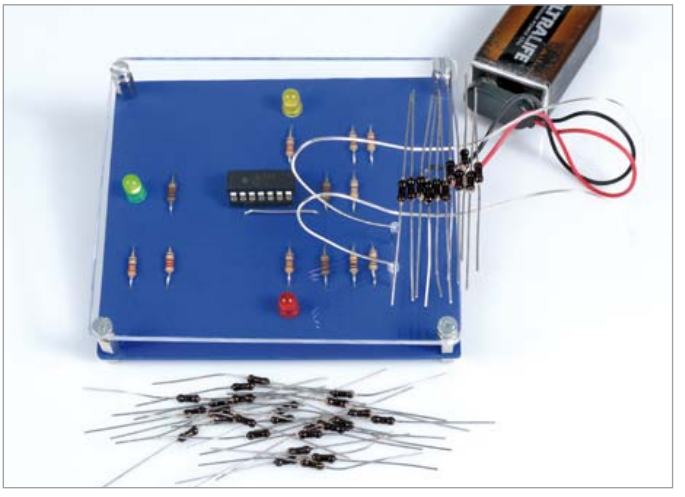
Room for a Small One?

By Stefan Hoffmann (Germany)

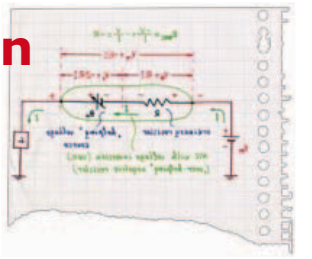
As practically every *Elektor* reader will attest, electronics can be a lot of fun. The circuit described here, a small electronic game for two or more players, proves the point. The game takes the form of a balance, with weights being represented by resistors.

The players take turns to place resistors (whose values they do not know) on one 'pan' of the electronic balance, which is formed by two bent wires. The 'counterweight' is another resistor, whose value is also not known to the players. The state of the balance is indicated by three LEDs of different colors: yellow, indicating that the pan is too light; green, indicating balance; and red, indicating that the pan is too heavy. The object of the game is to place as many resistors as possible on the electronic balance without lighting the red 'too heavy' LED. Bonus points are awarded to a player who can get into the relatively narrow central zone corresponding to perfect balance.

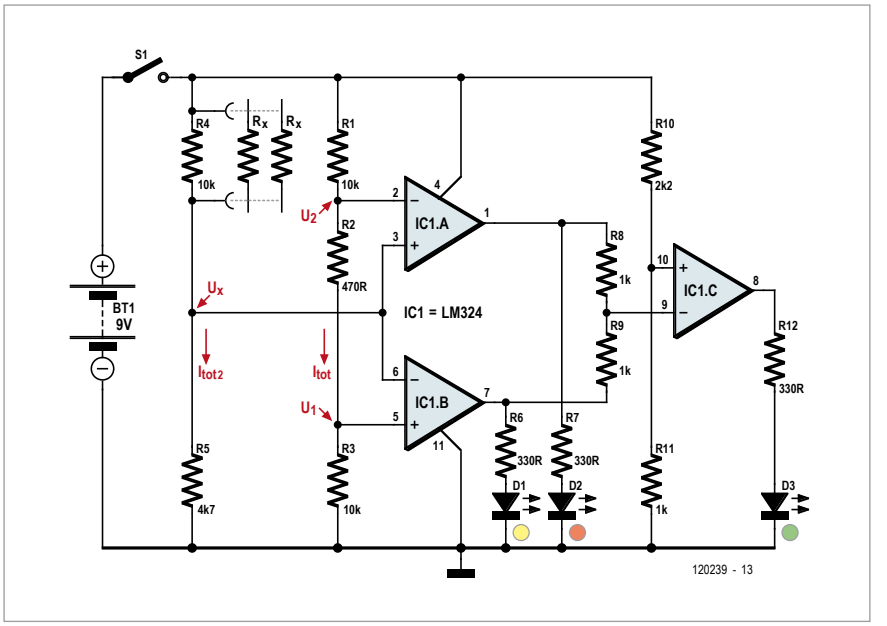




The circuit is based around a number of voltage dividers and three operational amplifiers, used as comparators. When switch S1 is closed the 9 V supply is provided to the circuit and the game is started. The first voltage divider is formed by resistors R4 and R5. The two wires that play the role of the balance pan are at either end of R4. If resistor R_x is absent, as at the beginning of the game, the voltage U_x will be around 2.88 V. As the game progresses, more and more resistors are added at R_x between the two wires. These resistors are all in parallel with R4. The more resistors are added to the electronic balance, the lower the total resistance between the ends of resistor R4 and so the higher the voltage U_x. The voltage divider formed by the three resistors R1, R2 and R3 is responsible for determining the voltages that are the thresholds for the comparators to which they are connected, and hence for the boundaries between the different states in which the balance can be. With the values given in the circuit diagram we obtain a value for U_1 of about 4.4 V and for U_2 of about 4.6 V. If U_x is lower than 4.4 V the output of IC1.B will swing to the positive supply rail. This will in turn light the yellow LED to indicate that the balance pan is too light. If U_x is greater than 4.6 V the output of IC1.A will swing to the positive supply rail and the red LED will light to indicate that the balance pan is too heavy. If U_x lies between 4.4 V and 4.6 V then the system is balanced. In this situation the



voltages at both the output of IC1.A and the output of IC1.B will be at 0 V and therefore the voltage at the inverting input of IC1.C will also be 0 V. The voltage divider formed by resistors R10 and R11 set the voltage at the non-inverting input of IC1.C at about 2.81 V, and as a result when the system is balanced the output of IC1.C will be at the positive supply voltage and the green LED will light. The voltage divider formed by resistors R8 and R9 produces a voltage half-way between the output voltages of IC1.A and IC1.B and feeds this into the inverting input of IC1.C. The consequence of this is that the green LED only lights when the system is balanced.



There are various ways that the game could be played: the author's suggestion is as follows. At the beginning of the game each player receives ten resistors, whose colored bands have been made unreadable using a black felt-tip pen (see photograph). Players then take it in turns to add one of their resistors to the electronic balance. If the yellow LED remains lit he receives ten points and play passes to the next player. If the red LED lights the player loses his points and the round is over. If the green LED lights, the player receives ten points for his resistor and then doubles his score. In this case also the round ends. Instead of playing a resistor a player can 'fold' and leave the round, halving his current score. Play then passes to the next player, who must choose whether to add another resistor or also fold, again halving his score. If the next player chooses to play and the yellow light remains on, he receives ten bonus points, and, if the green LED lights, he receives the ten bonus points and doubles his score. However, if the red LED lights, the player loses his points as before. At the end of each round each player adds his points to his running total. It is best to play as many rounds as there are players, so that each has one turn to start the game.

For the 'weights' the author recommends using fifty 100 kΩ resistors, five 47 kΩ resistors, three 33 kΩ resistors and three 22 kΩ resistors. The more low-value resistors there are the quicker each round will tend to be.

(120239)

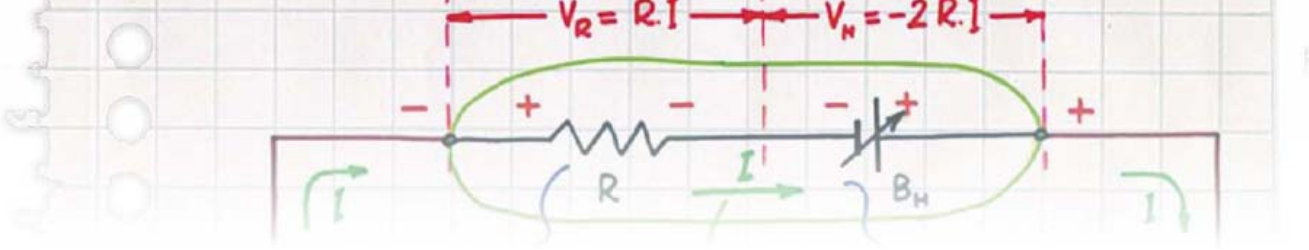
LC Oscillator with Pot Tuning

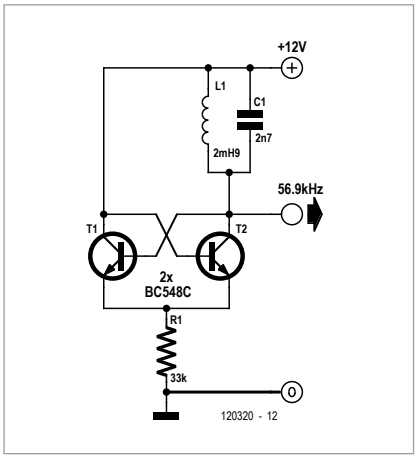
By Burkhard Kainka (Germany)

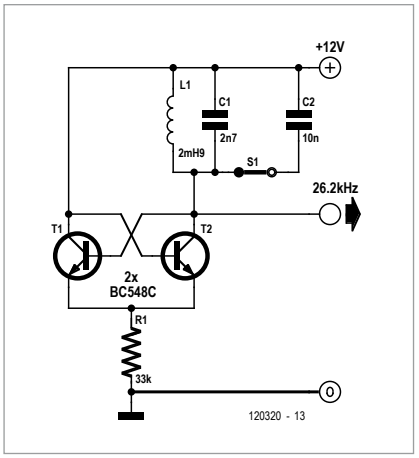
An LC oscillator is usually adjusted using a variable capacitor. However, for frequencies below around 100 kHz this calls for a variable capacitor with a value in the nanofarad range, which is somewhat impractical. In many situations, however, a potentiometer can be used instead.

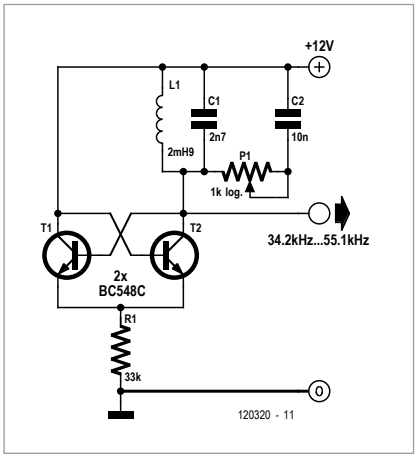
We start by looking at an oscillator using a 2.9 mH inductor salvaged from a low-energy lightbulb and a 2.7 nF capacitor (see upper circuit). The theoretical resonant frequency of this combination is 56.9 kHz.

The circuit operates from a supply voltage as low as 1 V, as the resonant circuit has a high Q factor. If an extra 10 nF capacitor is wired in parallel the resonant frequency falls to 26.2 kHz. The Q factor is reduced and so the gain in the circuit must be increased, and a supply voltage of at least 2 V is needed.









Using a switch it is possible to select between the two frequencies (see middle circuit).

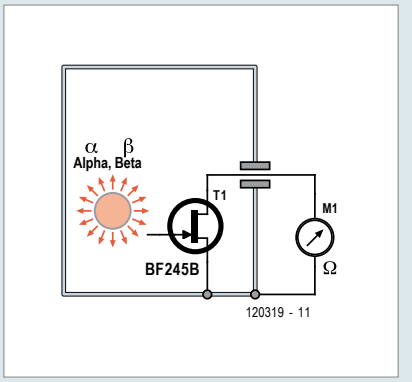
And now the subtle bit: instead of the switch we use a 1 kΩ potentiometer (see lower circuit). In this form the frequency of the oscillator can be smoothly adjusted using the potentiometer, almost as if we were using a 10 nF variable capacitor. Experience shows that using a linear potentiometer gives a rather non-linear frequency adjustment, and so it is preferable to use a logarithmic potentiometer. A further problem is the high level of damping: the energy loss needs to be made up for with higher gain, and so with a higher emitter current. This can be achieved either by reducing the emitter resistor or by increasing the supply voltage.

Experiments show that the maximum frequency coverage possible is around a 2:1 range. If the two capacitors are very different in value the damping in the middle of the frequency range is so great that oscillation stops. With the values shown in the circuit diagram the frequency can be adjusted between 34.2 kHz and 55.1 kHz.

(120320)

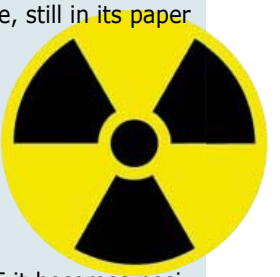
FET Radiation Meter

By Burkhard Kainka (Germany)



What must be the simplest possible radiation meter consists of just a BF245 JFET and an ohmmeter. Ions produced as a result of the radiation charge up the gate of the FET and thus change its resistance. The FET needs to be enclosed in a metal tin to screen it from electric fields and from ions that might normally be present in the atmosphere. After taking a calibration measurement we can experiment by placing various samples inside the tin. The device was tested using a small sample of pitchblende (a uranium ore), a ^{241}Am source taken from a smoke alarm, and a gas mantle, still in its paper sleeve. The results were as follows.

Reference (no sample)	160.2 Ω
Pitchblende	156.3 Ω (−3.9 Ω)
^{241}Am source	155.9 Ω (−4.3 Ω)
Gas mantle	159.0 Ω (−1.2 Ω)



The results are clear: when a sample is placed near the FET it becomes positively charged, reducing its drain-source resistance. The experiments above were repeated several times and showed good reproducibility. In practice it takes around half a minute for the FET's resistance to settle.

(120319)

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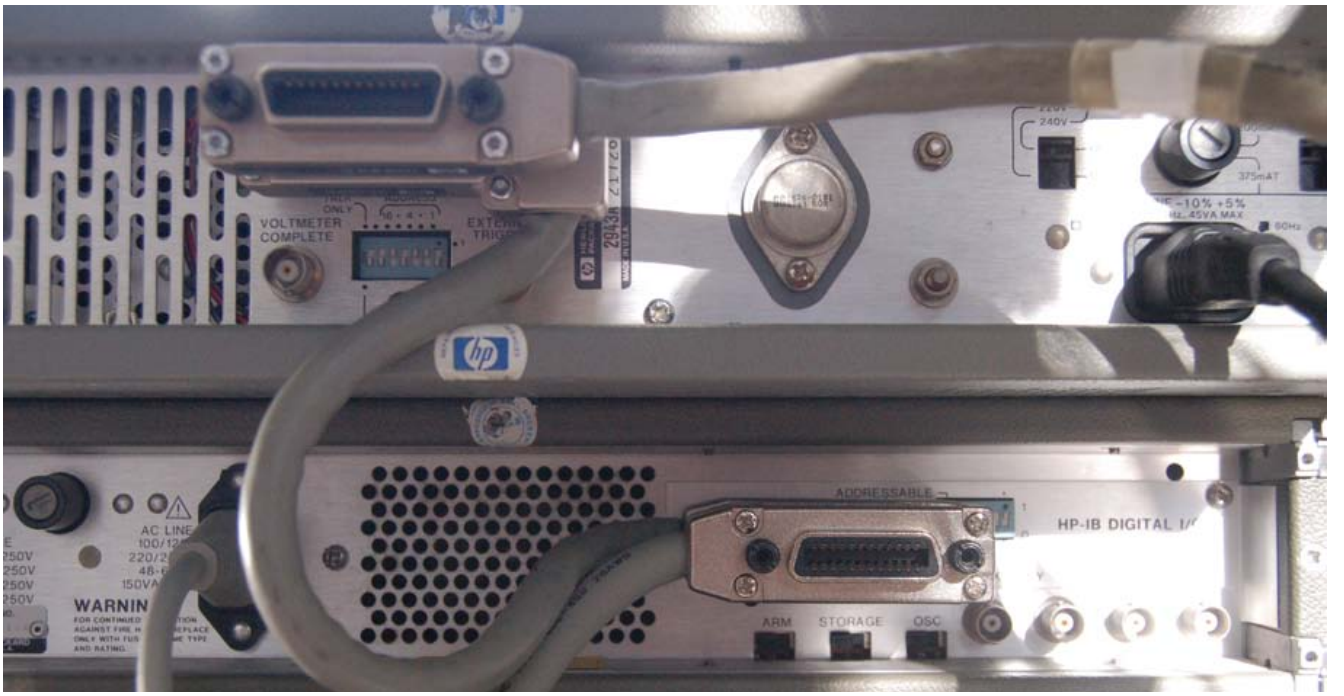
Gee Whiz, a GPIB-to-USB Converter

$50 interface circuit brings 80s/90s edebris to life



If the acronym GPIB is new to you, you are either Young, Innocent, Unelektorized or even Delektorized. Everyone else: here's a low cost converter that connects legacy GPIB equipment to your PC via contemporary USB.

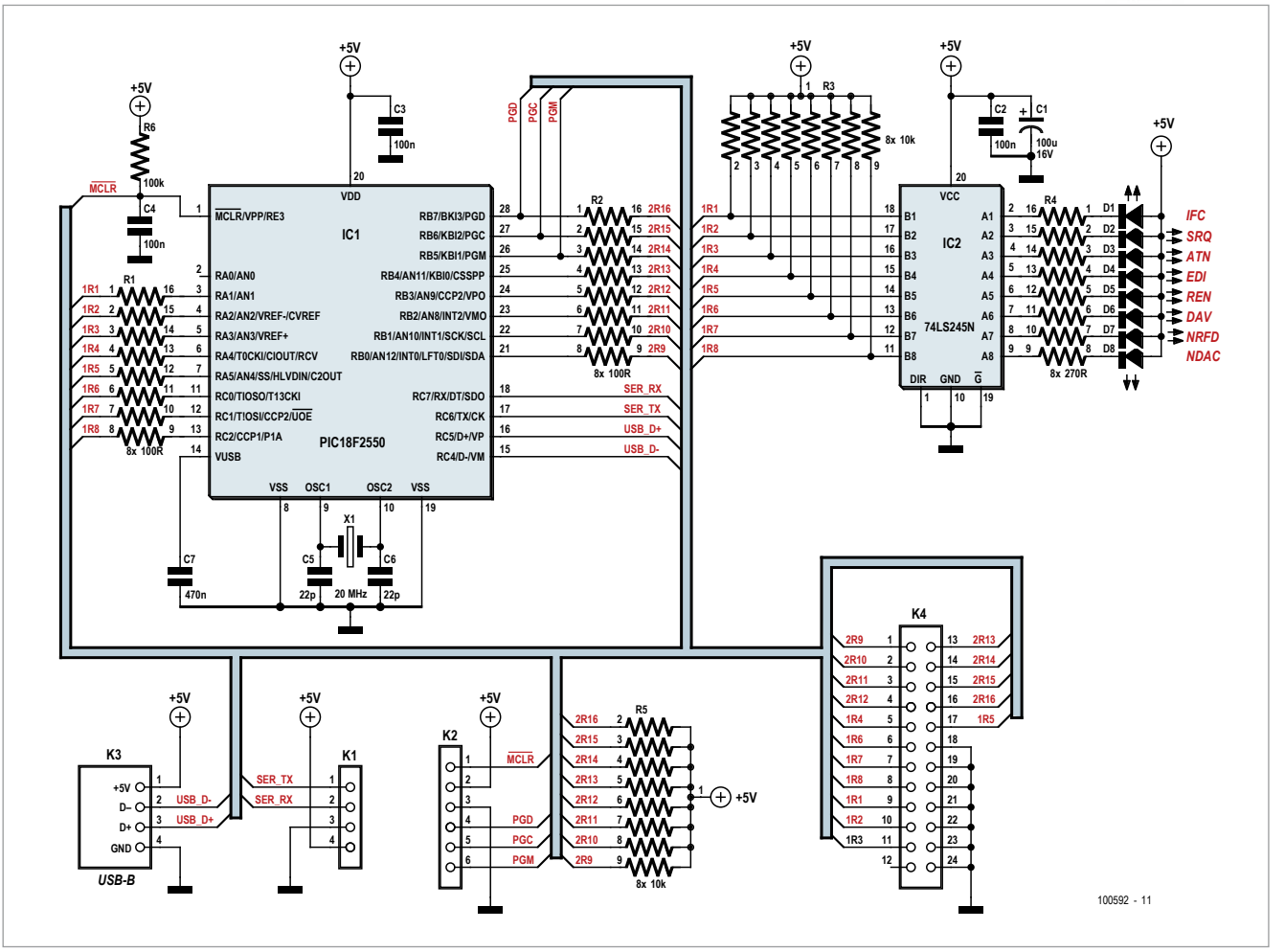
By Anders Gustafsson (Finland)

GPIB (General Purpose Interface Bus) refers to an IEEE 488 standard parallel interface originally defined in 1984 for attaching sensors and programmable instruments to a computer. Using a 24-pin connector, up to 15 devices can be daisy chained together and addressed individually. Hewlett Packard's version of the GPIB is unsurprisingly called HPIB. GPIB equipment being horribly expensive in its heydays, and the comms protocol over intricate, it never entered the hobbyist's realms. GPIB equipment at the time was for high brow professionals and rocket scientists — everyone else on a paper round just dreamt of it.

To what purpose?

So what's the point in building a converter to bring that old 1980/90s grot to life? The answer: 30+ years on, you buy quality and ruggedness at a fraction of the original price. GPIB was widely used for high-end measurement equipment and today there is a flourishing market for second-hand instruments.

Several vendors sell reconditioned and calibrated instruments and if you look on places like eBay, good instruments from the likes of HP, Tektronix and Marconi can be had for less than 100 pounds, or even cheaper if you want to take a gamble and buy an instrument that's "beyond / in need of repair". Avoid the "FU" variety though.



While most modern Chinasian instruments are almost impossible to repair, old instruments are built from standard components mostly. In good US engineering tradition they are also built like tanks, and service manuals can often be downloaded for free from places like the Boat Anchor Manual Archive [1]. Thus fixing small and not so small faults should be feasible and may serve as an excellent exercise in Electronics. In fact, gurus like Jim Williams claim that fixing broken instruments is the best way to learn electronics [2].

Lots of formerly up-market, now 2nd, 3rd, … 10n-hand instruments you may stumble upon are equipped with a 24-pin GPIB connector. It has a 'Centronics look' as you can see from the picture. You rarely see it on present-day instruments, but for several decades, the GPIB bus reigned supreme in the field of sampling & data collection and was occasionally used for other things as well like Commodore's printers and floppy disk drives.

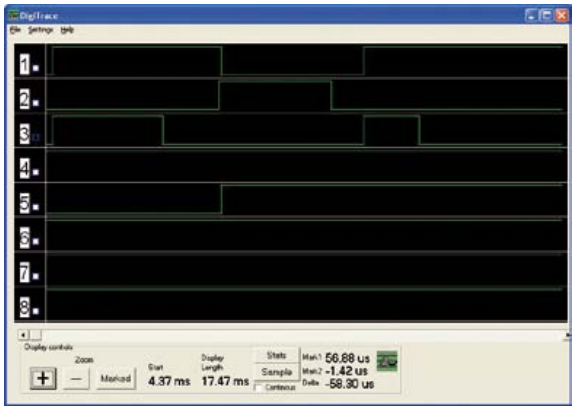
GPIB-USB Converter Features

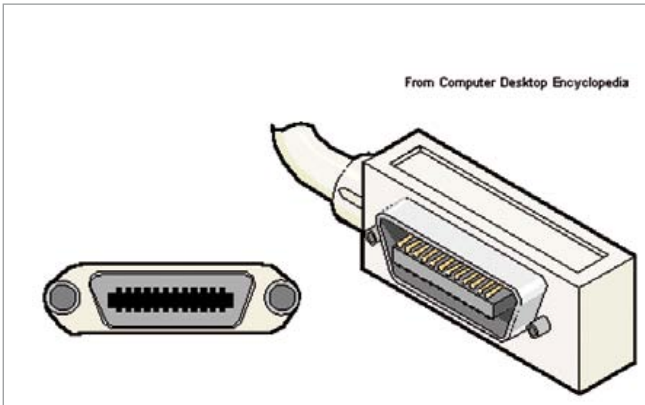
- Low-cost external adapter
- Full GPIB / IEEE488 functionality by USB
- PIC18F2550 @ 20MHz with on-chip USB interface
- Emulation and enumeration of PC COM port
- Software developed in C and MCHPFSUSB Framework

A thorough description of GPIB is beyond the scope of this article, but suffice it to say that you can hook up all your GPIB compatible instruments to a USB-equipped computer and then address and configure them at will from that com-

Elektor Products & Services

- PIC18F2550 source code files: free download from www.elektor.com/100592
- PCB # 100591-1: from www.elektorpcbservice.com





puter using the GPIB command set issued for the old — sorry – legacy equipment.
PC GPIB interfaces are available commercially but at high cost and usually in the form of plug-in cards. Prices have come down, but building one for connecting to the omnipresent USB is an interesting exercise and the component cost is less than 50 euros. Moreover the PC can remain closed.

Circuit and GPIB lines

As can be seen from the schematic, all that is needed for this simple GPIB-USB converter is a PIC MCU (ticking at 20 MHz), a 74LS245 bidirectional buffer IC and a handful of passive components. LEDs show the status of the GPIB command lines. The circuit is powered from the USB, i.e. by the PC. Most of the magic is done in software where we use the USB's CDC interface to make GPIB look like a legacy COM port. This way, even if you're under 25 you can use GPIB from any software package that can (or can be made to) talk to a COM port. Examples are provided for OpenOffice and Excel.

The full implementation of GPIB has eight data lines, labelled DIO1 through DIO8 and eight control lines of which only three are important for the actual transfer: DAV (Data Available), NRFD (Not Ready For Data), and NDAC (Not Data Accepted). When configured as outputs, the latter two are normally open-collector with a pull-up, meaning that all listeners on the bus need to set them High for the talker to read a High. Consequently the bus automatically adjusts to the slowest listener, ensuring no data is lost. This is called a three-way-handshake. In the timing diagram pictured here the top three signals are DAV, NRFD and NDAC, the rest is data. We see NRFD going High when all listeners are ready to accept data. At that point the talker puts data on the bus and pulls DAV Low. When the last listener has read the data NDAC goes High and milliseconds later DAV, then the cycle repeats.

Dedicated chips for interfacing to GPIB exist, for example the SN75160/162, but they are obsolete hence hard to find. In this implementation we use the standard PIC I/O ports and

PIC2550 burn instruction

(pic2550.txt in software archive 100592-11.zip)

Modify the PICDEM FSUSB demos for 2550/breadboard. LEDs connected to PORTC 0..3

1. Make a copy of HardwareProfile → PICDEM FSUSB.h, call it HardwareProfile → PICDEM FSUSB 2550.h
2. Edit HardwareProfile.h; add a line:

```
#if defined(__18CXX)
    #if defined(__18F4550)
        #include "HardwareProfile - PICDEM FSUSB.h"
    #elif defined(__18F2550)                                    //
        #include "HardwareProfile - PICDEM FSUSB 2550.h"        // Added
```

3. Change the processor type in MPLAB (Configure, select device) to 18F2550

Pin	Label	Signal Name
1	DIO1	Data Transfer
2	DIO2	Data Transfer
3	DIO3	Data Transfer
4	DIO4	Data Transfer
5	EOI	End Or Identify
6	DAV	Data Valid
7	NRFD	Not Ready For Data
8	NDAC	Not Data Accepted
9	IFC	Interface Clear
10	SRQ	Service Request
11	ATN	Attention
12	Shield	Chassis Ground

Pin	Label	Signal Name
13	DIO5	Data Transfer
14	DIO6	Data Transfer
15	DIO7	Data Transfer
16	DIO8	Data Transfer
17	REN	Remote Enable
18	GND	DAV Ground
19	GND	NRFD Ground
20	GND	NDAC Ground
21	GND	IFC Ground
22	GND	SRQ Ground
23	GND	ATN Ground
24	GND	Signal Ground

fake the open collector by making the port an output for a Low, and an input for a High. The input impedance is very high and the net result is a three-state that does not affect the bus. If you need to control a lot of instruments on the same bus, using high speeds and/or using long cables, then dedicated bus interface chips might be a good idea.

In a perfect world the GPIB standard mandates that an instrument that's turned off should present a high-impedance to the bus. In real life that is not always the case and an instrument that's powered off might stop the bus from working. If in doubt, just have all instruments on the bus turned on.

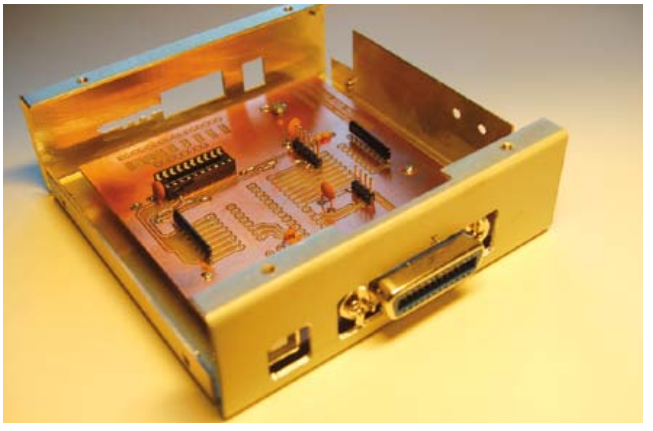
Some Words Challenging Under-25s

Analog Circuit Design, ASCII, Boat Anchor, Carriage Return, Centronics, ~~Centronix~~, COM, Commodore, floppy disk, FUBR, Jim Williams, GPIB, IEEE, ruggedness, SN75160, SN75162.

Software Dept.

The software developed for this project is built upon the USB routines provided by Microchip. They are free but copyrighted, and thus cannot be redistributed as source. The archive file containing all other elements necessary to burn your own PIC for the project is in the expected place [4]. Go to the same url for ready-programmed PIC18F2550s directly from Elektor.

To build the HEX file for the PIC you first download the USB samples (part of the MCHPFSUSB Framework [3]). Then navigate to C:\Microchip Solutions\USB Device → CDC →



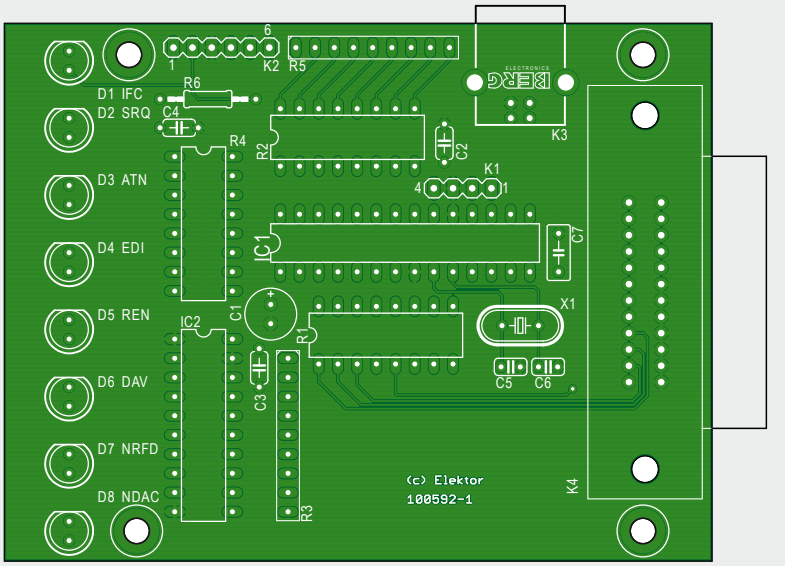
COMPONENT LIST

Resistors
R1,R2 = 100Ω, DIL16 array
R4 = 270Ω, DIL16 array
R3,R5 = 10kΩ, SIL9 array
R6 = 10kΩ

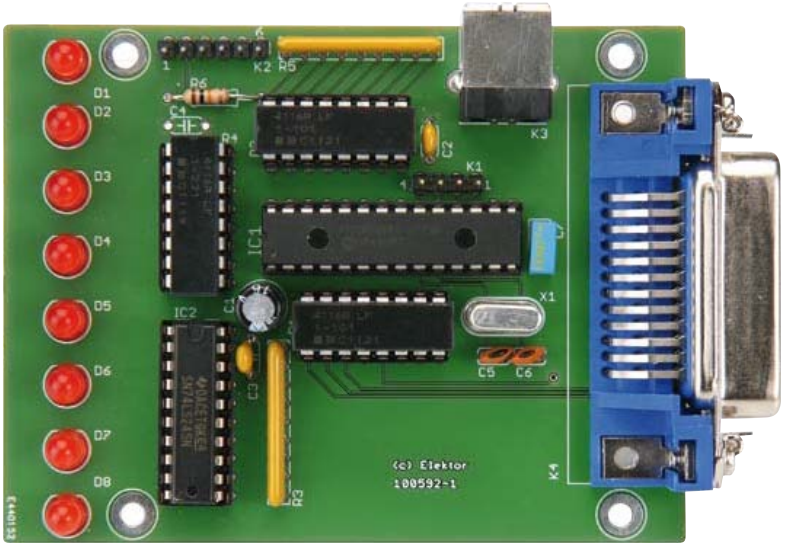
Capacitors
C1 = 100µF 16V, radial
C2,C3,C4 = 100nF
C5,C6 = 22pF, ceramic, lead pitch 2.5mm
C7 = 470nF

Semiconductors
D1–D8 = LED, 3mm, red
IC1 =PIC18F2550-I/SP, programmed, Elektor # 100592-41
IC2 =74LS245

Miscellaneous
X1 = 20MHz quartz crystal
K1 = 4-pin pinheader, pitch 0.1" (2.54mm)
K2 = 6-pin pinheader, pitch 0.1" (2.54mm)
K3 = USB socket, Type B, PCB mount
K4 = 24-way IEEE488/Centronics connector, male, PCB mount. Alternatively, IDC version wired to board (Farnell # 1099278).
PCB # 100592 from www.elektorpcbservice.com



Basic Demo. Under that, you will find a directory called CDC → Basic Demo → Firmware. Make a copy of that and call it something like "CDC - Basic Demo – Firmware GPIB". Copy the files provided to the same dir and do the modifications described in 'pic2550.txt' (also printed here) and in readme.txt. Then open the project USB Device → CDC → Basic Demo → C18 → PICDEM FSUSB.mcp and build! The build should complete without errors. Then just program the PIC18F2550 from MPLAB.



Building, connecting up, examples

The converter (some say: "adapter") is easy to build on the printed circuit board shown here. The 24-way IEEE/Centronics style male connector for board mounting proved hard to get and as you can see from the photograph it may be substituted by a plug part (salvaged from a cable connector) and 24 discrete wires. A neater solution might be to obtain an IDC version of the 24-way plug.

Assuming the build was as successful as the software's, connect the converter to the computer using a USB cable. The computer should report *New Hardware Detected* and ask for information. Point it to mchpcdc.inf in C:\Microchip Solutions\USB Device → CDC → Basic Demo\inf. If all is well you should now see a new COM port. Assuming this is COM4, you should be able to talk to it with, say, HyperTerminal.

Connect your GPIB instrument(s), making sure they all have unique addresses. To set an instrument to address 22 decimal, set the switches (5,4 … 1) as 10110. The instrument can now be addressed as '6' for Listener and 'V' for Talker. To make the instrument talk, send 2<space>?UV Ctrl-Enter;

By your GPIB Command

The software receives data on GPIB and passes it on as is to USB. When sending, data is passed as packets where the first is a command and the second is blank (reserved for future use). Valid commands are:

' ' – Send string as is (ATN de-asserted)

'2' – Send string as GPIB command with ATN asserted

'4' – Interface clear (resets all instruments)

'6' – Assert GPIB REN (puts instrument in remote mode)

'8' – De-assert REN

'V' – Verbose mode, echoes typed commands

'Q' – Verbose off

Command strings are terminated by either a line feed (ASCII $0A_h$) which will trigger an EOI on the bus or an ETX (ASCII 0x03) which will not. The latter is useful when you need to switch between Command and Data modes in the middle of a message.

you should now see the instrument outputting its readings on HyperTerminal. *It's life Jim but not as we know it!*
Since the original HPIB/GPIB standard does not define what commands an instrument can accept, it is best to refer to the instrument manual for actual examples. For instance, to set an HP3456A to AC Volts from GPIB, you need to first address the instrument in Command mode (ATN asserted) with ?U6, then send the actual command F2 in Data mode (ATN de-asserted). The actual string to do so becomes:

```
2<SPC>?U6<ETX><SPC><SPC>F2<CR><LF>
```

where <SPC> is a space, <ETX> is Ctrl-C and <CR><LF> is Carriage Return and Line Feed.

The spreadsheet example included in the software download for the project assumes two instruments, one HP 3456A DMM addressed as 22 and one HP 5328A Counter addressed as 23. The macro will loop 20 times, taking two readings, one from each instrument, and put them in spreadsheet columns B and C respectively.

It is hoped that the circuit described here is helpful in some way to prevent a few GPIB equipped instruments from ending up in dumpsters, skips, landfills, incinerators or other places unworthy of their heritage status.

(100592)

Internet Links

[1] http://bama.edebris.com/manuals/

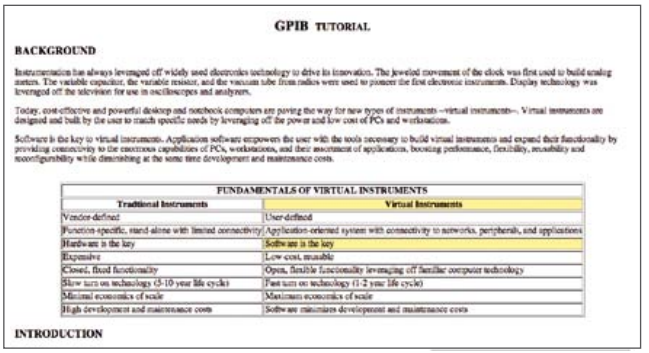
[2] *The Art and Science of Analog Circuit Design*, page 3.

[3] www.microchip.com/stellent/idcplg?IdcService=SS_GET_PAGE&nodeId=2651&param=en534494

[4] www.elektor.com/100592

Also worth seeing & reading

Short GPIB tutorial:
www.hit.bme.hu/~papay/edu/GPIB/tutor.htm



GPIB TUTORIAL

BACKGROUND

Instrumentation has always leveraged off widely used electronics technology to drive its innovation. The jeweled movement of the clock was first used to build analog meters. The variable capacitor, the variable resistor, and the vacuum tube from radios were used to pioneer the first electronic instruments. Display technology was leveraged off the television for use in oscilloscopes and analyzers.

Today, cost-effective and powerful desktop and notebook computers are paving the way for new types of instruments –virtual instruments–. Virtual instruments are designed and built by the user to match specific needs by leveraging off the power and low cost of PCs and workstations.

Software is the key to virtual instruments. Application software empowers the user with the tools necessary to build virtual instruments and expand their functionality by providing connectivity to the enormous capabilities of PCs, workstations, and their assortment of applications, boosting performance, flexibility, reusability and reconfigurability while diminishing at the same time development and maintenance costs.

FUNDAMENTALS OF VIRTUAL INSTRUMENTS

Traditional Instruments	Virtual Instruments
Vendor-defined	User-defined
Function-specific, stand-alone with limited connectivity	Application-oriented system with connectivity to networks, peripherals, and applications
Hardware is the key	Software is the key
Expensive	Low cost, reusable
Closed, fixed functionality	Open, flexible functionality leveraging off familiar computer technology
Slow turn on technology (5-10 year life cycle)	Fast turn on technology (1-2 year life cycle)
Minimal economies of scale	Maximum economies of scale
High development and maintenance costs	Software minimizes development and maintenance costs

INTRODUCTION

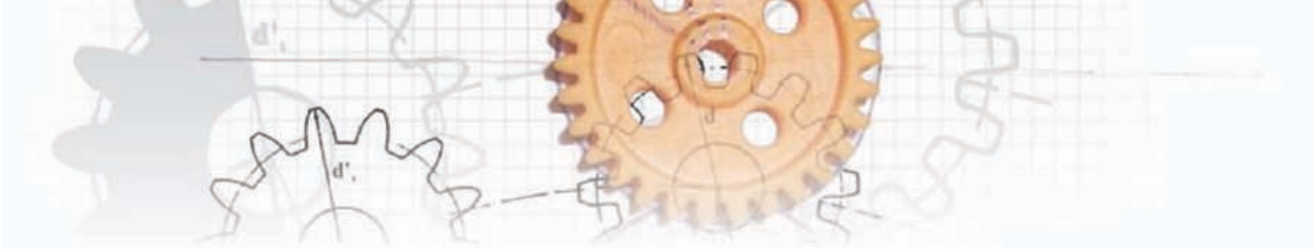
Tutorial from HP:
http://bitsavers.org/pdf/hp/hpib/TutorialDescrOfHPIB.pdf

Author's project site: www.dalton.ax/gpib

WHAT vintage GPIB equipment 4 me

Pen/X-Y plotter
Oscilloscope
Power Supply
Data Logger
Sample & Hold Unit
Telemetry Unit
Spectrum Analyzer
Multiplexer
Function Generator
Network Analyzer

Keywords:
Agilent, Advantest, Fluke, Hewlett Packard, Marconi, National instruments, Tektronix, IEE 488.



16 Ways to Switch your AC Power On

By Vladimir Mitrovic (Croatia)

Connect this microcontroller controlled switch between an ordinary AC Power On/Off switch and the load, and you have 2^4 (say, sixteen) ways available for managing how and when the load actually gets powered. Your options are listed in the table!

As soon after the AC outlet voltage (230 VAC or 115 VAC) is applied to the Live (L) and Neutral (N) input terminals (USA: G; Ground), the voltage across C2 will rise above 2.7 V and the ATtiny13 microcontroller (IC1) will start to execute the program held in its flash memory. The program controls the logical state of output pin PB4 in order to switch the power supply to the load on and off. In detail:

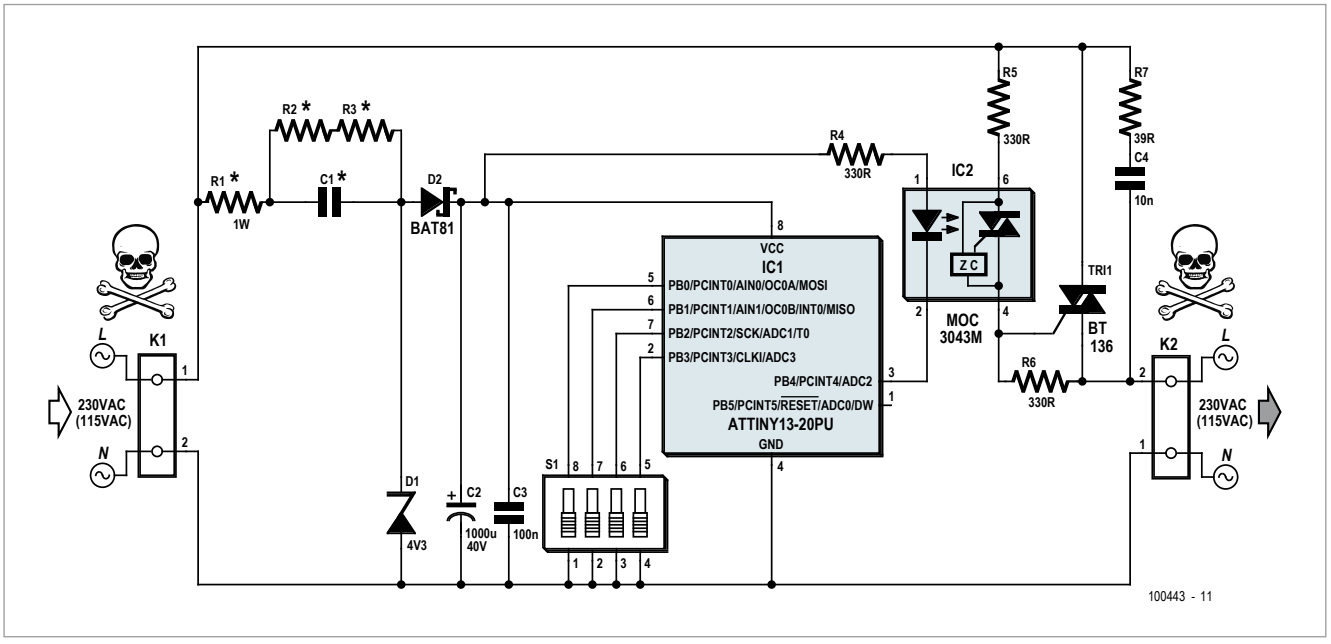
if PB4 is at '1', the current through the LED inside optoisolator IC2 is interrupted causing the internal triac driver and triac Tr1 to be held Off; consequently no current flows through the load connected to the AC Power output terminals;

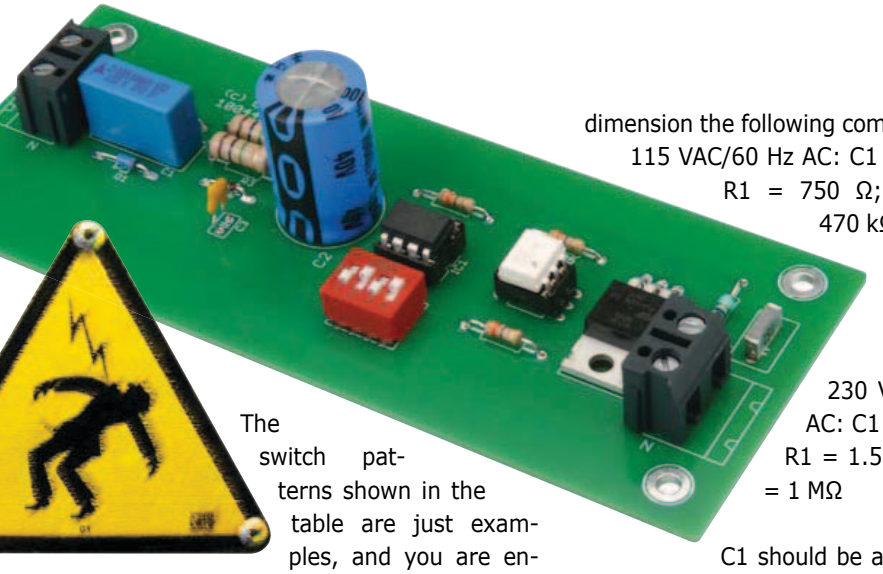
if PB4 is at '0', current flows through the LED inside IC2, the internal triac driver and Tr1 are switched On; consequently AC current flows through the load connected to the output terminals.

The circuit, in particular, the ATtiny13 firmware, has full control of the power distribution to the load as long as the AC Power On/Off switch (not shown here) is on. For example, the program can switch on the load with a delay, keep the load switched on for a predetermined time period, switch the load on and off according to some pattern... you name it!

An example Bascom-AVR program called "EE_prog_switch.bas" is written to illustrate the possibilities. The program is a free download from [1]. 'Bascom-AVR is supplied by MCS Electronics — a free Demo version limited to 4 KB source code size is available [2]. Initially the program checks the state of configuration switches S1-S4 and calls the relevant pre-programmed routine from a set of 16 — see the table.

'One-shot' routines will execute only once; to repeat them you should switch the AC Power switch ahead of the circuit Off and On again. Routines with a repeating pattern ('once every...') will execute in a loop as long as the AC Power is on. If you want to select a different pattern, you should switch AC Power off and flip to another setting on S1-S4. The new setting will be recognized the next time your AC Power switch is switched to On.





The switch patterns shown in the table are just examples, and you are encouraged to define and implement other patterns that suit your applications. If there is only one On/Off pattern that the switch should follow, you can omit switches S1-S4 and thus make the circuit even simpler.

It should be noted that the design does not accommodate for precise timing. The overall accuracy primarily depends on the accuracy of the ATtiny's internal RC oscillator (<10%; <3% if calibrated), while the Wait routines in Bascom-AVR are accurate to within 1%.

Depending on your local power grid, dimension the following components:

115 VAC/60 Hz AC: C1 = 0.68µF; R1 = 750 Ω; R2,R3 = 470 kΩ

230 VAC/50 Hz AC: C1 = 0.33µF; R1 = 1.5kΩ; R2,R3 = 1 MΩ

C1 should be an X2 class capacitor with a minimum specified operating voltage of 250 VAC; for example, WIMA MKP-X2, WIMA MP3-X2, Epcos MKP X2 or similar, rated for 250, 275 or 305 VAC voltages. As these capacitors are normally available with ±20% tolerance, the value is calculated to ensure 10 mA of current even in a worst-case, i.e. when the capacitance is significantly out of tolerance. As a matter of fact, the total AC current flow through C1 exceeds 20 mA, but half the current is 'lost' because of the half-wave rectification. Most of the current flows through the LED inside IC2: some 5-6 mA when switched on (if necessary, adjust the value of R4 to keep this current within range). The ATtiny13 runs on its internally calibrated 9.6 MHz oscillator, but the clock frequency is lowered to 600 kHz to keep power consumption under 1 mA. The rest of the current flows through zener diode D1 which acts as a shunt regulator and provides a reasonably stabilised voltage for the circuit. You can expect about 4.4 V across C2 when IC2 is switched off, which will drop to some 3.4 V when IC2 is switched on. The actual values depend primarily on D1.

Resistor R1 limits the inrush current during power-on, but sadly also causes some unwanted losses during operation. You may use a 1 watt non-flammable resistor in place of R1, but a better solution would be to use a NTC resistor. Unfortunately, we were unable to find an appropriate NTC for limiting the inrush current to 200 mA. Therefore, two series connected Epcos NTC thermistors may be considered with a

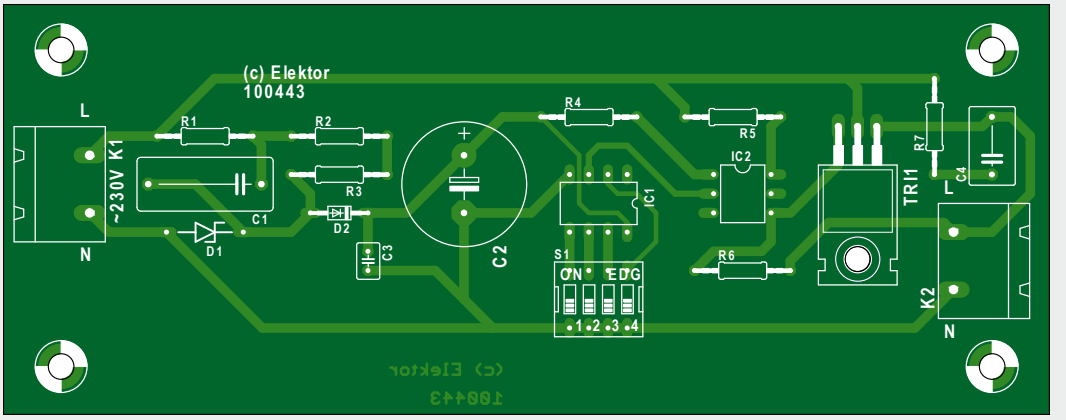
Description of the pre-programmed routines (example program)

S4	S3	S2	S1	switch on	switch off
off	off	off	off	as soon as AC power is switched on	never
off	off	off	on	as soon as AC power is switched on	10 minutes after switch-on
off	off	on	off	as soon as AC power is switched on	30 minutes after switch-on
off	off	on	on	as soon as AC power is switched on	60 minutes after switch-on
off	on	off	off	10 minutes after AC power is switched on	never
off	on	off	on	30 minutes after AC power is switched on	never
off	on	on	off	60 minutes after AC power is switched on	never
off	on	on	on	10 minutes after AC power is switched on	10 minutes after switch-on
on	off	off	off	10 minutes after AC power is switched on	30 minutes after switch-on
on	off	off	on	10 minutes after AC power is switched on	60 minutes after switch-on
on	off	on	off	once every 20 minutes	10 minutes after switch-on
on	off	on	on	once every 30 minutes	10 minutes after switch-on
on	on	off	off	once every 60 minutes	10 minutes after switch-on
on	on	off	on	once every 12 hours	1 hour after switch-on
on	on	on	off	once every 24 hours	1 hour after switch-on
on	on	on	on	never	never

COMPONENT LIST

Resistors
R1 = 1.5kΩ 1W
(115VAC: 750Ω)
R2,R3 = 1MΩ
(115VAC: 470kΩ)
R4,R5,R6 = 330Ω

Capacitors
C1 = 0.33µF 250VAC, MKP (115VAC: 0.68µF) (see text)
C2 = 1000µF 63V radial
C3 = 100nF
C4 = 10nF class X1/ Y2



Semiconductors
D1 = 4.3V 0.5W zener diode
D2 = BAT85
IC1 = ATtiny13-20PU, programmed, Elektor # 100443-41
TRI1 = BT136

Miscellaneous
K1,K2 = 2-way PCB screw terminal, pitch 7.5mm
SW1 = 4-way DIP switch block

PCB # 100443-1 from www.elektorpcbservice.com

resistance of 680 Ω (at 25°C). These thermistors are intended for temperature measurement and compensation, but work well as inrush current limiter, too. For 115 VAC, it is safe to use just one 680 Ω NTC thermistor.
The BT136 triac is rated for 4 A_{RMS} on-state current. Consider replacing it with a stronger device if the load current can be expected to exceed 3 A. Components R7-C4 form a snubber network and may not be necessary depending on the particular triac and load used.

A 1-second delay is provided at the beginning of the example program. Therefore, the expression "as soon as the power is switched on" from the table should be read as "1 second after the power is switched on". This was found necessary as the voltage across C2 rises slowly at power-up and there is not enough power to switch on IC2 and Tr1 until the voltage across C2 reaches more than 3.5 V. A 1-second delay will allow the voltage across C2 to reach at least 4 V before the program actually starts to run, which will ensure that IC2 and Tr1 can be reliably switched on at the very beginning of the program.

The ATtiny13's fuse bits should be set during programming to enable the On-chip Brown-out detection (BOD) circuit to monitor the VCC level with a trigger level fixed to 2.7 V, and to configure the micro to run on the calibrated internal RC oscillator at 9.6 MHz clock frequency. It is the programmer's (i.e. your!) responsibility to set a divide-by-16 prescale factor at the beginning of the program to lower the clock frequency to 600 kHz. If you are not into programming microcontrollers, order your ATtiny13 ready programmed from Elektor (# 100443-41) [1].

Caution. The circuit is at Live AC potential and potentially hazardous to touch. Never work on the circuit while it is connected to the AC power outlet. The circuit must be enclosed in an approved enclosure preventing any part of it from being touched. When in doubt, ask for the assistance of a qualified electrical engineer.

(100443)

Internet Links

www.elektor.com/100443

www.mcselec.com

Elektor Products & Services

- Bascom-AVR source code file: # 100443-11.zip, free download from www.elektor.com/100443
- Ready programmed ATtiny13: #100443-41, www.elektor.com/100443
- Printed circuit board # 100443-1: www.elektorpcbservice.com

A snippet of the BascomAVR source program.

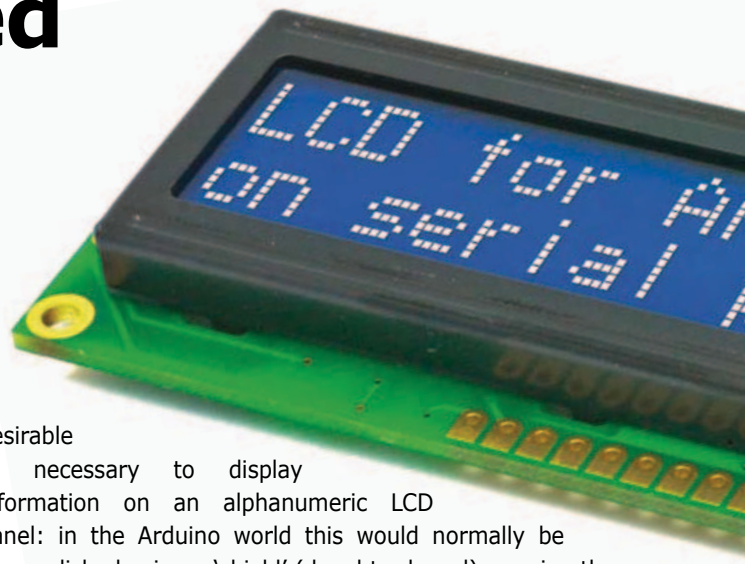
```
Dim S1_s4 As Byte , Minute As Byte , Hour As Byte

Control_pin Alias Portb.4
Sw_on Alias 0
Sw_off Alias 1

Config Clockdiv = 16                        'clock = 600kHz
nop

Config Pinb.4 = Output
Control_pin = Sw_off                        'switch off the load

Config Pinb.0 = Input
Config Pinb.1 = Input
Config Pinb.2 = Input
Config Pinb.3 = Input
Portb = Portb Or &B00001111                 'enable pull-up resistors
Wait 1
S1_s4 = Pinb And &B00001111                 'read S1-S4...

Select Case S1_s4                           'and execute corresponding routine
   Case &B00001111
      Control_pin = Sw_on
   Case &B00001110
      Control_pin = Sw_on
      minute = 10 : Gosub Wait_minute
      Control_pin = Sw_off
   Case &B00001101
      Control_pin = Sw_on
      minute = 30 : Gosub Wait_minute
      Control_pin = Sw_off
   Case &B00001100
      Control_pin = Sw_on
      minute = 60 : Gosub Wait_minute
      Control_pin = Sw_off
   Case &B00001011
      minute = 10 : Gosub Wait_minute
      Control_pin = Sw_on
   Case &B00001010
      minute = 30 : Gosub Wait_minute
      Control_pin = Sw_on
   Case &B00001001
      minute = 60 : Gosub Wait_minute
      Control_pin = Sw_on
   Case &B00001000
      minute = 10 : Gosub Wait_minute
      Control_pin = Sw_on
      minute = 10 : Gosub Wait_minute
      Control_pin = Sw_off
   Case &B00000111
      minute = 10 : Gosub Wait_minute
      Control_pin = Sw_on
      minute = 30 : Gosub Wait_minute
      Control_pin = Sw_off
   Case &B00000110
      minute = 10 : Gosub Wait_minute
      Control_pin = Sw_on
      minute = 60 : Gosub Wait_minute
      Control_pin = Sw_off
   .
   .
```

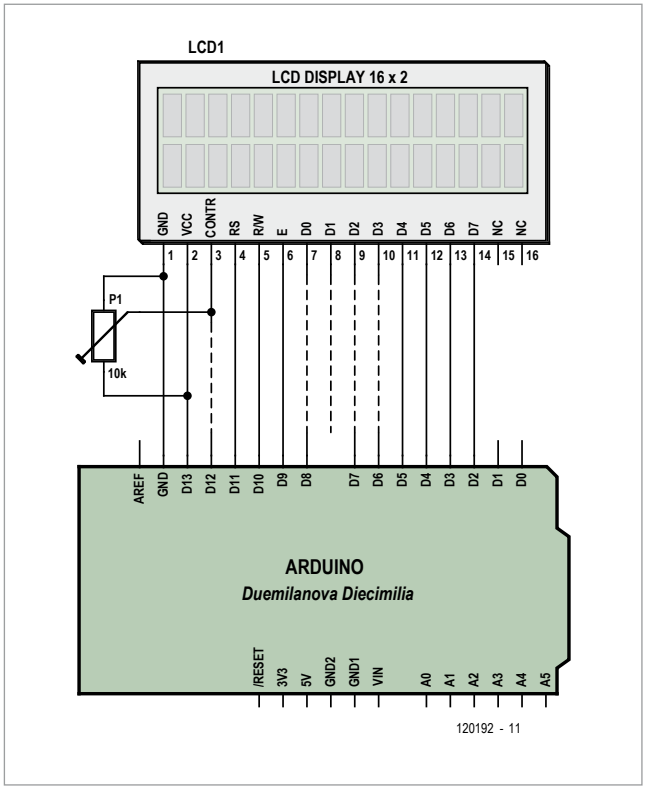
Arduino LC'Deed

Control a display using a (virtual) serial port

By Michael Gaus (Germany)

The Arduino platform provides an easy way to get started in the world of microcontrollers, and is enjoying ever-increasing popularity. What's more, there is a wide range of compatible hardware and software available. In many projects it is desirable or necessary to display information on an alphanumeric LCD panel: in the Arduino world this would normally be accomplished using a 'shield' (daughter board) carrying the LCD. However, there is a much simpler way, as we shall see.





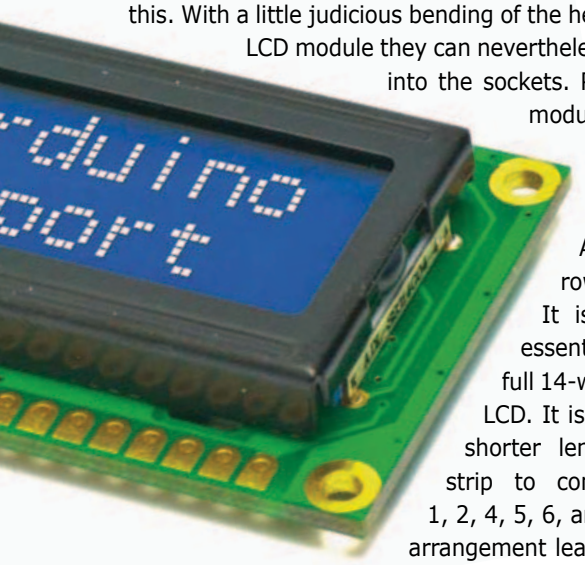
Dot-matrix alphanumeric LCD panels by and large conform to a 'standard' in that most types are compatible with one another in terms of their supply voltage, pinout and control interface, and in the command set supported by the LCD's controller. If we examine the pinout of one of these LCDs we see immediately that in principle it could be connected directly to the sockets on a Uno, Diecimila or Duemilanove Arduino board. It is therefore not necessary to go to the trouble of building a shield.

The LCD's controller must be an HD44780 or compatible device, and the pinout of the module must adhere to the 'standard' mentioned above (see table). It is important that the display supports four-bit interface mode, since when we fit the module directly not all of the LCD's data lines will be connected. The display must also be able to run from a 5 V power supply. And one final requirement: the pins on the LCD must have a pitch of 2.54 mm so that a corresponding header can be soldered directly to it.

Finding a display meeting all of the above conditions might sound like quite a task, but in fact there are surprisingly many suitable modules, the *Elektor* 'standard LCD' [1] included.
First solder a 14-way header to the LCD (or several shorter headers: see below). The display can now be fitted to the Arduino's sockets so that pin 1 of the LCD mates with the GND pin of the Arduino board, the adjacent pins connect to 'Digital 8' to 'Digital 13', and pin 14 of the LCD mates with Arduino pin 'Digital 2'. Arduino pins 'Digital 0', 'Digital 1' and 'AREF' remain unconnected: see the circuit diagram.

Table: Pinout of a 'standard' LCD

Pin	Signal
1	GND
2	VCC
3	V0 (contrast)
4	RS
5	RW
6	E
7 to 14	D0 to D7



Unfortunately the two socket rows that include the digital pins on the Arduino board are not spaced a multiple of 2.54 mm apart: in fact, the distance is somewhat less than this. With a little judicious bending of the header pins on the LCD module they can nevertheless be made to fit into the sockets. Pin 8 of the LCD module will then find itself dangling in free space between the Arduino's two rows of sockets.

It is not absolutely essential to solder a full 14-way header to the LCD. It is sufficient to use shorter lengths of header strip to connect just pins 1, 2, 4, 5, 6, and 11 to 14. This arrangement leaves Arduino pins D12, D8, D7 and D6 free for use as inputs or outputs for other purposes.

The power supply for the LCD module is provided by Arduino pin D13. The firmware running in the device must configure this line as an output and set it to a high level to turn on the LCD. Since LCDs of this type generally have a current consumption of less than 10 mA, the output pin has no difficulty in handling the load. A trimmer is required to allow the contrast voltage of the LCD to be set: this can easily be soldered directly to the pins on the LCD. Most LCD modules need a contrast voltage of between 0 V and 1 V.

For greater mechanical stability the LCD module can be mounted on nylon spacers.

To demonstrate how to drive the LCD from the Arduino the author has written an example program (called a 'sketch' in Arduinoese), which can be downloaded for free from the web pages accompanying this article [1]. In the sketch file 'arduino_lcd.pde' two lines must be adjusted to reflect the number of lines in the LCD module and the number of characters per line. These are defined as the constants LCD_ROWS and LCD_COLUMNS respectively: the default values provided are suitable for a two-row, 16-column display. When the system is reset the greeting 'Arduino LCD' should appear: if it does not, it may be that the contrast voltage is not correctly set.

The icing on the firmware cake is that the display can also be controlled from a PC over the Arduino's USB connection, using a virtual COM port and either a terminal emulator program or more specialized software. By default the interface runs at 9600 baud, but this can be changed in the setup() function with a suitable call to Serial.begin().

Commands and text to be displayed can be sent over the serial interface. Commands always begin with a backslash character ('\', ASCII value 0x5C), followed by a sequence of bytes whose length depends on the command.

To set the cursor position a total of four bytes is required. The command starts with the backslash, followed by a single ASCII decimal digit representing the desired row (for example, '1' for row 1 or '2' for row 2). Next come two ASCII decimal digits giving the desired column (for example, '01' for the leftmost column or '16' for column 16). A complete example might be '\105', which would move the cursor to row 1, column 5. To erase all the text on the display, send '\c' (the 'c' standing for 'clear').

The icing on the firmware cake is that the display can also be controlled from a PC over the Arduino's USB connection.

Commands and text can be intermingled in a compact fashion. For example, sending '\201Hello World!' will cause the string 'Hello World!' to appear on the second line of the LCD. To display a backslash character it must be doubled in the transmitted string: '\\'.

The 'Serial Monitor' in the Arduino IDE can be used for testing.

(120192)

[1] www.elektor.com/120192

Elektor Products & Services

- Software (free download): 120192-11.zip
- Suitable LCD module (2 by 16): 120061-71

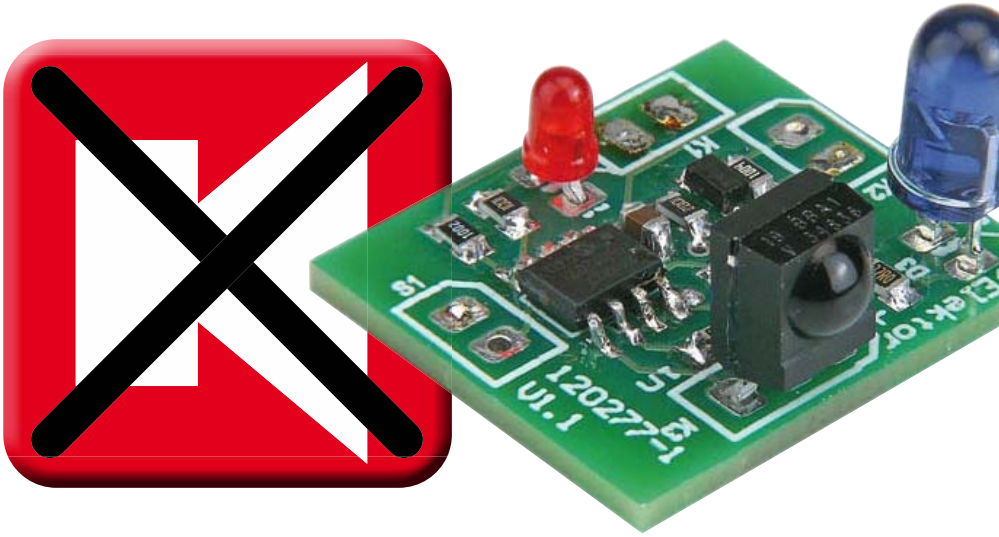
Products and downloads available through www.elektor.com/120192

Mini-Mute

Kill noisy TV commercials with one stroke

You must know the feeling: you're watching a great movie and all of a sudden a commercial comes blasting into the room. Your instinctive response is to turn down the sound or press the mute button – but where's the zapper?

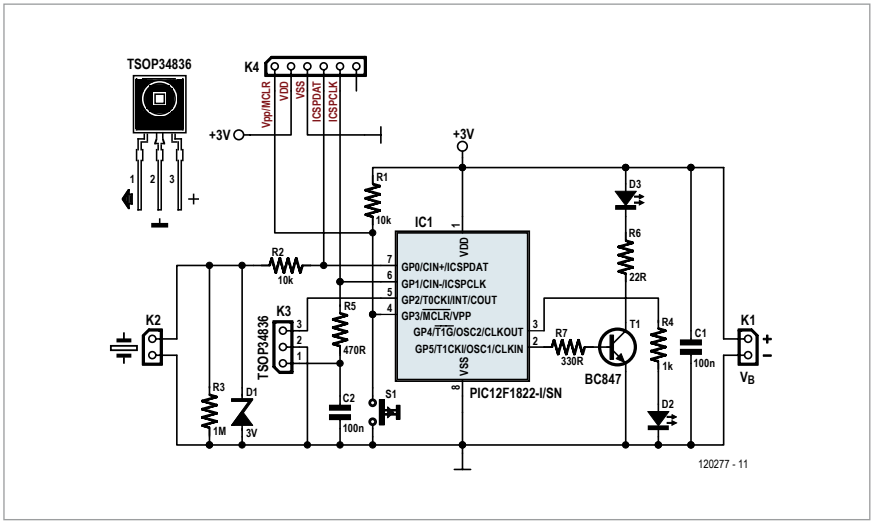
By Peter de Bruijn (Netherlands)



This handy circuit does the job for you. It converts your coffee table into one big button: if you rap on the table, the TV sound is muted right away. When the film resumes, you can restore the sound by rapping on the table again.
The circuit uses a piezoelectric transducer fitted in the bottom of an enclosure. The transducer acts as a shock sensor. The transducer is fitted at the rear of the enclosure touching a screw that rests on the table, and two feet are fitted at the front to improve the operation of the transducer. A yoke made from a length of solid electrical wire provides a mount for an IR transmitter that sends the mute command to the television set. This gives the IR transmitter a clear view of the television set, even if cups and the like are standing on the table.

Just a PIC

The circuit is very simple and essentially consists of an 8-pin PIC microcontroller. The piezoelectric transducer is connected to the GP0 input, and zener diode D1 limits the maximum voltage applied to the input. The GP5 output drives an IR LED via transistor T1 to send IR commands to the television set. Pushbutton S1 allows the circuit to learn the right mute command. If it is pressed and held for a while, indicator LED D2 lights up and the mute code transmitted by the original remote control unit can be read in using an IR receiver module (type TSOP34836) connected to K3. This code is stored in the PIC. Connector K4 is used for programming the PIC. The pinning is compatible with the Microchip PICkit programmer, among others.



The circuit can be powered by a 3 V button cell or two 1.5 V cells in a bat-

tery holder. The circuit draws less than 100 nA in the quiescent state (ultra low sleep mode), so a power switch is not necessary.
The PCB for the advert killer has been kept very small by using predominately SMDs. Note: the prototype version shown in the photo does not have a programming connector, but this connector is present in the final version.

Construction

The circuit board and a pair of 1.5 V cells can easily be fitted in a standard box measuring 5 × 2.5 × 7 cm (2 × 1 × 2 3/4 inch). Of course, a much smaller box can be used with a button cell. Remember to program the PIC before closing the box (the source and hex code are available at [1]).

Drill a hole the bottom of the box at the rear so that the middle of the piezoelectric transducer is accessible from outside when the box is resting on its base. Then secure the piezoelectric transducer in the bottom of the box with hot-melt glue or silicone adhesive. Thread a screw into the hole until it touches the transducer. Glue the screw firmly in place (see the accompanying construction drawing: (1) screw, (2) piezoelectric transducer, (3) PCB). At the front of the box, fit two feet to enhance the operation of the vibration sensor.
Fit a bracket (made from 2.5 mm² / AWG13 electrical wire, for example) on the box for mounting the IR LED. This gives it a free view of the television set. With a bit of imagination, you can transform the box into something that looks nice on the table. For instance, the author 'dressed up' the prototype with a toy dragon.

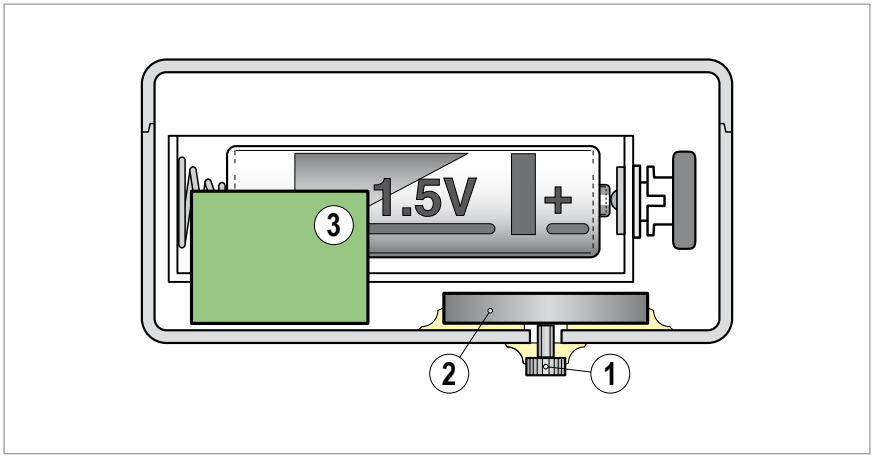
Use

Start by learning the right mute code. Press and hold the button until the indicator lamp (D2) lights up (longer than 3 seconds). Hold the original remote control a few centimeters in front of the IR receiver and press the Mute button twice. If the code is received properly, it will be saved and the circuit will return to normal mode. If no code is received within 10 seconds or a bad code is received 6 times, the program automatically returns to normal mode. The learning function works with virtually every remote control unit.

Now you can place the advert killer on your coffee table or the like. Tap the table or the box when you want to switch the TV sound on or off. The sensitivity can be optimized by choosing the right location on the table.

The advert killer also responds to cups set down hard on the table, but everyone quickly learns not to do this, and it has the advantage that the table is less likely to be damaged.

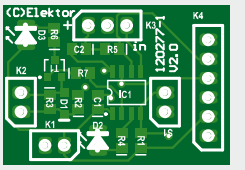
(120277I)



Internet Link

[1] www.elektor.com/120277

COMPONENT LIST



Resistors
(SMD0805)
R1,R2 = 10kΩ
R3 = 1MΩ
R4 = 1kΩ
R5 = 470Ω
R6 = 22Ω 0.25W
R7 = 330Ω 0.25W

Capacitors
(SMD0805)
C1,C2 = 100nF

Semiconductors
D1 = 3V 0.375W zener diode (SOD123F)
D2 = LED, low current, red, 3mm
D3 = IR-LED, 5mm (e.g. Vishay TSUS5202)
T1 = BC847 (SOT23)
IC1 = PIC12F1822-I/SN (SOIC8)
IR receiver module, 36kHz (e.g. TSOP34836)

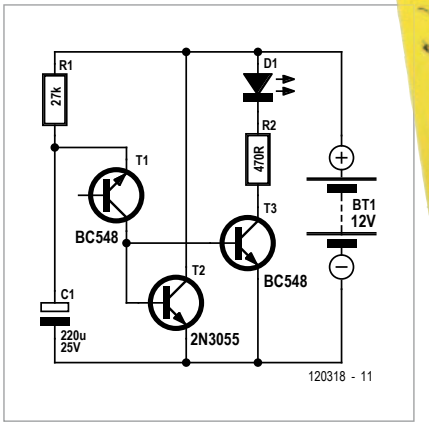
Miscellaneous
K1,K2,S1 = 2-pin pinheader, pitch 0.1 in. (2.5mm)
K3 = 3- pin pinheader, pitch 0.1 in. (2.5mm)
K4 = 6- pin pinheader, pitch 0.1 in. (2.5mm)
Piezo buzzer (e.g. Kingstate KPEG165)
Pushbutton with make contact, panel mount
2 AA or AAA batteries with holder, or 3-V button cell
PCB # 120277-1

Battery Maintainer

By Burkhard Kainka (Germany)

The author found that a long-neglected gel battery in a hand-held vacuum cleaner had gone high-resistance. It took some effort to make it usable again, by alternately applying voltages of opposite polarities to it. A reverse voltage can help to break down the internal non-conducting layers which can form when the battery is left idle. The battery is now back in action and charging and discharging as normal.

Unfortunately, however, the battery will probably start to fail again if we once more leave the appliance lying around unused for a while. To prevent this happening the author applied a well-known technique: the battery is intermittently presented with a very brief high-current load. The circuit shown here does the job: every two seconds it draws a current of about 1 A for 2 ms. This corresponds to an average current of about 1 mA, which is of comparable magnitude to the self-discharge of the battery. Although the circuit does not consume much energy, it can keep the battery fresh.



The circuit is based on the NPN relaxation oscillator from the 2011 Project Generator Edition of Elektor (www.elektor.com/110195), here delivering the base current for the power transistor. In the prototype the current was measured at around 1 A: to be on the safe side, you can add an extra load resistor to the circuit.

The LED indicates when each current pulse occurs, which also serves as an indication of the battery's charge state: the less frequently the LED flashes, the lower the battery voltage.

(120318)

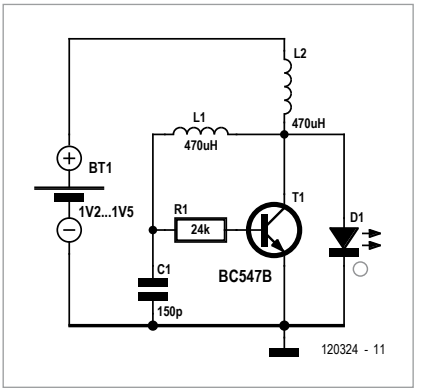
One-transistor Voltage Converter

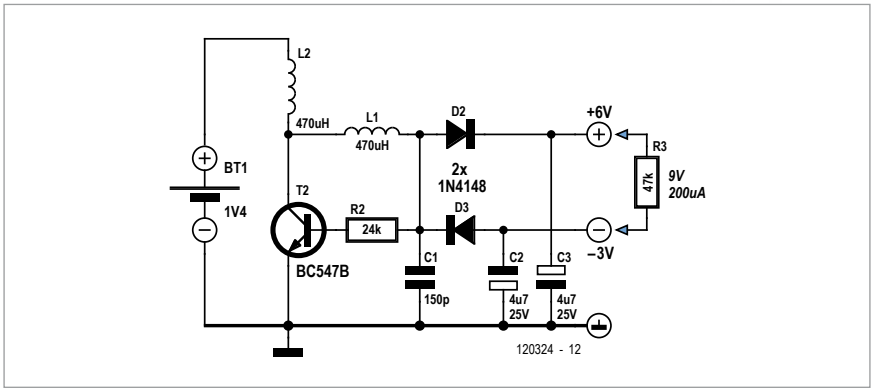
By Burkhard Kainka (Germany)

Taking apart a solar-powered lamp revealed a single-transistor voltage converter circuit that allowed an LED to be driven from a 1.2 V cell. The l/h diagram shows the circuit (with slight modifications). The circuit oscillates at about 500 kHz and, at a cell voltage of 1.4 V, draws 11 mA with a respectably bright LED. The circuit works down to a supply voltage of 0.8 V.

The oscilloscope shows 3 V_{pp} at the LED, as expected. The left-hand coil and the capacitor form a series resonant circuit, excited by the collector of the transistor which alternates periodically between conducting and blocking. When the transistor is off the upper coil dumps its stored energy so that the voltage on the collector rises to about double the cell voltage.

A sine wave voltage of 35 V_{pp} (!) was measured across the capacitor in the resonant circuit. Using a two-channel





oscilloscope showed the phase relationships: the resonant circuit shifts the phase by about 90 degrees. The base resistor coupled with the base capacitance and the Miller capacitance (http://en.wikipedia.org/wiki/Miller_effect) of the transistor add a further phase shift.

The voltage increase obtained using the series resonant circuit can be used to make a bipolar voltage converter, for example to power operational amplifiers (see r/h diagram). Two electrolytic capacitors and two diodes rectify the voltage. The circuit can deliver a voltage difference of 9 V at 0.2 mA, which is enough for a low-power opamp.

(120324)

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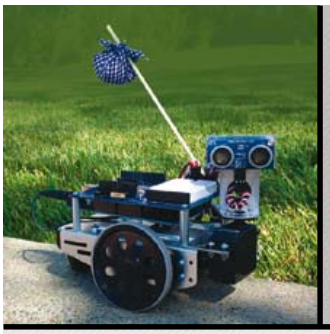

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Elex Board Layout in LochMaster

By Luc Lemmens (Elektor Labs)

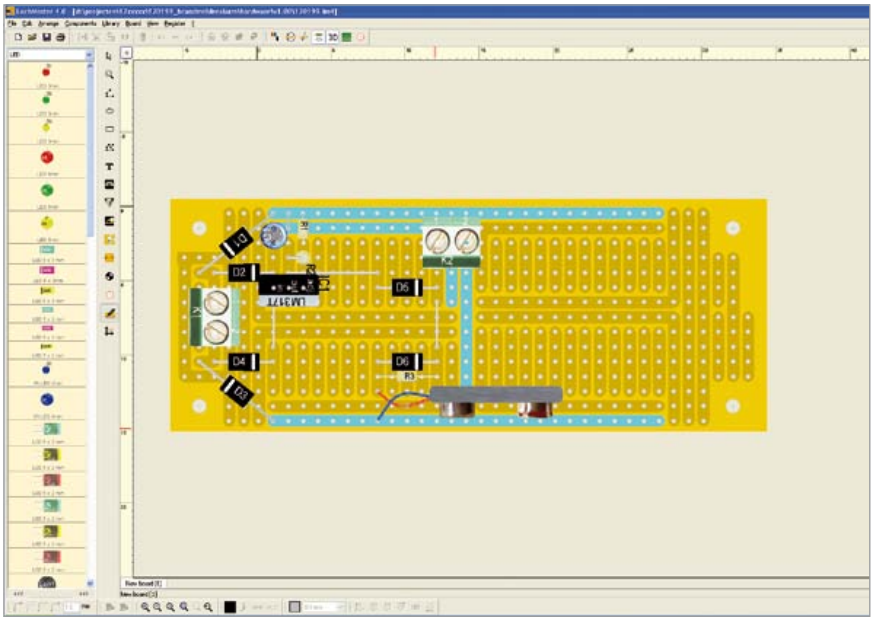
For the construction of (small) through-hole prototype boards use is often made of stripboard (Veroboard), a fast and easy way to build relatively tidy and usable circuits in conjunction with wire-wrap or tinned copper wire.

Stripboards come in many types and sizes and Elektor has its own variant: the prototyping boards that were designed for Elex projects and which are still available from our shop. These

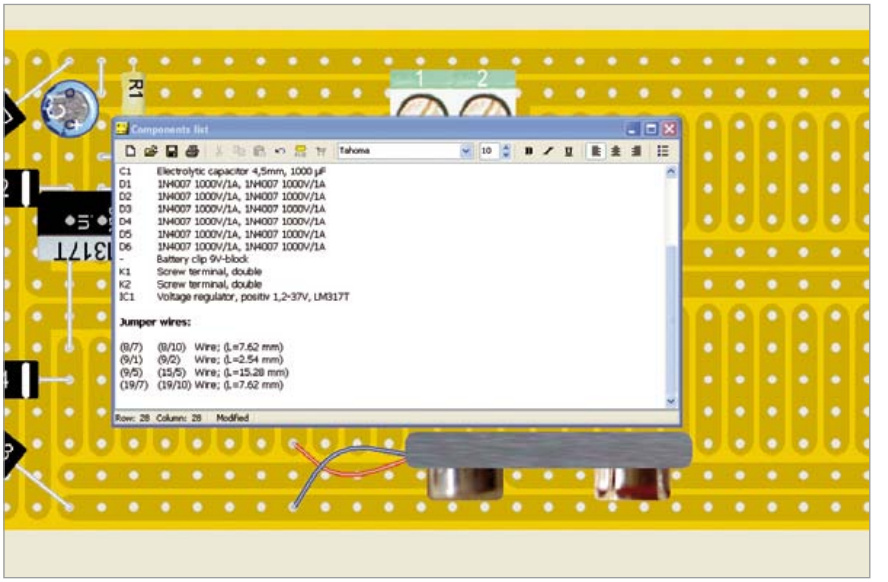
an affordable and simple aid for the design of the layout of components and wire links onto stripboards, using a computer

boards which also go under the type name of 'UPBS-1', -2 (Universal Prototyping Board Size-1 or -2) come with a thoughtfully laid out set of tracks, so that a small circuit can be created using a minimum number of wire links.

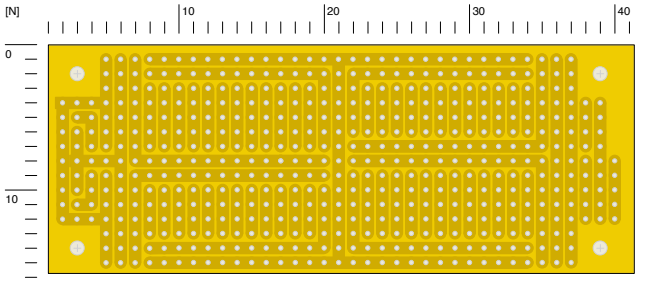
Just as with 'real' PCBs the success or failure of the board and the simplicity of the layout depend on the amount of thought put into the placement of the components. The PC program LochMaster from Abacom [1] is an affordable and simple aid for the design of the layout of components and wire

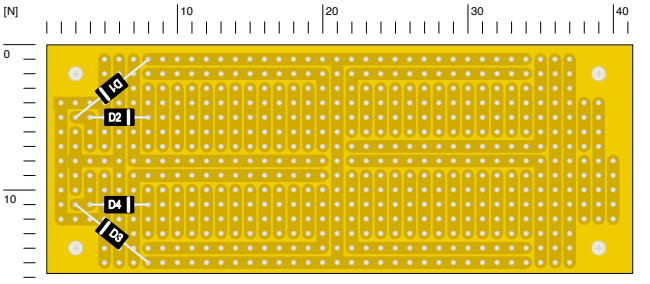


When you click on a track whilst in test-mode you can see which other tracks and links are connected together.



LochMaster can also generate a parts list, including an overview of any wire links.



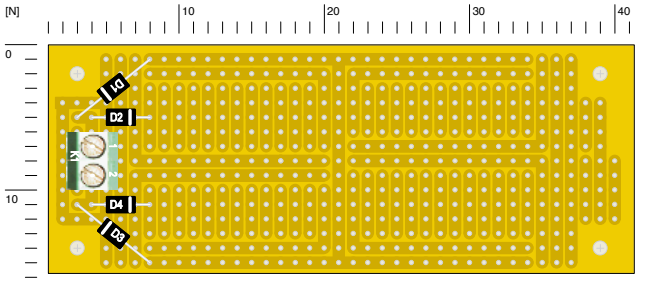


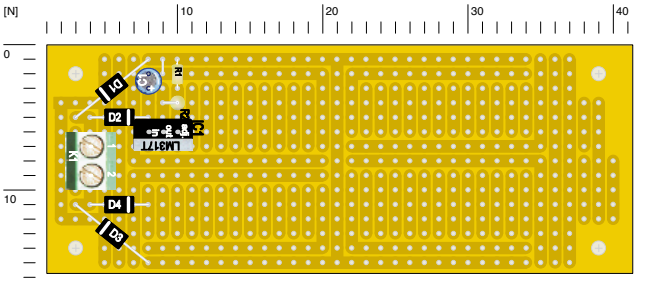
links onto stripboards, using a computer. The program comes with extensive libraries with standard components that can be placed with just a few mouse clicks.
Wire links can be easily added and everything can still be moved about or modified. Before you build the actual

LochMaster also comes with a set of templates of the layout for various prototyping stripboards. We have added the track layouts of our own Elex boards to these. The templates are available as a free download from the Elektor website [2]. You can add these templates by saving them in the 'Board

sional PCB design package and there are several areas in which there is room for improvement. However, it is still a very useful development tool, which we gladly make use of at Elektor Labs!

(120301)





circuit you can carry out a simple connection check so you can find short circuits or open connections and correct them before doing any soldering. The end result is a fairly realistic representation of the board, which can be printed out and be used as a template for the soldering.

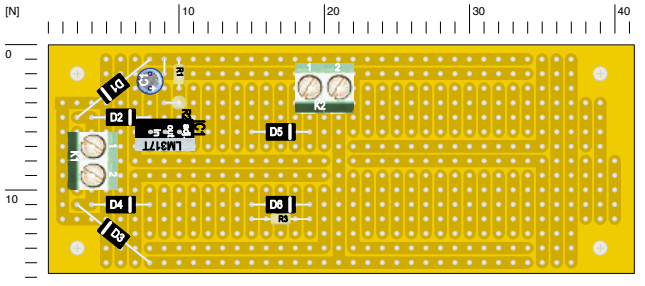
Layouts' folder of the LochMaster folder. When you start a new design in LochMaster (from menu, File –> New), this folder opens automatically and you simply select the required layout.

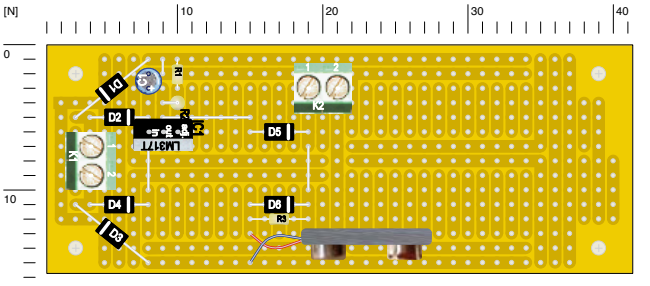
You can't really compare the facilities of LochMaster with those of a profes-

Internet Links

[1] www.abacom-online.de/uk/html/lochmaster.html

[2] www.elektor.com/120301





LED Garland Controller

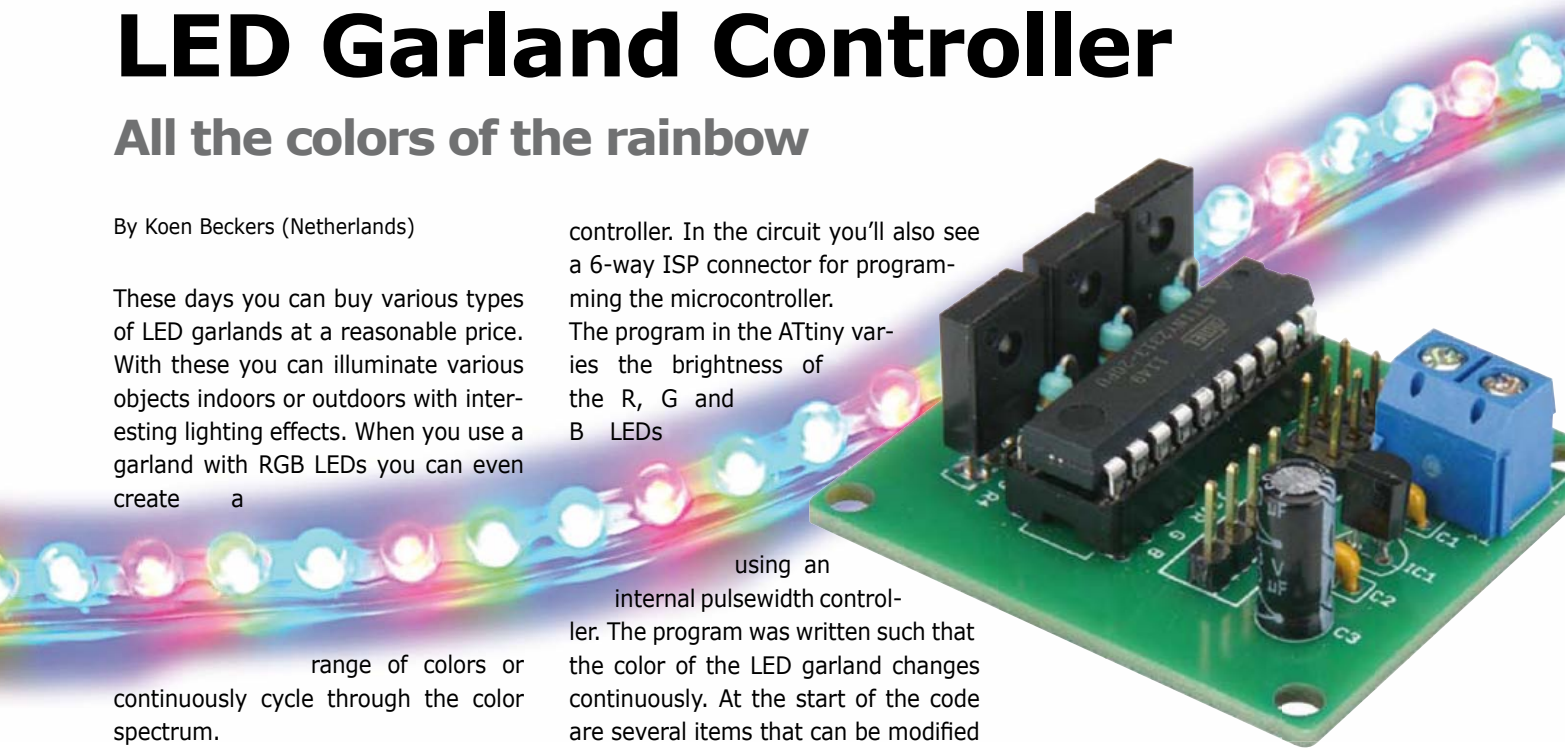
All the colors of the rainbow

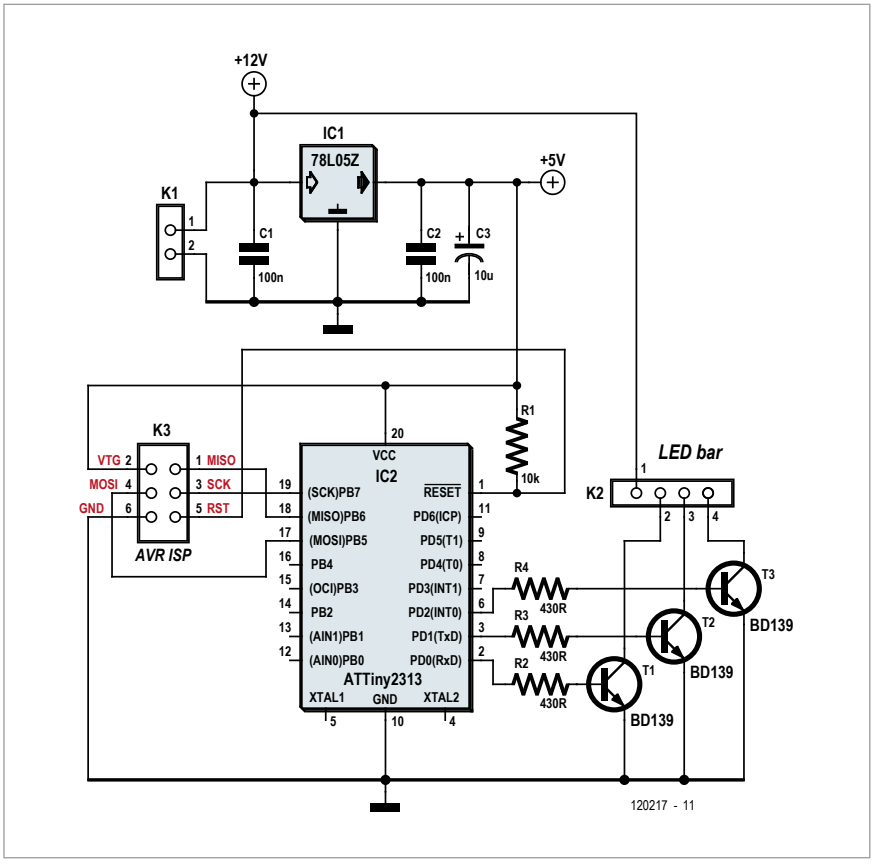
By Koen Beckers (Netherlands)

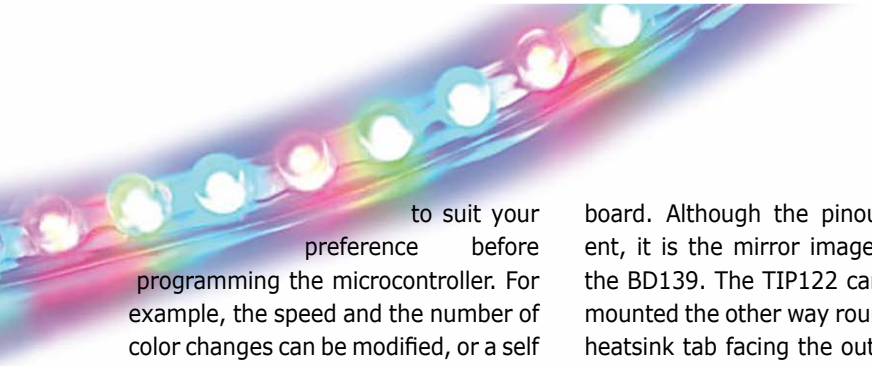
These days you can buy various types of LED garlands at a reasonable price. With these you can illuminate various objects indoors or outdoors with interesting lighting effects. When you use a garland with RGB LEDs you can even create a range of colors or continuously cycle through the color spectrum.

In this case the author wanted to enhance several kitchen cabinets with a novel lighting system. To this end a waterproof LED garland with built-in resistors was chosen. This type of garland can be obtained from e.g. [1]. The strip is available in lengths up to 5 m (approx. 16 ft) and it comes with double-sided sticky tape so it can be mounted onto any clean, flat surface. The supply voltage required by the LEDs is 12 V and the power requirements for the strip used by the author is 7.2 watts per meter.

Various types of controller can be bought to drive such RGB LED garlands, but as an electronics hobbyist you 'just' design one yourself of course, so that it does exactly what you want it to do. The design for this circuit turns out to be very simple: an ATtiny2313 microcontroller surrounded by a 5 V voltage regulator and three power transistors. The latter are driven via base resistors from port pins PD0 to PD2 of the microcontroller. In the circuit you'll also see a 6-way ISP connector for programming the microcontroller. The program in the ATtiny varies the brightness of the R, G and B LEDs using an internal pulsewidth controller. The program was written such that the color of the LED garland changes continuously. At the start of the code are several items that can be modified







to suit your preference before programming the microcontroller. For example, the speed and the number of color changes can be modified, or a self test can be activated. If this is selected then just after the circuit is switched on, it will show the colors red, green and blue sequentially, followed by white. This way it is easy to verify that all LEDs in the strip are still working.
The current consumption of the LED garland is in practice very close to that stated by the manufacturer. Each LED color takes a current of just over 200 mA/m.

When the transistors specified in the circuit are used (BD139, I_{Cmax} 1.5 A) you could in theory drive a strip with a length of 1.5/0.2 = 7.5 m. In practice it's best to limit this to about 5 m.
For higher currents you can change the BD139 to a TIP122. This can handle 5 A so that it should be able to cope with LED garlands up to a length of 20 m. Remember that in that case you'll need a power supply that is rated at least at 12 A at 12 V.

If you decide to use the TIP122 there is no need to modify the printed circuit board. Although the pinout is different, it is the mirror image of that on the BD139. The TIP122 can simply be mounted the other way round, with the heatsink tab facing the outside, which makes it possible to mount the transistors on a common heatsink next to the PCB. Note that the PCB tracks are not designed to cope with currents of 10 A or higher.

It can happen that the R, G and B labeling is incorrect on some LED garlands, so it's best if you check that they correspond to the correct LEDs before connecting the LED garland to the PCB.
The source and hex code for the program can be downloaded from the Elektor website [2].

(120217)

Internet Links

[1] www.ledlightdepot.co.uk/9-led-waterproof-flex-strip

[2] www.elektor.com/120217

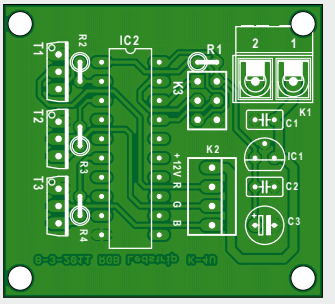
COMPONENT LIST

Resistors
R1 = 10kΩ
R2,R3,R4 = 430Ω

Capacitors
C1,C3 = 100nF
C2 = 10µF 16V radial

Semiconductors
T1,T2,T3 = BD139 (or TIP 122, see text for mounting)
IC1 = ATtiny2313-20PU, programmed
IC2 = 78L05Z

Miscellaneous
K1 = 2-way-PCB terminal block, pitch 5mm



K2 = 4-pin pinheader, pitch 2.5mm
K3 = 6-pin (2x3) pinheader, pitch 2.5mm
PCB # 120217-1, see [2]

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Lengths Counter for Swimmers

By Michel Kuenemann (France)

An example application using speech synthesis, an accelerometer, and a magnetometer

There's no lack of distance counters for walkers or cycling; but swimmers are reduced to mentally totting up how many lengths of the pool have been complete, for want of a counter suitable for their favorite sport. The project described on these pages got designed to build an electronic solution that takes care of this tedious counting. The result is a device that's reliable, handy, light, discreet – and inexpensive. We're happy to be able to share with you here.

If I'm always getting lost when counting my lengths, it's because I'm thinking of how to get a microcontroller to do it for me! As a result, I end up doing too many lengths, and the more I swim, the more I think.

So the project took form in the water and ideas jostled with one another in my head: because of the need for the case to be watertight, I didn't want any buttons, displays, or indicators; it would have to go into standby automatically at the end of the session, after a vocal announcement of the lengths swum, audible underwater without any special device or earpieces. The device would be self-contained and require no external action for counting the distance. The error rate would be less than 5 % and the maximum dimensions 100 × 50 × 30 mm. 'Only' three details then remained to be solved:

- What physical principle and what type of detector to use to measure the distance swum in a pool?
- How to produce vocal announcements audible in the water without waterproof earpieces?
- What techniques to use to obtain a compact device, with low power consumption, using cheap and readily available components?

I may as well tell you that for months I thought of nothing but this during my twice-weekly swims. Here are the results of some of my aquatic cogitations.

Detecting the turns

When a sport swimmer turns in a pool, their body performs one or more coordinated rotations So it's reasonable to imagine that, in order to detect the turns and add up the lengths, all we need do is to capture these rotations by means of MEMS-type gyroscopes.

Main technical specifications

- small unit worn on the back of the swimmer's head, under the goggles strap
- vocal announcement of distance without waterproof earpieces
- error rate < 5 %
- powered by two AAA cells
- compact: 96 × 47 × 24 mm (3¾ × 1⅞ × 15/16 inch)
- system open to lots of other applications

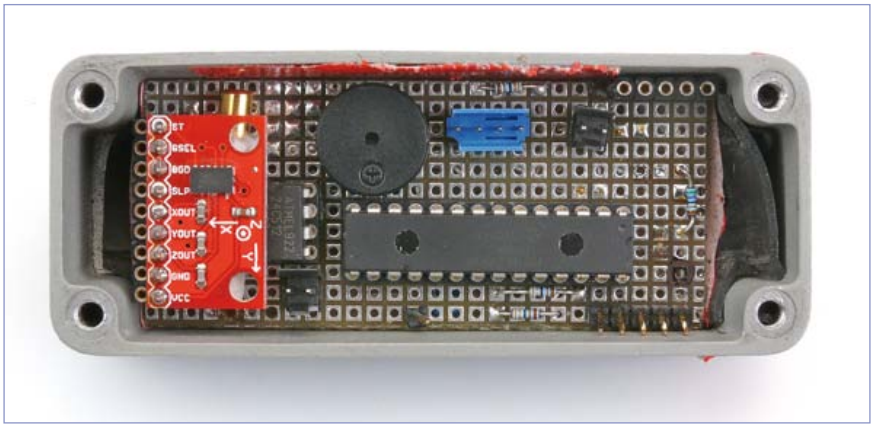


Figure 1. For my first tests, I had started with an MEMS gyroscope system and Morse code. Unfortunately, the accuracy left a lot to be desired (just like my knowledge of Morse code).

I built an operational prototype fitted with IDG-500 triple-axis gyroscopes [2]. To keep it simple, the total lengths were announced in Morse code by a small sounder (**Figure 1**).

After a great many tests in the workshop and in the pool on all styles of swimming, the results were encouraging, but the error rate of around 15 % exceeded my target of 5 %. It proved impossible to optimize the counting algorithm using just gyroscopes: if I increased the sensitivity, the swimmer's spurious movements caused false counting. Conversely, an overly-selective algorithm would miss turns that were rather too gentle. So I had to base my counting on a common element that is relevant for all types of turns in a swimming pool: the thrust against the side of the pool just after the turn. For a sports person, it ought to be possible to detect these vigorous thrusts using an accelerometer. So that set me on the road to a prototype using an accelerometer (see box), which did give better results. However, my system was still sensitive to the swimmer's style, so, undaunted, I decided to pursue my research.

A friend suggested using a GPS to locate the swimmer, but I raised the objection that GPSs don't work inside buildings. However, his idea of using the swimmer's physical position, rather than their movements, was interesting: let's determine the swimmer's heading, at some given moment; if just afterwards the heading has changed by 180°, we can deduce from this that they have turned, and thus swum one length of the pool. QED.

The accelerometer prototype

During the tests with the gyroscope, I wasted a lot of time because I was modifying the software blind, without knowing exactly what the detectors were giving during the swimming pool tests. In order to optimize the software, I needed to have been able to record the detector data during the swim and then analyze them quietly back in the workshop. Not wanting to make the same mistake in the new testing phase, I decided to work more methodically:

- build a prototype that would let me record the data from the detector during the swim
- develop a program for displaying and analyzing the data on a PC
- deduce from this a counting strategy
- develop, then test a counting algorithm off-line on a PC
- transfer the algorithm onto the target circuit
- test the algorithm in the swimming pool

The accelerometer prototype comprises three active devices: an accelerometer, an 8-bit microcontroller, and an I²C EEPROM. In the role of the accelerometer, I used the MMA7361L component from Freescale, as its sensitivity of ±1.5 g on each axis seemed well suited to the values I expected to find during my tests. The µC is a PIC18F2685, a classic that I am very familiar with. A 24C512 EEPROM, with a capacity of 64 kB, available in an 8-pin DIP package, is tasked with storing the data supplied by the detector. The acquisition frequency of 50 Hz is chosen so as to be able to reproduce the swimmer's movements faithfully.

The data are offloaded to the PC using a simple serial link.

On the PC side, the programs were developed in the LabVIEW 2009 environment from National Instruments, an essential tool when you need to analyze data and evaluate processing algorithms.

In the end, there were no less than four different pieces of software to develop:

- the acquisition program carried by the swimmer
- the LabVIEW program for offloading the data and storing them in a file
- the LabVIEW program for analyzing and processing the data
- the final counting program, carried by the swimmer

Keeping on track, in lane

To determine the heading, there's nothing better than an electronic compass using a magnetometer, like the MAG3110 [4] from Freescale. This obliging device comes with an I²C link and is quite happy with the unregulated voltage supplied by two batteries. The price is reasonable, even in one-off quantities. The only downside is the tiny 2 × 2 mm SMD package with ten connections, impossible to solder by hand. Luckily, on the Internet [9] we can find a little board fitted with this device and a 0.1 inch pitch connector, so it's possible to build an evaluation model.

To produce an electronic compass, it's not enough just to scale the raw data supplied by the MAG3110: determining the heading requires some trigonometric calculations, and we must compensate for the permanent stray magnetic field in the unit we build. What's more, I learnt from the application notes [4] that the heading provided by a magnetometer will suffer from major errors if it is not horizontal, which is very likely to be the case for a detector worn by a swimmer. To eliminate this error, the magnetometer inclination has to be compensated using data provided by an accelerometer [3]. Fortunately, the document also offers the solution: an algorithm to do just that (with source code), which lets us convert the three pieces of raw field data provided by the magnetometer and the three components of the gravitational field given by the accelerometer into three angles called **pitch**, **roll**, and **yaw** (**Figure 2**). The heading we're after corresponds to the yaw.

With the accelerometer already built in to my second model, and armed with the code (in passing, it's well written and documented) provided by Freescale, after a few hours of manipulations and development I arrived at an honourable electronic compass.

Sound reproduction

The second challenge to be addressed was the reproduction of the vocal announcements in the water. I had successfully evaluated a voice compression/reproduction algorithm rather poetically named Adaptive Differential Pulse Code Modulation (ADPCM) described in the AN643 application note from Microchip. This technique is ideally suited to an 8-bit microcontroller and gives a quality of reproduction that is satisfactory for my application. Several other projects that have appeared in Elektor have also used this principle [7].

The sound signals synthesized by the µC will have to be amplified and reproduced using a small loudspeaker, but how can we ensure that the swimmer is going to be able to hear them properly with their ears under the water? So I built another model to test the sound reproduction: the µC chosen is a PIC18F27J13 with 128 kB of flash memory (for the sound samples), able to operate at a voltage of less than 3 V. The initial tests using a small watertight loudspeaker, whose membrane was in direct contact with the water were disappointing, and in any case the speaker was too big. In the end,

the best results were obtained using a mini speaker just 20 mm ($13/16$") in diameter, fitted inside the watertight case — as long as I drove it with several hundred milliwatts so that the voice announcements could be heard under water. To do this, I chose an integrated Class-D amplifier developed by Analog Devices (SSM2301).

Eureka!

The block diagram (**Figure 3**) brings together my four main active components: the accelerometer, the magnetometer, the audio amplifier, and the microcontroller. The PIC18F27J13 receives the information provided by the accelerometer directly on three analog inputs AN1, 2, and 9. Port RC0 enables or disables this device so as to minimize power consumption. The magnetometer supplies its data via a private I²C bus, operating in 'bit bang' mode and using ports RC5 and RC6.

The pulsewidth modulated audio signals are supplied by the µC on wire CCP10. The passive low-pass filter eliminates most of the 16 kHz components arising from the sampling. The amplifier, which is capable of supplying up to 1.5 watts, drives the loudspeaker directly without any output filtering.

Connector K4 allows communication with the µC via the I²C bus. Although it is not used here, this 'secret door' will allow this board to be used for other purposes in the future.

The 'RUN' LED and connector K3 are key allies while the software is being perfected. K2 is the programming connector to which we will connect a PIC programmer (ICD3, PICkit, etc.) in order to flash and debug the software.

Jumper CNF lets us configure the length of the user's usual pool: 25 m

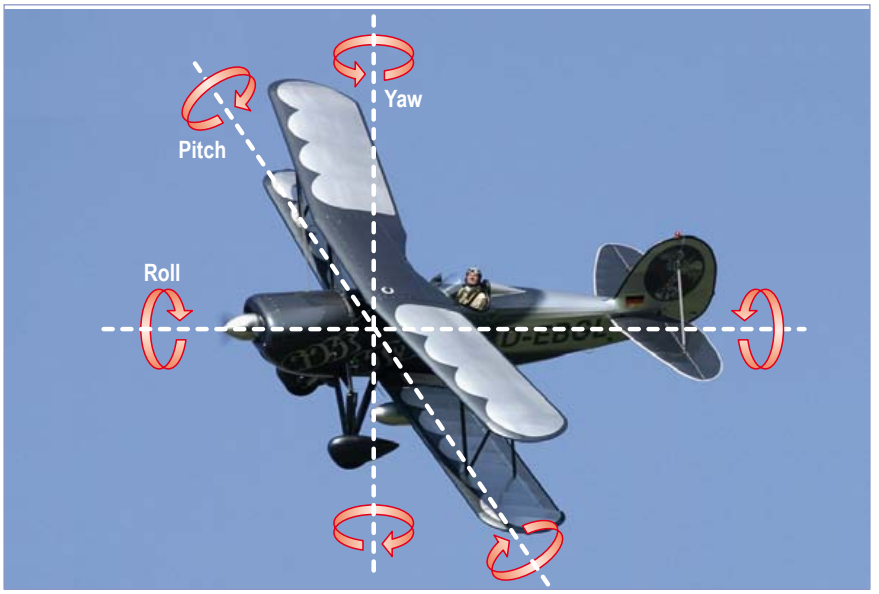


Figure 2. Illustration of the notions of pitch, roll, and yaw.

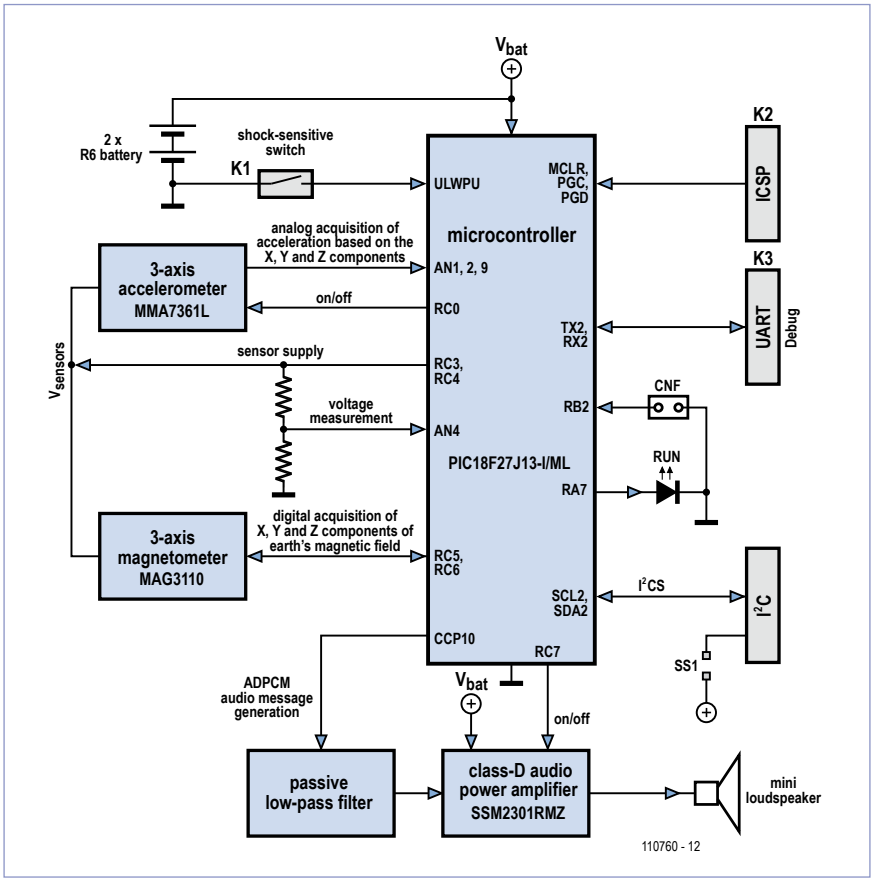


Figure 3. Block diagram of the solution adopted.

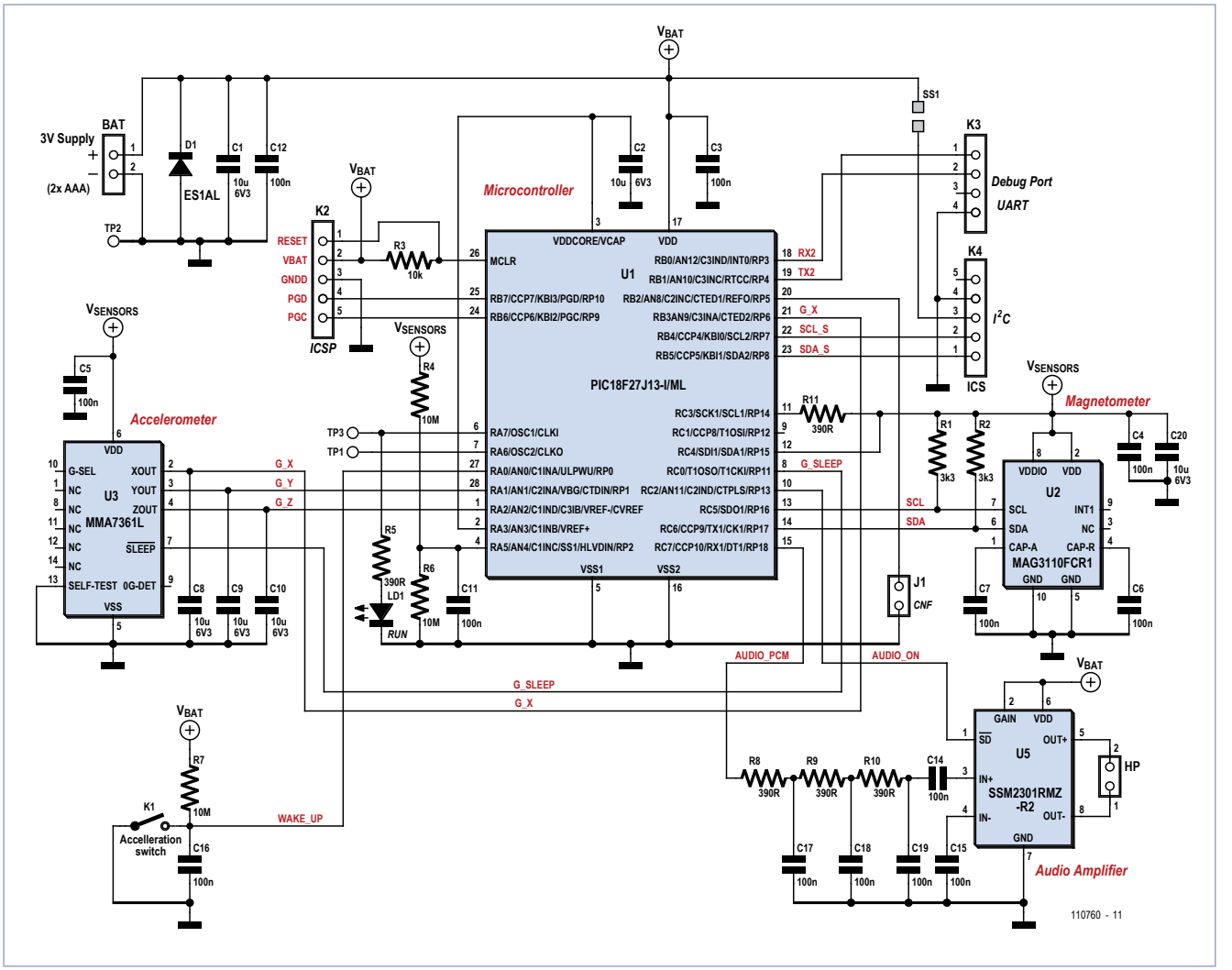


Figure 4. Just like the block diagram, but this time with actual devices.

(82 ft.) without the jumper, 50 m (164 ft.) with the jumper.

The impact-sensitive switch K1 is connected to an Ultra Low-Power Wake-up input. As the name ULPWU indicates, this takes the µC out of its deep sleep mode when the switch is closed by a (small) impact given by the user. This is how we will be able to dispense with an on/off switch and avoid any problem of watertightness.

All the devices chosen offer the possibility of being taken out of service at any time, in order to reduce their power consumption both in operation and during periods of stand-by. The microcontroller and amplifier are powered directly from the batteries (V_{bat}), while the detectors are powered via ports RC3 and RC4 ($V_{detectors}$). Be sure to also read the box **'Limiting the power consumption in stand-by mode'**.

In order to monitor the battery voltage, a divider connected to the $V_{detectors}$ voltage, which is very close to the battery voltage and changes with it, is connected to analog input AN4. When the detectors are disabled, the consumption of this divider itself also drops to zero. When the voltage is being measured, the reference is taken from the V_{ddcore} voltage, which is regulated and close to 2.5 V.

It's only a small step from the block diagram to the outline circuit (**Figure 4**): once again, we find the four active devices that have already been described in some detail.

Diode D1, in inverse parallel with the power input, will save the life of your distance counter if you accidentally fit the batteries the wrong way round; in this event, the residual voltage of the batteries short-circuited by the diode will be of the order of 1 V and hence harmless to the circuit. You'll realize your mistake straightaway, as you won't hear the usual welcome message. Refit the batteries the right way round at once, and everything will be OK again.

You'll notice a lot of decoupling and filtering capacitors, including C2. The unusual value of 10 µF is recommended by Microchip, as the V_{ddcore}/V_{cap} pin is internally connected to the output of the 2.5 V regulator that powers the µC core. According to the manufacturer, it is essential to decouple this point using a high-value capacitor with low internal resistance (low ESR).

The accelerometer's three analog outputs, labeled G_X, G_Y, and G_Z are connected to C8, C9, and C10. Together with the device's 32 kΩ output impedance, these three 10 µF capacitors form a first-order low-pass filter. The cut-off frequency obtained, around 0.5 Hz, makes it possible to sample at a low frequency (a minimum of 1 Hz, according to the Shannon criterion), without having to worry about very low frequency phantom signals caused by spectral aliasing.

The amplifier input has a simple 3rd-order passive low-pass filter. The (free) LTspice simulator [8] shows us that the attenuation of this filter is 2 dB @ 600 Hz and 38 dB @ 16 kHz (cut off frequency). The in-band attenuation is not a problem, as the µC provides a high amplitude signal (3 V_{pp}) and the amplitude has a gain of 12 dB.

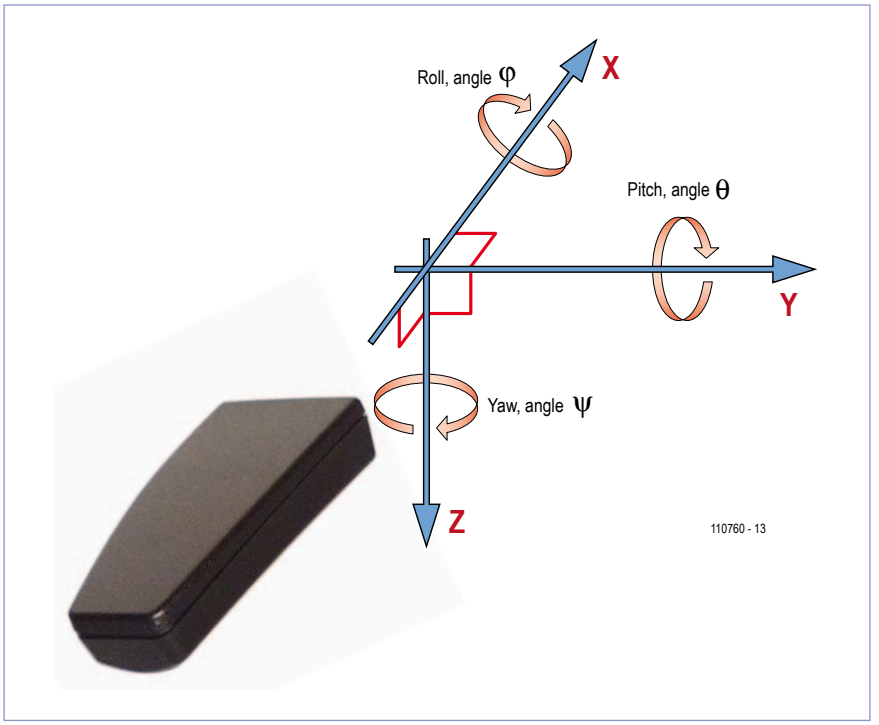


Figure 5. Marking the axes for the device.

Diving right on in…

Although my initial tests had certainly confirmed the feasibility of the project, I had not been bothering very much about its final size. So it now remained for me choose the housing for the main active components, and above all a case that would meet the requirements of being as compact as possible, but still able to hold two AAA cells; if possible watertight; and available in one-off quantities at a reasonable price.

I found the perfect case in the Smart Case M from OKW, which met all my specifications… except for the watertightness. My solution is simple but effective: a couple of turns of electrical insulating tape, and think no more

Limiting the power consumption in stand-by mode

Microchip guarantees a consumption in 'deep sleep' mode of ten or so nanoamps for its PIC18F27J13 microcontroller. Similarly, Analog Devices claims 20 nA in stand-by for its SSM2301 amplifier. So these two devices are going to have virtually zero consumption while asleep.

The consumption claimed by Freescale for the magnetometer and the accelerometer in operation is 1 mA and 400 µA, while their consumption in sleep is 2 µA and 3 µA respectively. Although it is very low, this stand-by consumption is still around 100 times greater than that of the microcontroller and amplifier combined. An elegant solution consists in powering the low-consumption detectors directly from the microcontroller ports. In this way, we can be certain that by sending a 0 to these ports, the consumption of the detectors is going to drop to 0 nA in stand-by.

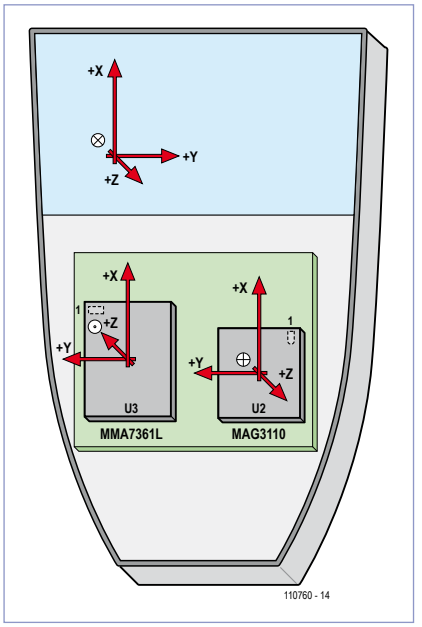


Figure 6. The rules for orientation of the axes must be transferred to the PCB and the detector it carries. A little bit of software takes care of the rest.

Figure 7. My prototype. The magnetometer is extremely sensitive and is affected by the speaker's permanent magnet. I kept them as far apart as possible, otherwise the total saturation of the magnetometer would have prevented any valid measurements. In spite of everything, the permanent magnetic field from the L/S magnet received by the detector is relatively high, but the compensation algorithm makes it possible to cancel out the effects.

about it for months. The battery life is such that you hardly have occasion to open the case more often than that.
Unfortunately, several of our devices only exist in tiny packages that are impossible to solder by hand. The µC was chosen in a 6 × 6 mm QFN28 package, the magnetometer in a 2 × 2 mm DFN10 package, the accelerometer in a 3 × 5 mm LGA14 package, and the amplifier in a 3.25 × 3.25 mm MSOP8 package. The first three packages don't have pins, so manual soldering is out of the question.

For practical reasons, I chose not to use packages smaller than 0805 for the passive components. It's now possible to find 10 µF / 6.3 V ceramic capacitors in an 0805 package at reasonable prices.

The track layout for the double-sided PCB didn't cause any special problems, other than that the pitch of the active components and the diameter of the vias obliged me to employ Class 6 routing.

The detector signal processing algorithms in this device provide angles with respect to a system of coordinates called NED (North, East, Down). **Figure 5** shows this system of coordinates applied to our project.
In order for the software to be able to make use of the information supplied by the accelerometer and magnetometer, we need to make sure that the orientation of these detectors inside the device is consistent with the NED coordinate system of the unit as a whole.

Figure 6 shows the detector sensitivity axes and those of the device. It can be seen that the detectors have been oriented (turned) in such a way that their sensitivity X axes are in line (or parallel) with the unit's X axis, and in the same sense. Perfect! For the Y axis, we are still in line, but the sense of the vectors is reversed for both detectors. The directions with arrows tell us that the values returned by the detector vary in the opposite sense to what the NED system expects. So to get back on an even keel, the software will have to invert these data, which can be achieved simply by just multiplying them by −1. And to conclude, the Z axis needs to be inverted for the accelerometer but not for the magnetometer.

Casing up

It is inadvisable to attempt to solder the components for this project by hand. If you are interested in an assembled, tested, ready-to-use module, we invite you to let us know by e-mail to editor@elektor.com. If there is sufficient demand, Elektor will have a module produced.

Casing up (**Figure 7**) will then take only a few minutes:

Fit fine, insulated wires to the two battery clips which will be located at the bottom of the unit;
Connect two more clips to the board's power input, taking care to maintain the polarity;
Fit the four clips, using flat-nosed pliers;
Solder two fine wires approx. 6 cm (2.5 inch) long to the speaker output and twist them together;
Solder them onto the speaker;

Fix the PCB into the case using a 2.7 mm (0.10 inch) self tapping screw;
Stick the back of the speaker to the cover, close to the well where the case fixing screw goes, using either a spot of hot-melt glue or a small piece of double-sided tape;
Insert two new AAA cells into the unit, taking care to observe polarity;
The speaker, that's Kenneth, should announce "Welcome!" then the length of the pool (25 m or 50 m, depending whether the configuration jumper is fitted or not);

Close the case and tighten the screws;
Seal the case using two turns of insulating tape. Don't forget to put a small square of insulating tape over the screw.

Software

The software functions are summed up in the block diagram (**Figure 8**); the most interesting part involves the calculation of the compensated heading, in the middle of the diagram. The compensated heading and pitch angle are used by the turn detection and distance totalling algorithms. Logically enough, these functions call upon the speech synthesis module, based on the famous ADPCM modulator, to make the announcements to the swimmer. The 'sleep and wake management' module recovers the swimmer's physical position. If the swimmer has not done any lengths for the last 10 minutes, this module puts the µC and its peripherals into 'deep sleep' mode. Only the detection of a knock or re-applying power to the unit will awaken the µC from its slumber. Battery monitoring is managed by a separate routine which, when the time comes, will cause a dry "Low battery" to be announced.
All the processing described above is

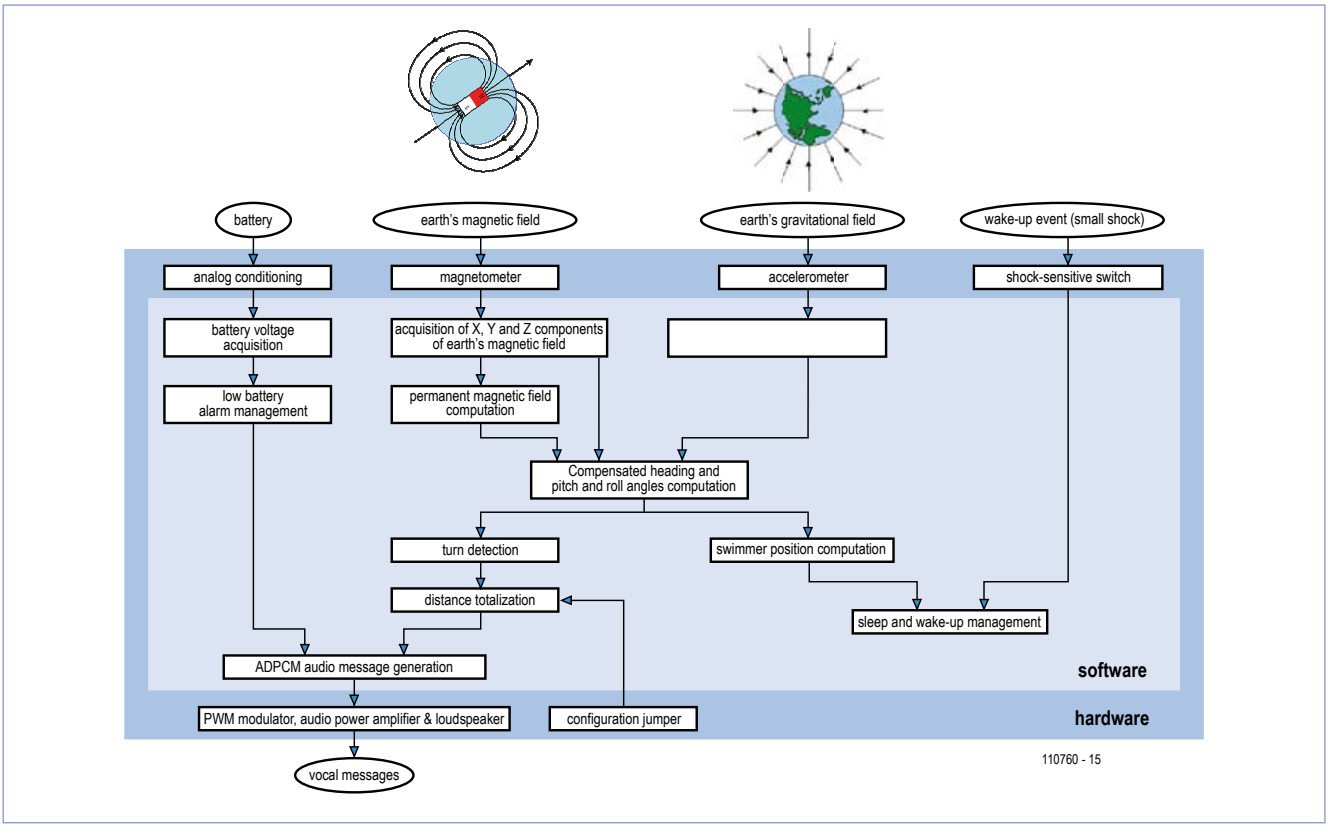


Figure 8. The software block diagram and its position in the real world.

Table 1. The application breaks down into 6 tasks	
Task name	**Function**
`acquire_attitude`	Reads the data from the accelerometer and magnetometer, scales the data, compensates for the permanent field, calculates the pitch, roll, and heading angles. Task executed every 400 ms
`swimmer_position`	If the swimmer stays standing up for more than 10 s, the unit goes into pause. If the swimmer is horizontal for more than 5 s, counting starts again. Task executed every 500 ms
`count_turns`	If a change of heading of more than 60° is detected for 10 s consecutively, the length count variable is incremented. Task executed every 500 ms
`manage_battery`	If the battery voltage is too low for 20 s consecutively, the "Low battery" announcement is given and repeated every 5 min. Task executed every 2,000 ms
`manage_sleep`	If the swimmer does not swim any length for 10 min, the unit goes into stand-by.
`heart_beat`	Manages the flashing of the LED

carried out by five asynchronous tasks (**Table 1**).

During the testing phase that led to the final version of the project, I was careful to write drivers that could be used for the strategic functions and devices employed. By going about it like this, I knew I'd save a lot of time and effort when I came to incorporate the modules into the final project. As I already had drivers for the basic peripherals (analog/digital converter, I²C bus, serial link, dynamic memory) as well a robust multitasking core, it made writing and integrating the main application easier. In its final form, the project includes no less than 14 source files in C (**Table 2**). As usual, the whole of this software is available from the Elektor website [1].

Table 2. Software source files	
Module	**Function**
COLO.c	Application main file
COLOutil.c	Application utilities
COLOspeech_samples.c	Speech samples
YASKpic.c	Cooperative multitasking core
CMPAdev.c	Attitude compensated compass
M310dev.c	Manager for MAG3110 magnetometer
ADPp18.c	Manager for ADPCM modulation for speech reproduction
MFSp18.c	Single file system manager
MEMp18.c	Dynamic memory manager
ADCp18.c	Analog/digital converter manager
I2Cp18_sw.c	Manager for I²C in bit bang mode
TTYp18.c	Serial link (UART) manager
IOSp18.c	Input/output manager
SYSp18.c	Centralization of interrupts and system timers

Using it in practice

Fitting the batteries into the unit is greeted with a polite "Welcome!" This kind little word will reassure you that the batteries have been fitted correctly and the unit is working properly. The unit will then announce the pool length selected via the configuration jumper (25 m or 50 m).

Before you leap into the water with your new toy (and Beyonce in Bikini), re-tighten the case fixing screw and check that the two turns of insulating tape are watertight. Fit the counter behind your head, the widest part at the top, held in place by your goggles strap, and head off to the shower. After a few seconds, the unit will say "Pause" – it has detected that you are standing up. In pause, the distance is not counted. In the meantime, the device has discreetly calibrated itself. Once you're in the water, start your first length. After 5 s, a chime will tell you that counting has begun, then, a few seconds later, a sonar 'ping' will tell you that one length has been counted. When you reach the other end of the pool, turn as usual (this version of the software does not yet take into account the quality of your turn!) After a few seconds, a new 'ping' will sound and Kenneth will announce "Two laps", i.e. two lengths of the pool. After the 'ping' for the fourth length, the voice will announce "Four laps", i.e. four lengths, and so on. As the device's counting capacity is 299 lengths, i.e. around 7.5 km (4.7 miles) in a 25 m pool, you'll have to put in quite some effort before you can go right round the clock in a single session.

Once out of the pool, rinse and dry the unit before you put it away in your

sports bag. After 10 min of inactivity, the counter will say "Goodbye" and go into stand-by automatically. There's no point removing the batteries when it is not in use. You can also stop it immediately by giving it a flick on the side, it won't mind and will answer "Goodbye" before going to sleep. At the start of your next session, give the case another flick on the side before you fit it under your goggles strap. It will reward you with "Welcome!" to tell you it has woken up. If you hear "Low battery" every five minutes during your training, replace the batteries. Unfortunately, the device does not memorize the total of all the lengths swum during successive training sessions. It could do it, it's only a question of software — over to you!

Main components used in project

PIC18F27J13-I, Microchip, MCU, 8 bit, 128 KB Flash, 3 KB RAM (QFN28)
MAG3110FCR1, Freescale, 3-axis magnetometer w. I2C interface I2C (DFN10)
MMA7361LCR1, Freescale, 3-axis accelerometer w. analog outputs (LGA14)
SSM2301RMZ-R2, Analog Devices, 1.5 W class D audio amplifier (MSOP8)
ASLS-2, Assemtech, Acceleration sensitive switch (2G),

OKW Smart Case M A9066109 + A9166001 : recommended housing
ADS02008MR-R Projects unlimited : mini LSP 8 Ω, Ø20 mm

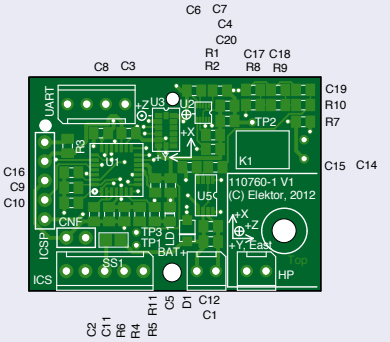


Figure 9. The author's double-sided PCB design.

Other possible uses

If you're more interested in robotics or modelling than swimming, this little board with its open-source software forms an excellent basis for a central inertial base with six degrees of freedom. Connector K4, connected to the microcontroller's I²C port, will give you the best communication interface there is. It's up to you to let us know if you'd like us to come back to this in a future issue. Do tell us if you're interested in this project and the developments it might lead to.

(110760)

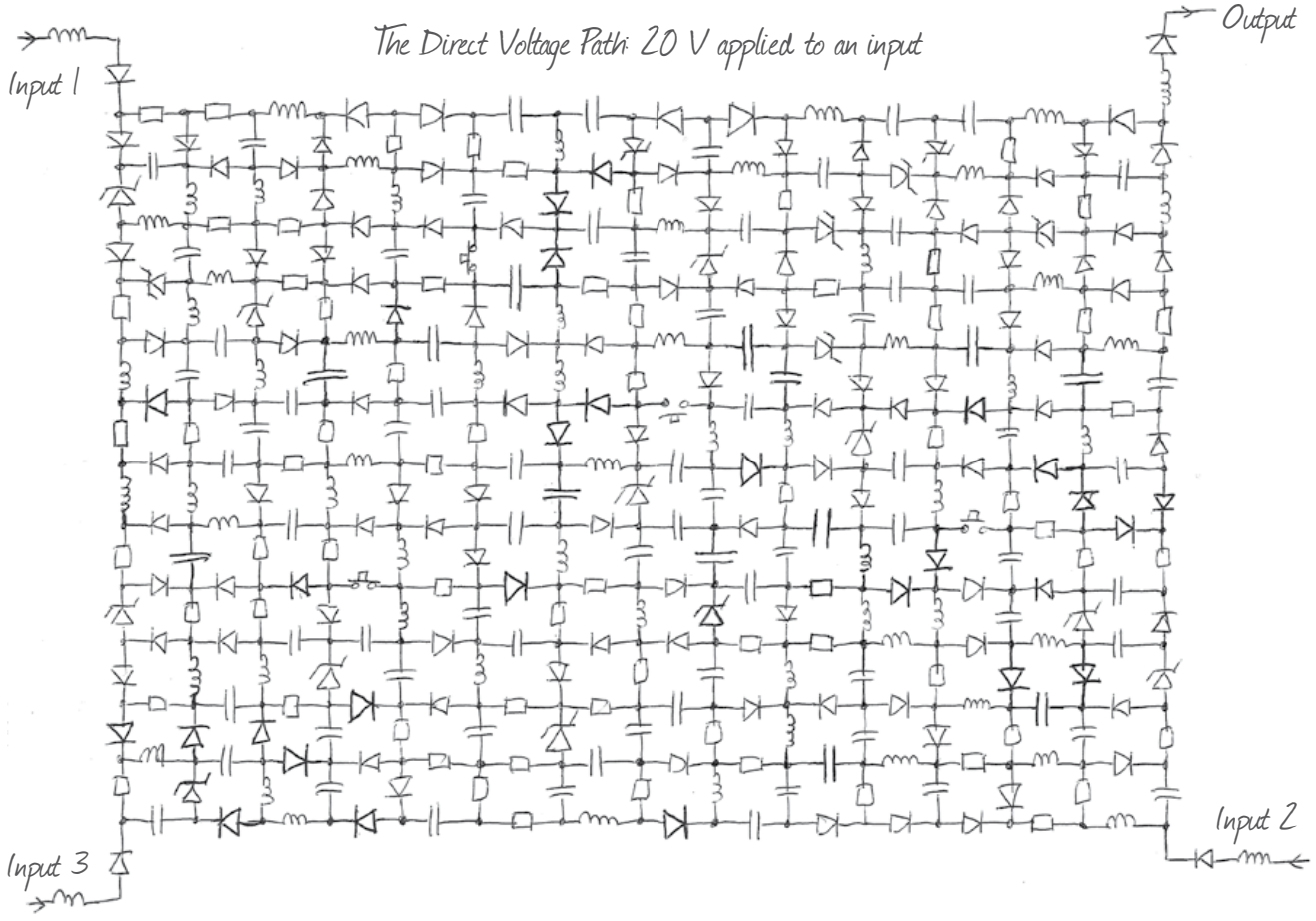
Internet Links

[1] www.elektor.com/110760
[2] Gyroscope http://invensense.com/mems/gyro/idg500.html
[3] Accelerometer www.freescale.com - search keyword: MMA7361
[4] Magnetometer www.freescale.com - search keywords: MAG3110, AN4246, AN4247, AN4248, AN4249
[5] LabVIEW www.ni.com/labview/f
[6] MPFS file system www.microchip.com – search keyword under 'Search Microchip': AN833 (the search will return the application note about the TCP/IP stack, which MPFS is part of)
[7] ADPCM modulation www.microchip.com – search keyword: AN643
www.elektor.fr/nouvelles/explorer-16-i-creating-and-adding-sound-files-to.155918.lynkx
www.elektor.nl/Uploads/Files/CreateYourOwnSound-Files.pdf
[8] LTspice simulator www.linear.com/designtools/software
[9] Sparkfun www.sparkfun.com

Acknowledgements

I'd like to thank Messrs Antoine Authier, Denis Meyer, and Clemens Valens who were always forthcoming with good ideas and advice throughout the construction of this project, as shown by the abundant e-mail correspondence exchanged over a few months (around 400 messages). Thanks also to Kenneth Cox, one of Elektor's freelance translators, who kindly provided the voice for the speech samples.

The Maze of the Lost Electronic



Diode: V_F = 0.6 V

Zener: V_z = 36 V

Resistor: R = 10 Ω

Inductor: L = 10 µH

Capacitor: C = 1 µF

Push-button

By Sadettin Commert (France)

Ariadne, Theseus and the Minotaur, Chartres, *'The Name of the Rose'*, to name but a few – there's no shortage of mazes in our imagination. What's more, to please the calculator wizards, Elektor has already published a number of labyrinthine puzzles that have proved pretty tough. Now this time we have a variant in the form of a circuit diagram, which we've kept deliberately simple so everyone can have a go. The grid contains only passive components, whose DC behavior is easy to understand.

Enter the maze and leave it with a prize worth over $900.

Have fun and learn

Let's leave it to its inventor, Sadettin Commert, to explain: "Like any trainer or teacher, when I prepare my lessons or when I'm at the blackboard, I'm always on the lookout for methods that will encourage assimilation. I fine-tune my teaching, adapting to the students' level, since levels and abilities vary a lot. I try to use analogies with physical phenomena that are familiar in everyday life (mechanics, hydraulics, thermal, optics, acoustics, and so on). In electricity and electronics, these sorts of analogies allow us to perceive the currents and voltages that are otherwise intangible and invisible on our human scale.

Now what sort of fun can we have with just four components (R, L, C, and D)? In wondering about that, I came up with the

s Technician

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idea for this game. Everyone likes a maze, they encourage perseverance, and it's rare for anyone to give up before finding the way out!"

And now you too can go and play with it, and get other people to play as well, whether they're electronics technicians or not. To play, all you need is to have a rudimentary idea of the way these components behave at DC. Put yourself in the place of an electron — or an electronics technician — lost in this electronic labyrinth, and feel the excitement of getting lost, and the relief when you find the way out.

Before setting off, you just need to bear in mind that the **diode** is a one-way device — it works in the direction of the arrow. There's no question of current flowing in the opposite direction, just like in a one-way street. With the **capacitor**, which would let AC current pass in both directions, here we have a complete block, as we're in DC — the current can't pass in either direction. The **inductor** lets the DC current pass in both directions, just like the **resistor** and the **switch** (as long as it is closed). Now it's over to you! Find the path the current will take if we apply a DC voltage of 20 V to one or other of the inputs. **To which of the three inputs 1, 2, or 3 must we apply this voltage for the current to arrive at the output?**

If several of you want to have a try, don't forget to make a number of photocopies of this page before you start.

A superb prize offered by Matrix Multimedia

Send in your answer by e-mail only before 15th August 2012 to: labyrinth@elektor.com. The body of the messages won't be read. Only the 'Subject' line will count, it will be analyzed automatically, and it must contain the right answer in the form of a number (1, 2, or 3) followed by a number in answer to the following subsidiary question:

How many correct answers to the maze question will we have received by 15th August 2012?

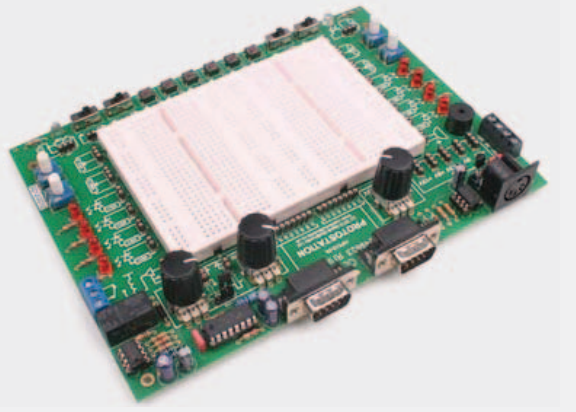
Thanks to the generous sponsorship by Matrix Multimedia, the winner of this competition will win the following two-part prize:

Electronic Workstation – Desktop

Approx. value $900.00

With its small benchtop footprint and a high specification, this self-contained, easily portable Electronic Workstation is the perfect tool for electronics education and prototyping. The Workstation includes a number of PC-based virtual instruments: a two-channel oscilloscope, spectrum analyzer, signal generator, 8-channel logic analyzer, digital signal generator, and serial communications analyzer. The Workstation also includes a power supply and an 8-channel PC interface that is compatible with Flowcode, Visual Basic, C# and LabView. Other characteristics are described here:

www.matrixmultimedia.com/product.php?Prod=HP886EU&PHPSESSID=



The free workstation will be accompanied by the Protostation Advanced Breadboard, normally available as an optional extra and approximately $200.00.

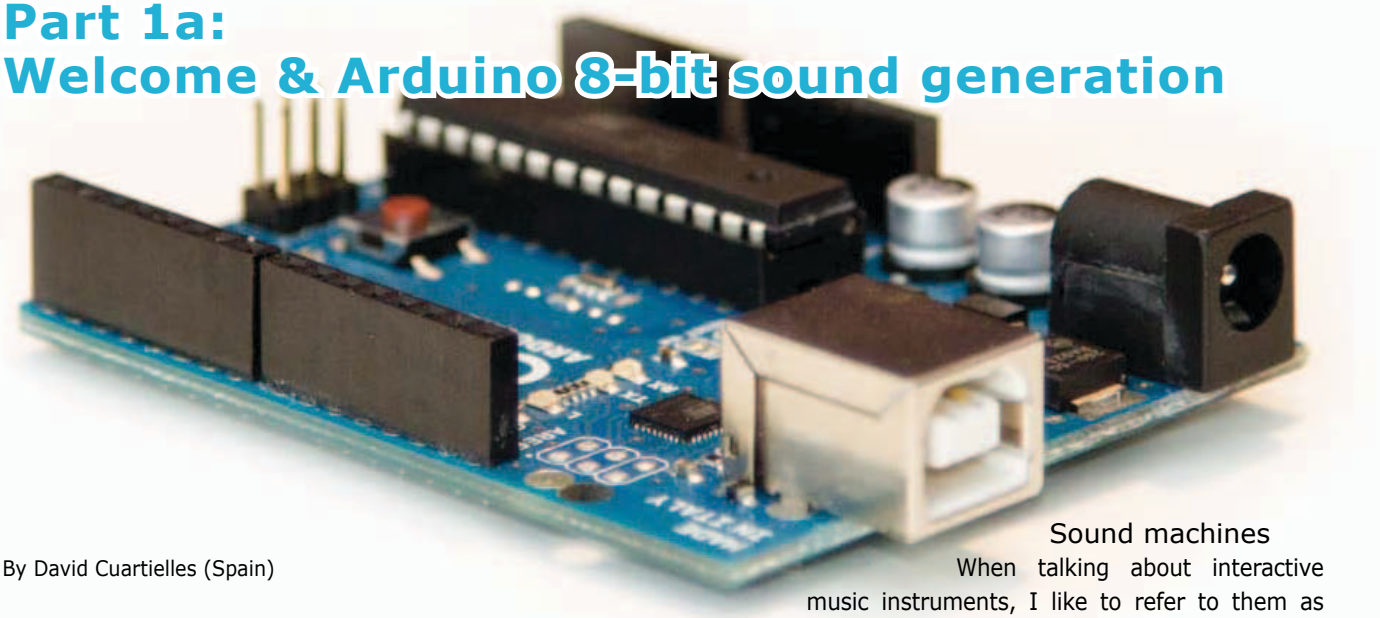
The unit includes not only a large prototyping area, but also a whole array of switches, potentiometers, LEDs and sensors that are easily connected to the prototype area. An on-board function generator provides sine or square waves (10 Hz – 10 kHz). Two connectors are provided for easy connection to E-blocks or the Electronic Workstation.

www.matrixmultimedia.com/product.php?Prod=HP512&PHPSESSID=

Now it's your turn! The solution will be published in the October 2012 edition, which will be out in mid September.

Arduino on Course (1a)

Part 1a:
Welcome & Arduino 8-bit sound generation



By David Cuartielles (Spain)

Practice makes perfect and in this the first of a series of articles I will focus in presenting all the bits and pieces you need to understand in order to play 1-bit sound from a digital pin on your Arduino board. We will start by looking at the easiest way to create sound by means of a simple piezo buzzer or a speaker. I will then introduce the Arduino Tone Library, as a simplified way to achieve the same functionality. And I will close by introducing an advanced technique that allows playing short sounds stored in the form of .wav files.

When it comes to the theory, you will be introduced to a technique known as 1-bit Delta Sigma Digital to Analog conversion, but don't be scared by the name, the methods and technologies are presented along with examples you can easily reproduce with a minimal set of parts.

Get out your materials

If you aim at reproducing all the examples in this article you need to have:

- an Arduino Uno board, though some of the other boards in the Arduino line using ATmega328, ATmega168, ATmega128 or ATmega256 will work as well;
- a USB cable to connect your Arduino to a computer;
- a piezo buzzer to play tones;
- alternatively a mini loudspeaker or headphones and a socket to connect them to the Arduino board;
- a computer running the Arduino IDE and a tool called SoundData for the IDE (check the download links in the references section).

Sound machines

When talking about interactive music instruments, I like to refer to them as Sound Machines. They consist of three blocks: the data used to generate the sound, the user interface, and the actual sound engine.

The data refers to the way the sound is used. It could be generated, we could play back sounds from a sample collec-

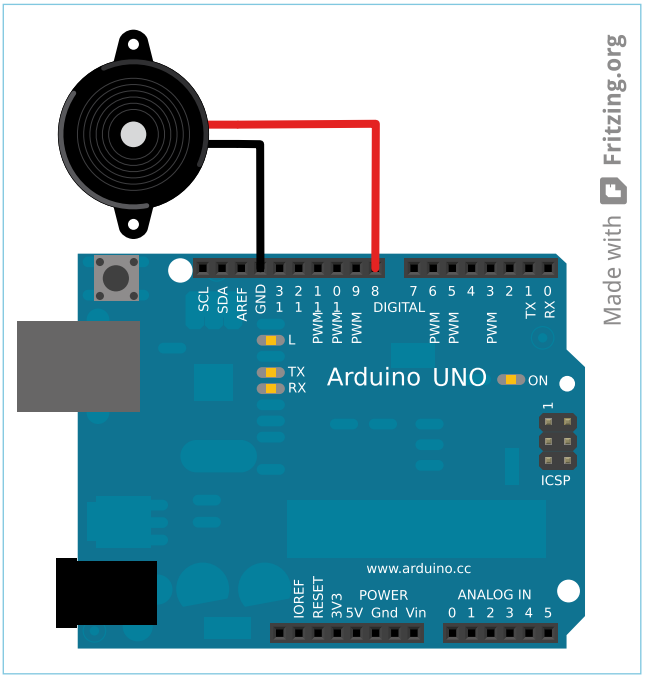


Figure 1. Arduino UNO hooked up to a piezoelectric buzzer.

This article is going to lay the foundations for creating Interactive Sound Machines using a standard Arduino Uno board. However, all the knowledge described here as well as the code can be easily ported to Arduino Mega, Arduino Mini or any other member of the Arduino 8-bit family. Jump the Arduino bandwagon, this stuff comes straight from a creator of the platform!

tion, or just perform real-time sound alteration. Data is the actual sound, the tones in a piano, or the bytes stored inside the channels in a sampler.
The user interface defines the way the sound structures will be manipulated, or the mechanisms to modify the sound characteristics. The easiest example is the volume control usually implemented as potentiometer or rotary encoder. The UI is what the user manipulating the instrument has his/her hands (or mind) on to alter the sound engine's behavior. Finally, the engine defines the way data is displayed. It takes the data and renders it as sound according to the control parameters introduced by the user through the UI. In our case, the engine is the Digital to Analog converter we are going to implement via software.

From blink to bee

The "Hello World" example to start using Arduino is making the LED on pin 13 blink. The code looks like this:

```
/*  Blink
    Get the LED on pin 13 to go on/off
    http://arduino.cc
*/

int ledPin = 13; // define the LEDs pin

void setup()
{
       pinMode( ledPin, OUTPUT );
            // configure the pin as output
}

void loop()
{
       digitalWrite( ledPin, HIGH );
                        // turn the pin on
       delay( 1000 ); // wait 1sec
       digitalWrite( ledPin, LOW );
                        // turn the pin off
       delay( 1000 ); // wait 1sec
}
```

The example is self explanatory. With little changes we can use the same example to start playing sound out of our Arduino. We will be using a piezoelectric buzzer and later on we will move into using a proper loudspeaker to increase the quality of the sound output.

The piezoelectric buzzer

The contact microphone, also known as piezo buzzer is an electronic component made of a combination of two discs of different materials. One of them is metallic and the other one is usually ceramic, having the piezoelectric properties. When applying a voltage to the component, the materials will repel each other, producing an audible click. Making the voltage difference zero will cause the materials to return to their original position, again producing a click sound.
By applying a voltage of a sufficiently high frequency, the click produced by the piezoelectric will modulate into an audible tone.
You can test this by connecting a piezoelectric buzzer to Arduino by wring its positive pin to, say, Arduino's pin 8 and the negative pin to Arduino ground (GND), see **Figure 1**. Take the previous code and modify the line that determines the pin the LED is connected to:

```
int ledPin = 8; // define the pin for
          // your Speaker or Piezoelectric
```

When running this program you will hear the piezoelectric clicking once per second, which is the times when the voltage changes at its pins. You can modify the code to make the delay between clicks. The smaller the delay, the more the clicks will merge into a modulated tone. Try to change both lines in your program affecting the time between clicks to be:

```
delay( 1 );
```

Now you will be hearing a sound with a frequency of 500 Hz. You will also notice the sound to be louder due to a property of the piezoelectric components. They resonate in the kilohertz range, at least the ones we find commercially available, as they are designed to be buzzers or contact microphones.
If you want to experiment further in sound production with this technique, I would encourage you to not use the `delay()` function from Arduino. The reason for this is that you

will need a better time-resolution to produce a richer selection of tones. The function `delayMicroseconds()` is much more suitable to sound production, as it is three orders of magnitude more accurate.
Adding all these changes to the original Blink program, will give us the Bee program:

```
/*  Bee
    Make a piezoelectric oscillate
    on pin 8
    http://arduino.cc
*/

int piezoPin = 8; // define where the
             // piezoelectric is connected

void setup()
{
       pinMode( piezoPin, OUTPUT);
}

void loop()
{
       digitalWrite( piezoPin, HIGH );
       delayMicroseconds( 1000 );
       digitalWrite( piezoPin, LOW );
       delayMicroseconds( 1000 );
}
```

Playing tones

According to Fourier's Law every sound is the result of adding a series of sinusoidal sound sources having different phases and amplitudes. We could say that sine and cosine waves are the fundamental components of sound.

Unfortunately microcontrollers, and the one on the Arduino Uno is not an exception, cannot imitate the sinusoidal shape perfectly. We can anyway produce square waves by repeatedly switching a pin `HIGH` and `LOW`. The tones produced in this way have the same frequency, but are not clean as they add components to the pure sinewave. In musical terms, the instrument making square waves has a different tonal characteristic than the one making sinusoidal ones, although the tones proper are the same.
The only issue we find here is that sound is expressed in frequency (hertz or Hz) while microcontrollers work with time. The total amount of time a `HIGH-LOW` oscillation lasts is what we call the period (seconds). There is a relationship between period *p* and frequency *f* as expressed in the following formula:

$$f = \frac{1}{p} \rightarrow p = \frac{1}{f}$$

In other words, period is the inverse of frequency and vice-versa. In this way, if we want to know the delay needed to play say, the A_4 tone using Arduino, we need to do a bit of maths again like:

$$p = \frac{1}{440} = 0.002272\ s = 2.272\ ms = 2272\ \mu s$$

If we want the program "Bee" to play A_4, we need to modify it so that the total time in both calls to `delayMicroseconds()` adds up to 2272 microseconds.

```
digitalWrite( piezoPin, HIGH );
delayMicroseconds( 1136 );
digitalWrite( piezoPin, LOW );
delayMicroseconds( 1136 );
```

The different tones within a scale can be mapped to time-delays so that they can be played using Arduino. **Table 1** shows a full octave.

Table 1. Available musical notes / tone frequencies

Tone	Frequency [Hz]	Period [µs]	Delay [µs]
C_4	261.63	3822	1911
D_4	293.66	3405	1703
E_4	329.63	3024	1517
F_4	349.23	2863	1432
G_4	392.00	2551	1276
A_4	440.00	2272	1136
B_4	493.88	2025	1012
C_5	523.25	1911	956

Arduino's tone library

There is more to sound playing than just the tone. Musical scores are expressed in notes, which are the tones played for just a certain amount of time. In order to simplify the possibility of playing basic melodies using Arduino, we added a library to the system that handles all the math explained so far in this article, as well as note durations. Now that you understand how to play a tone at a relatively low level, I think it is convenient to introduce this abstraction to make easier for you to create programs playing sound.

This library is called `tone` and brings in a function allowing playing a tone. In the background this is done by controlling some of the internal timers in the processor. One timer takes care of the tone itself, while the other monitors its duration. There are two functions to play sound, called the same, but

with a different amount of parameters.

```
tone( pin, frequency );
  // play a tone
tone( pin, frequency, duration );
  // play a note, duration in milliseconds
```

You should note how time is measured. The function's argument 'duration' will play the note for a certain number of milliseconds (ms). If you want to have a function counting the time in a way that is closer to how it is made in musical scores, you will have to decide how long the different notes

```
/* we define durations as numbers
/  between 1 and 7:
   1 - whole note - 1 unit
   2 - half note - 0.5 units
   3 - crotchet - 0.25 units
   4 - quaver - 0.125 units
   5 - semi quaver - 0.0625 units
   6 - demi semi quaver - 0.03125 units
   7 - hemi demi semi quaver -
   0.015625 units
*/
void playNote( int speaker,
  int theTone, int duration )
{
  // we give for granted that the half
  // note lasts 0.5 seconds
  long time =  500 / pow( 2, duration-1 );

  // assign the note to the speaker
  tone( speaker, theTone, time );
}
```

will be. The following code assigns durations to the different notes considering that the basic note lasts 0.5 seconds.
The function above could also be written in a way that would make use of the more common variable of the beats per minute (bpm). In that way we could make the instrument play at different speeds depending on the desired tempo for the melody.

```
/* we define durations as numbers
/  between 1 and 7:
   [...]
*/
void playNote( int speaker, int theTone,
  int duration, int bpm )
{
  // menmotecnic: 120 bpm - - >
  // 1000 milliseconds for half note
  // source http://bradthemad.org/guitar/
  // tempo_calculator.php
  long time =  ( 1000 * bpm / 120 ) /
    pow( 2, duration );

  // assign the note to the speaker
  tone( speaker, theTone, time );
}
```

Chained melodies

It's "awesome and stuff" to play a short melody at some point during the execution of a program. A melody consists of notes and silences. Here we are going to see how to play a melody stored as an array of numbers. Inside the Arduino IDE there is an example dealing exactly with this. Open the program under *File → Examples → 2.Digital → toneMelody*:

```
/*
   Melody

  Plays a melody
  [...]
*/
 #include "pitches.h"

 // notes in the melody:
 int melody[] = {
   NOTE_C4, NOTE_G3, NOTE_G3, NOTE_A3,
        NOTE_G3, 0, NOTE_B3, NOTE_C4};

 // note durations: 4 = quarter note,
 // 8 = eighth note, etc.:
 int noteDurations[] = { 4, 8, 8, 4, 4,
   4, 4, 4 };

 void setup() {
   // iterate over the notes
   // of the melody:
   for( int thisNote = 0; thisNote < 8;
      thisNote++ ) {

     // to calculate the note duration,
     // take one second divided by the
     // note type. e.g. quarter note =
     // 1000 / 4, eighth note = 1000/8,
     // etc.
     int noteDuration = 1000 /
        noteDurations[thisNote];
     tone( 8, melody[thisNote],
        noteDuration );

    // to distinguish the notes, set a
    // minimum time between them.
    // the note's duration + 30% seems to
    // work well:
     int pauseBetweenNotes =
        noteDuration * 1.30;
     delay( pauseBetweenNotes );

    // stop the tone of playing:
    noTone( 8 );
   }
```

```
  }
}

void loop() {
  // no need to repeat the melody.
}
```

You will notice that the melody is stored in two arrays: the notes are in one, while the note durations are in a different one. Durations are expressed differently from what we saw earlier. Our previous example was using durations expressed in the way it is done in music.

The first command in the program includes a file called `pitches.h` that comes as part of the code into a different tab within the example. The file sadly is too large for printing here. It includes a series of constants representing the frequencies for each tone. In that way, the constant `NOTE_A4` represents the numeric value 440, or 440 Hz for the note A_4.

```
/*************************************
 * Public Constants
 *************************************/

#define NOTE_B0  31
#define NOTE_C1  33
#define NOTE_CS1 35
[...]
#define NOTE_G4  392
#define NOTE_GS4 415
#define NOTE_A4  440
#define NOTE_AS4 466
[...]
#define NOTE_CS8 4435
#define NOTE_D8  4699
#define NOTE_DS8 4978
```

The above example can be modified to make use of the beats-per-minute (BPM), what will allow changing the speed at which the melody plays. We just need to include the `playNote` function we made earlier and modify the way we express the durations to be expressed in the same terms as in our new function:

```
#include "pitches.h"

int melody[]= {
  NOTE_C4, NOTE_G3, NOTE_G3, NOTE_A3,
     NOTE_G3, 0, NOTE_B3, NOTE_C4};
int noteDurations[] = { 2, 3, 3, 2, 2, 2,
  2, 2 };
int bpm = 120;

void playNote( int speaker, int theTone,
   int duration, int bpm )
{
  // menmotecnic: 120 bpm - - >
  // 1000 milliseconds for half note
  // source http://bradthemad.org/guitar/
  // tempo_calculator.php
  long time =  ( 1000 / bpm * 120 ) /
     pow( 2, duration );

  // assign the note to the speaker
  tone( speaker, theTone, time );
  delay( time*1.30 ); // add 30% for the
                 // silence between notes
}

void setup() {
   for( int thisNote = 0; thisNote
      < 8; thisNote++ ) {
     playNote( 8, melody[thisNote],
        noteDurations[thisNote], bpm );
   }
 }

void loop() { // let's listen
              // to it just once
}
```

Now try including a potentiometer or any other analog sensor to modify the BPM rate and in that way play the melody at different speeds.

Our next installment begins with playing 1-bit notes and culminates in a method to make Arduino play a sound with barely more than a single line of code.

The files for this month's installment may be found at: www.elektor.com/120366

(120366)

The Author

David Cuartielles (1974, Zaragoza, Spain) is currently Head of the Prototyping Laboratory at K3, Malmö University, Sweden, and owns a Research Fellow position in Interaction Design at the Medea Research Studio. In 2005 he coauthored the Arduino prototyping platform. David has a permanent interest in embedded electronics and education, having taught and given lectures at several institutions around the world including: UCLA, NYU, Samsung Art and Design Institute, Copenhagen Institute for Interaction Design, Tecnologico de Monterrey, and others.

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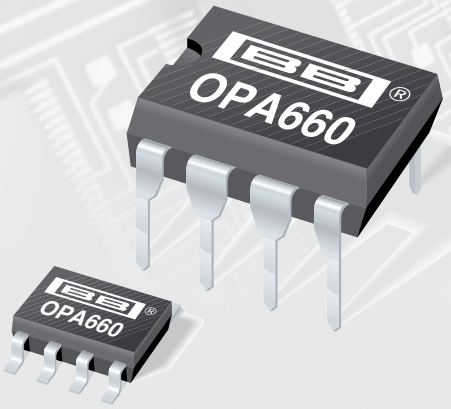
Component Tips

By Raymond Vermeulen (Elektor Labs)

OPA660: Diamonds are not forever



The OPA660 is no more. It has been obsolete for many years, although a few distributors like Rochester Electronics still have some in stock. The successor is the OPA860, but it is not entirely the same. The integrated buffer has a greater gain bandwidth and a higher slew rate, but the original open-loop amplifier has been changed to a closed-loop version. This eliminates the option of using it as a differential amplifier, despite the fact that this was one of the most attractive features of the OPA660 (see the application note [1]).

A few words about the heading of this item: the OPA660 was not made from diamond, but it was often called a 'diamond transistor'. This nickname comes from the symbol for a transconductance amplifier. The operating principle of a transconductance amplifier is very similar to that of a normal transistor, and the pins even have the same names: base, emitter and collector.

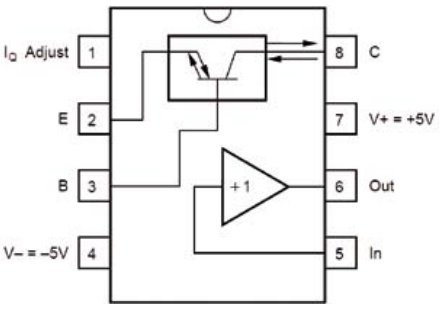
However, no external bias is necessary and if you apply an AC voltage with no DC offset to the base, you get an AC voltage with no DC component on the collector. This can be handy because it reduces the external component count. The transconductance can be adjusted by varying the current into pin 1 [2].
You may be wondering what this is good for. Well, audiophiles will probably use it to make simple amplifiers. Others may be inclined to do something with analog video, and people with a digital bent will be pleased with the steep signal edges, If you do find a use for it, please tell us about the results. I'm keen to know what you discover.

[1] 400 MHz differential amplifier with an OPA660: www.ti.com/lit/an/sboa049/sboa049.pdf

[2] OPA660 data sheet: www.ti.com/lit/ds/symlink/opa660.pdf

(120389)

Parameter	Condition	Value
OTA and buffer input impedance		1 MΩ || 2.1 pF
Buffer slew rate	5 V step	3000 V/µs
Buffer output bandwidth	V_o = ±1.4 V	800 MHz



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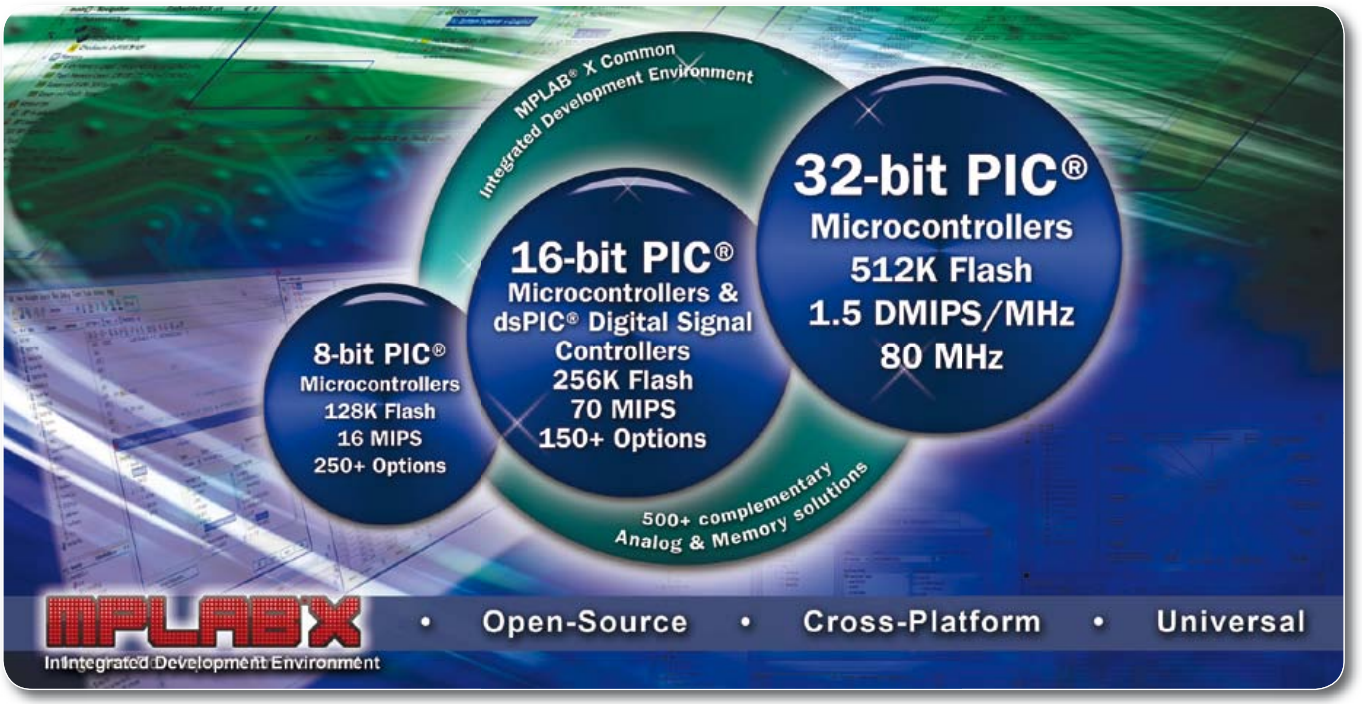

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Chateau Rising Damp

An ATM18 hygrometer

By Grégory Ester (France)

The elasticity and condition of the corks in your best bottled wines vary according to the humidity in the ambient air. So to avoid unpleasant surprises, you need to monitor the humidity and correct the value, which must be neither too high nor too low. The relative humidity varies according to the temperature of the ambient air, hence our ATM18 hygrometer is going to display both humidity and temperature.

And even if you're not a wine connoisseur, you'll be able to use this application to monitor the ambient air quality. Extreme levels are bad for your health and comfort in the home. Air that is too

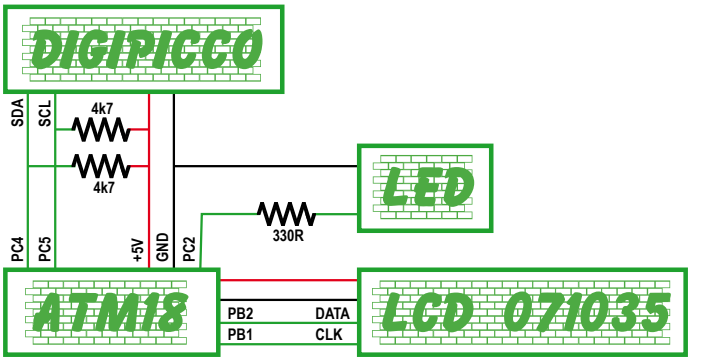
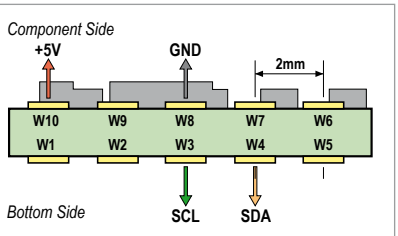
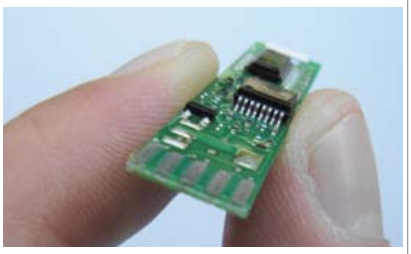


Figure 1. Wiring block diagram.





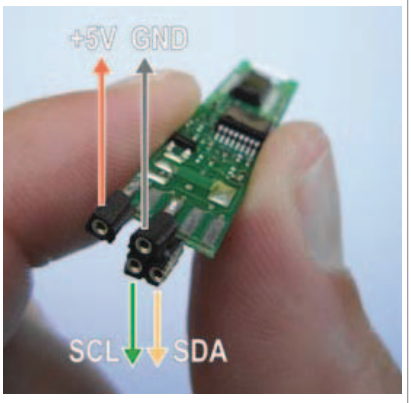


Figure 2. Soldering the single-pin sockets.

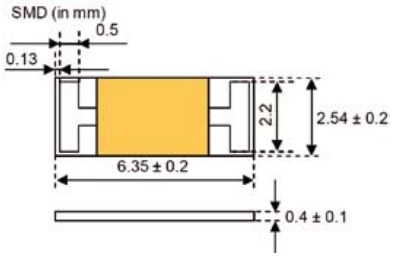


Figure 3. Air humidity detecting surface.

dry weakens the skin and respiratory system, while excessive air humidity can lead to moulds, allergic reactions, and stimulate the proliferation of dust mites. We'd be foolish to forego the benefits of electronics.

For this application, I chose the DigiPicco digital detector [1]; its characteristics are given in **Table 1**. It is supplied calibrated, which makes it easy to use. The signals connections are made via large tinned copper pads.

Once all the ingredients for the hygrometer have been brought together, it takes only a few minutes to connect up the hardware as per the block diagram (**Figure 1**): the data processing and display are going to be handled here by two circuits published by Elektor in 2008 – the ATM18 board [2] and a 2-wire display [3].

Preparation and implementation

Four single-pin sockets (**Figure 2**) are used to simplify feeding the power to the DigiPicco module and accessing the clock signal (SCL/Serial CLock) and data line (SDA/Serial DAta) that are needed for synchronous communication via the I²C bus. So it just takes a few wires simply plugged in to provide the electrical link between the DigiPicco module and the ATM18. Thanks to the extremely simple instructions offered by the famous Bascom-AVR, we can access, at clock rate, the temperature and humidity image bytes supplied by our DigiPicco module.

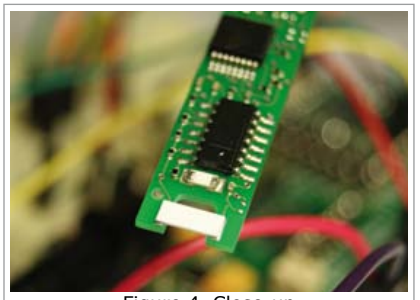


Figure 4. Close-up of the detectors.

DigiPicco, MaxiService!

The DigiPicco module from IST [4] has everything you need to be able to talk to it easily thanks to I²C communication and conveniently read the ambient temperature and relative humidity of the air you are breathing.

The P14 capacitive humidity detector [5] is formed by a porous electrode soldered directly to the base board. In **Figure 3**, we can see that the detector has a large exchange area, giving it improved sensitivity.

An SMD version PT1000 detector is used to measure the temperature. In **Figure 4**, we can clearly see the two detectors that convert the two physical quantities to be measured into electrical values.

Table 1. Characteristics of the humidity / temperature detector

temperature measured	from –25 °C to +85 °C
relative humidity	from 0 to 100 %
communication	serial via I²C bus
accuracy	< ±3 %RH (15 to 85 % RH @ 23 °C) < ±0.5 °C (–25 to +85 °C)
temperature detector	PT1000
humidity detector	P14
current consumption	< 3 mA
supply voltage	5 V

Figure 5. You'll need to check everything again…

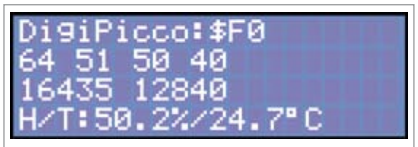


Figure 6. Isn't it nice when everything works?!

Just four bytes!

The address is factory-preconfigured to $F0 during manufacture. If the module is missing on the bus, the error message in **Figure 5** will be displayed. In this event, you'll need to check everything again.

Because this project is firmly intended to be instructive, I've made it display certain elements of the collected or calculated data (**Figure 6**). On the first line, the address visible is scanned automatically at start-up. The second line displays the most significant and least significant bytes corresponding to the humidity of the air; there then follow the most and least significant bytes of the temperature measured.

A little calculation lets us display the two results: the relative humidity for the first value on line 3, followed by the temperature. In point of fact, for the two quantities detected, the bytes are received in the order 'most significant byte' followed by 'least significant byte'. As a result, we need to offset the most significant byte eight bits to the left by multiplying it by 256, after having masked its MSB (01111111 = 0x7F) by means of a logical AND. Add to this the least significant byte and the result is a binary word coded in 15 bits.

A quick glance at the source code file will enable you to link the above explanations to the instructions.

The detector transfer functions are linear (0x0 – 0x7FFF (0 – 100 % RH), 0x0 – 0x7FFF (–40 to +125 °C). The proportional relationship lets us deduce the final values — here a relative humidity of 50.2 % for a measured temperature of 24.7 °C.

The display is updated every second; the 3 mm yellow LED indicates the activity on the I²C bus.

Note that in the current situation, it takes around 5 s to go from 100 % relative humidity to around 50 %. You can test this yourself by blowing close to the P14 detector. It will take around 5 s to return to the initial value.

(110488)

Internet Links

[1] http://uk.farnell.com/ist/digipicco-tm-basic-i2c-g/sensor-humidity-module/dp/1778051?Ntt=digipicco

[2] www.elektor.com/atm18

[3] www.elektor.com/071035

[4] http://www.ist-ag.com/

[5] http://www.ist-usadivision.com/resources/datasheets.php

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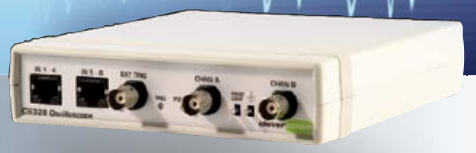

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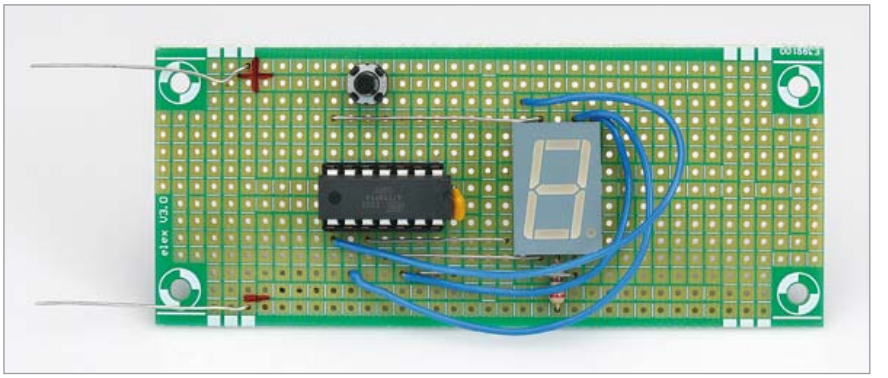
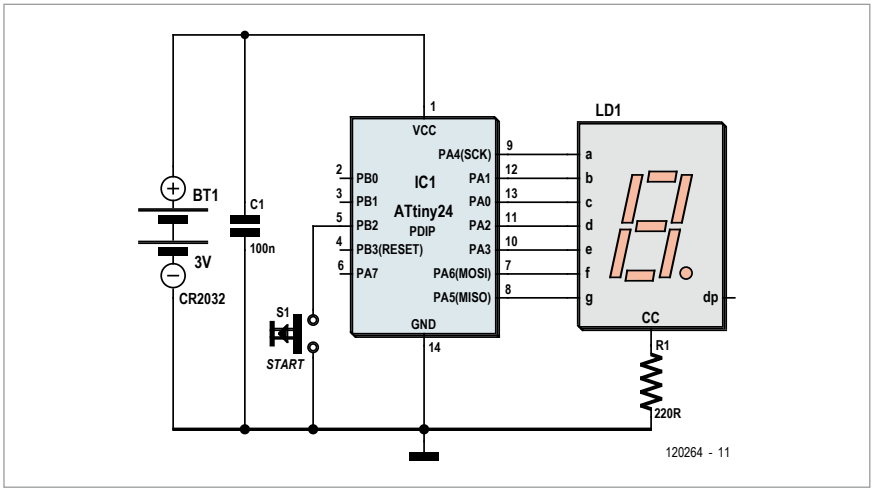
Economical 7-segment Display

By Jörg Trautmann (Germany)





Current consumption is always an important consideration when designing battery-powered devices. This circuit shows how a seven-segment display can be driven by a microcontroller in a way ideally suited for such applications. Furthermore, we even economise on component count!

In a conventional circuit where a single digit is displayed each individual segment is provided with its own current-limiting resistor through which it can be continuously driven. If the current consumption is 5 mA per segment then the total current draw when displaying an '8' will be 35 mA. If multiple digits are to be displayed, they are normally multiplexed in a sequential fashion so that only one digit is driven at a time. In this case the total maximum current draw remains at 35 mA per digit.

The circuit described here uses only one series current-limiting resistor per seven-segment display, and it is possible to reduce the total current consumption to 5 mA per displayed digit. The trick is to use multiplexing at the segment level, realized in software in a microcontroller (in this example an ATtiny24).

In the software each digit to be displayed is represented by a seven-bit string. Each position in the string corresponds to a segment to be driven and can take on the value 0 (for 'off') or 1 (for 'on'). For example, the digit 6 could be represented by the string '0111111', with all segments except the first being illuminated. The software examines the elements in the string one by one in sequence and turns the corresponding segment on or off (see listing). The time period allotted to each segment is about 2 ms and so the digit is refreshed at about 70 Hz, giving a flicker-free display.

As an example application of this technique the author has designed a digital die (see the circuit diagram). As long as input pin PB2 is held low by the user holding down button S1, a counter counts through the digits from 1 to 6 at a 1 kHz rate. When S1 is released the counter's current value is shown on the seven-segment display. There are only a few components in the circuit and so the whole thing can easily be constructed on a piece of prototyping board or on the ELEX-1 (UPBS-1) experimental printed circuit board. The

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- Free software download
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- Prototyping board: ELEX-1 (UPBS-1)

See www.elektor.com/120264

microcontroller is available ready-programmed from Elektor. A type CR2032 battery provides the circuit with a 3 V power supply, which is smoothed by capacitor C1. The output ports of the ATtiny24 are capable of switching currents of 5 mA without difficulty and so they can be connected directly to the corresponding inputs of the seven-segment display module. Only one segment is ever active at any one time and so R1 acts as a current-limiting resistor for the entire display. Be careful when selecting a display that it only includes one LED in each segment, as otherwise the supply voltage of 3 V will not be high enough.

In the interests of reducing power consumption button S1 has a further function: if it is held for more than two seconds, a minus sign flashes on the display for a few seconds and then the microcontroller switches into sleep mode. Current consumption in this mode is less than 1 µA. A further press of S1 will wake the microcontroller up again. If the user forgets to put the microcontroller to sleep, it will automatically switch to this mode two minutes after the last roll of the die. These functions obviate the need for an extra switch to interrupt the power supply.

(120264)

Listing

```
Sub Show_number(byval Number As Byte)

For J = 1 To 7    'display segments in multiplexed fashion
     digit = Mid(a(number), J, 1) 'extract segment value as
digit
     Port_value = Val(digit) 'state to be written to output port
(0 or 1)
     Select Case J
     Case 1
               Porta.0 = Port_value
     Case 2
               Porta.1 = Port_value
     Case 3
               Porta.2 = Port_value
     Case 4
               Porta.3 = Port_value
     Case 5
               Porta.4 = Port_value
     Case 6
               Porta.5 = Port_value
     Case 7
               Porta.6 = Port_value
     End Select
     Waitms 2      'shine segment for 2 milliseconds
     Porta = &B00000000   'clear all segments to zero
Next J

End Sub
```

MOSFET Circuit Breaker

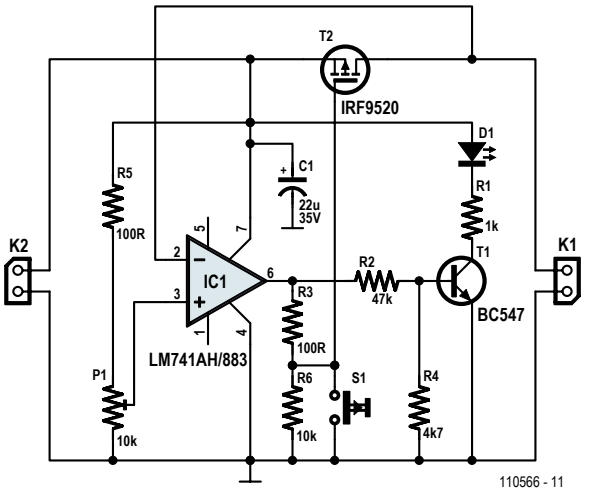
By Georges Treels (France)

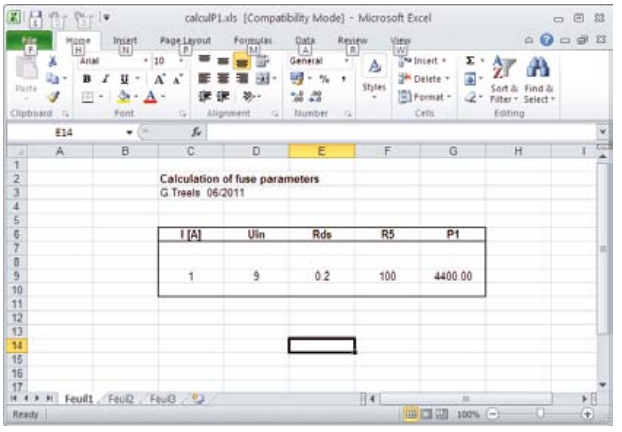
Cutting the power rapidly in the event of an overload implies monitoring the current through the load. This is usually done either by measuring the voltage difference across a series resistor, or by using a Hall-effect current sensor. This second solution is certainly appealing, but the cost of these sensors is still quite high, and they're not all that easy to implement. The disadvantage with the first solution is the voltage drop across the series resistor.

Having come to this conclusion, I had the idea of combining both methods by using a P-channel MOSFET as both disconnecting device *and* series resistor. To achieve this, I turn a (minor) drawback of MOSFETs to advantage: their drain/source resistance.

Opamp IC1 is wired as a comparator monitoring the voltage difference between the drain and source of the MOSFET T2, which is wired in series with the power rail to be monitored. This voltage drop is a function of the current flowing into the load, and hence through T2, and the latter's drain/source resistance. Now T2 will be turned on as long as its gate is kept at 0 (by R6).

The trigger threshold for IC1 is adjusted by preset P1 (in conjunction with R5). If this threshold is exceeded, IC1's output goes high, which turns off T2 via R3. At the same time, T1 turns on and LED D1 lights to show there is a fault. The circuit-breaker has tripped, and everything is safe again.





IRF9520					
I	**U**	**R_{ds}**	**U_{ds}**	**R5**	**P1 : theoretical value**
10	9	0.5	5	220	176
10	12	0.5	5	220	308
10	24	0.5	5	220	836
5	5	0.5	2.5	220	220
5	12	0.5	2.5	220	836
5	24	0.5	2.5	220	1892
1	5	0.5	0.5	220	1980
1	12	0.5	0.5	220	5060
1	24	0.5	0.5	220	10340
0.1	5	0.5	0.05	100	9900
0.1	12	0.5	0.05	100	23900
0.1	24	0.5	0.05	100	47900

Once the cause of the overload has been corrected, all we have to do to turn T2 back on is to force its gate to 0 by briefly pressing S1. The function of R3 is to protect IC1 output from excess current while S1 is pressed.
In order to make this circuit-breaker function, we just need to determine a few parameters for it:

- choice of MOSFET
- maximum current
- working voltage

then all we have to do is calculate the values for R5 and P1 accordingly.

Let's call the voltage on IC1's non-inverting input U_{ref}, the circuit-breaker input voltage U, the drain/source current I, and lastly, the MOSFET's internal resistance R_{ds}.
We can write that $U_{ref} = U \times P1 / (R5+P1)$
The voltage on pin 2 of IC1 is:
$U - (I \times R_{ds})$
So $P1 = [R5 \times (U - I \times R_{ds})] / (I \times R_{ds})$

Example:
U: 9 V
MOSFET R_{ds}: 0.5 Ω
I: 1 A
R5: 100 Ω
We will get:
P1 = 1,700 Ω, i.e. 2 kΩ in a practice.
If these little calculations bother you, don't worry, you can use a spreadsheet to do them for you (screen shot).

Depending on the (P-channel) MOSFET used, this system turns out to be very flexible. By skillfully combining R_{ds}, and I_{max} drain/source, it is possible to monitor currents from 1 to 100 A, or even more.
Of course there's a downside to everything, and this circuit isn't perfect either. To detect weak over-currents, you'll need to choose a MOSFET with quite a high drain/source resistance. You'll also need to recalculate the trigger threshold if the input voltage

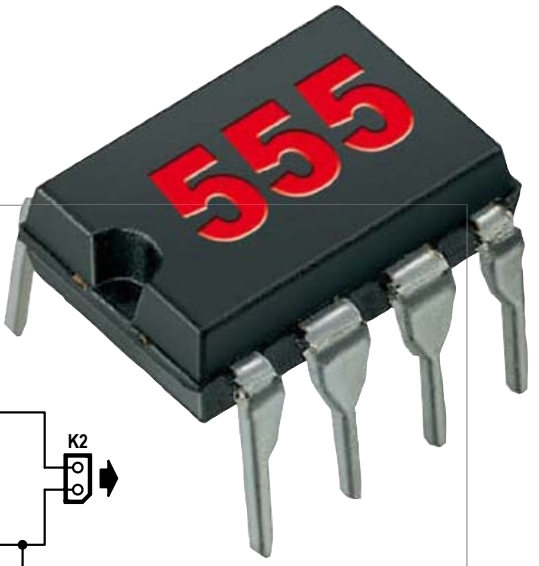
changes. By way of an example, the table gives practical values for a circuit-breaker from 5–24 V and 0.1–10 A, based on the common, cheap IRF9520 MOSFET.

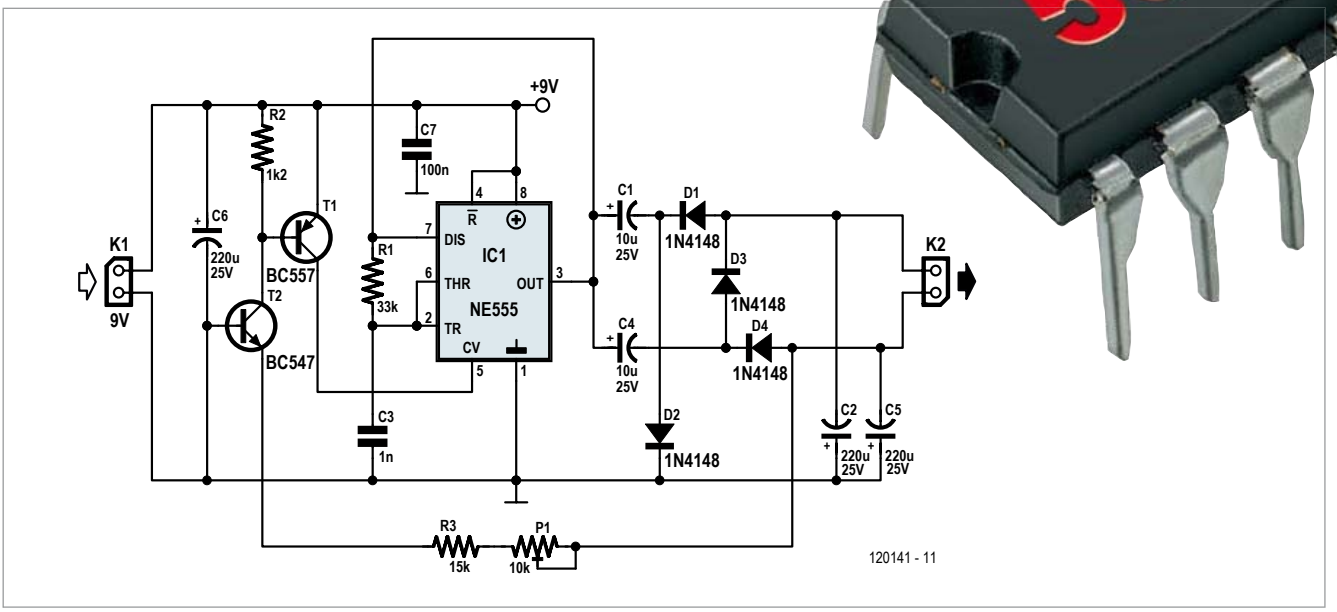
In general terms, for this sort of circuit to be reproducible, you need to make allowance for the component tolerances, in particular the MOSFET's R_{ds} resistance, which is quite sensitive to device temperature.

In my view, the advantages more than outweigh the disadvantages, as this electronic circuit-breaker is compact, works every time and without fine tuning, while P1 lets you cover a wide current range.

(110566)

Voltage Inverter using a 555



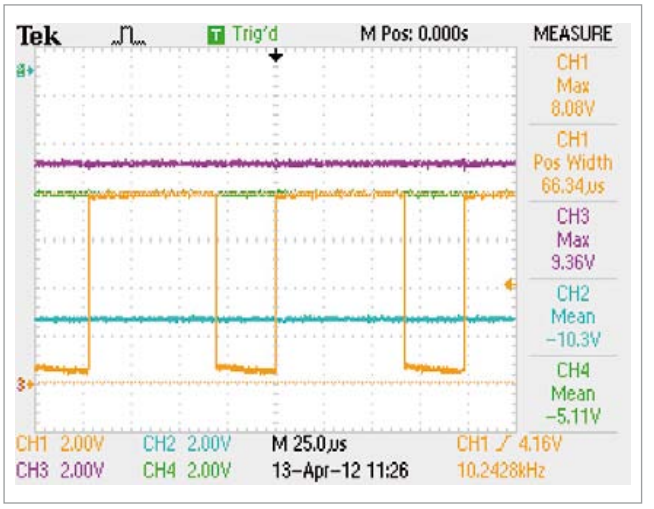


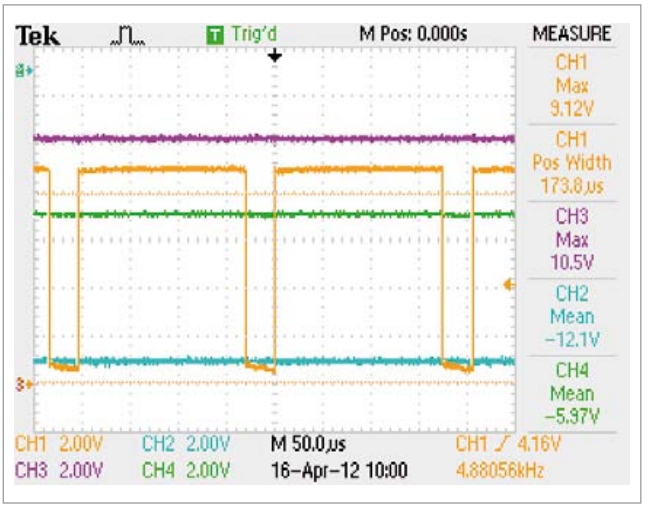
By Peter Krueger (Germany)

In many circuits we need to generate an internal adjustable voltage. This circuit shows how it is possible to use a trusty old NE555 timer IC and a bit of external circuitry to create a voltage inverter and doubler. The input voltage to be doubled is fed in at connector K1. To generate the stepped-up output at connector K2 the timer IC drives a two-stage inverting charge pump circuit.

The NE555 is configured as an astable multivibrator and produces a rectangular wave at its output, with variable mark-space ratio and variable frequency. This results in timing capacitor C3 (see circuit diagram) being alternately charged and discharged; the voltage at pin 2 (THR) of the NE555 swings between one-third of the supply voltage and two-thirds of the supply voltage.

The output of the NE555 is connected to two voltage inverters. The first inverter comprises C1, C2, D1 and D2. These components convert the rectangular wave signal into a negative DC level at the upper pin of K2. The second inverter, comprising C4, C5, D3 and D4, is also driven from the output of IC1, but uses the negative output voltage present on diode D3 as its reference potential. The consequence is that at the lower pin of output connector K2 we obtain a negative voltage double that on the upper pin.





Now let us look at the voltage feedback arrangement, which lets us adjust this doubled negative output voltage down to the level we want. The NE555 has a control voltage input on pin 5 (CV). Normally the voltage level on this pin is maintained at two-thirds of the supply voltage by internal circuitry. The voltage provides a reference for one of the comparators inside the device. If the reference voltage on the CV pin is raised towards the supply voltage by an external circuit, the timing capacitor C3 in the astable multivibrator will take longer to charge and to discharge. As a result the frequency of the rectangle wave output from IC1 will fall, and its mark-space ratio will also fall.

The source for the CV reference voltage in this circuit is the base-emitter junction of PNP transistor T1. If the base voltage of T1 is approximately 500 mV lower than its emitter voltage, T1 will start to conduct and thus pull the voltage on the CV pin towards the positive supply.
In the feedback path NPN transistor T2 has the function of a voltage level shifter, being wired in common-base configuration. The threshold is set by the resistance of the feedback chain comprising resistor R3 and potentiometer P1. When the emitter voltage of transistor T2 is more than approximately 500 mV lower than its base voltage it will start to conduct. Its collector then acts as a current sink. Potentiometer P1 can be used to adjust the sensitivity of the negative feedback circuit and hence the final output voltage level.
Using T1 as a voltage reference means that the circuit will adjust itself to compensate not only for changes in load at K2, but also for changes in the input supply voltage. If K2 is disconnected from the load the desired output voltage will be maintained, with the oscillation frequency falling to around 150 Hz.

A particular feature of this circuit is the somewhat unconventional way that the NE555's discharge pin (pin 7) is connected to its output (pin 3). To understand how this trick works we need to inspect the innards of the IC. Both pins are outputs, driven by internal transistors with bases both connected (via separate base resistors) to the emitter of a further transistor. The collectors of the output transistors are thus isolated from one another [1].

The external wiring connecting pins 3 and 7 together means that the two transistors are operating in parallel: this roughly doubles the current that can be switched to ground.

The two oscilloscope traces show how the output voltage behaves under different circumstances. The left-hand figure shows the behaviour of the circuit with an input voltage of 9 V and a resistive load of 470 Ω connected to the lower pin of output connector K2. The figure on the right shows the situation with an input voltage of 10 V and a load of 1 kΩ on the lower pin of output connector K2. The pulse width and frequency of the rectangle wave at the output of IC1 are automatically adjusted to compensate for the differing conditions by the feedback mechanism built around T1 and T2.

Because of the voltage drops across the Darlington output stage in the IC (2.5 V maximum) and the four diodes (700 mV each) the circuit achieves an efficiency at full load (470 Ω between the output and ground) of approximately 50 %; at lower loads (1 kΩ) the efficiency is about 65 %.

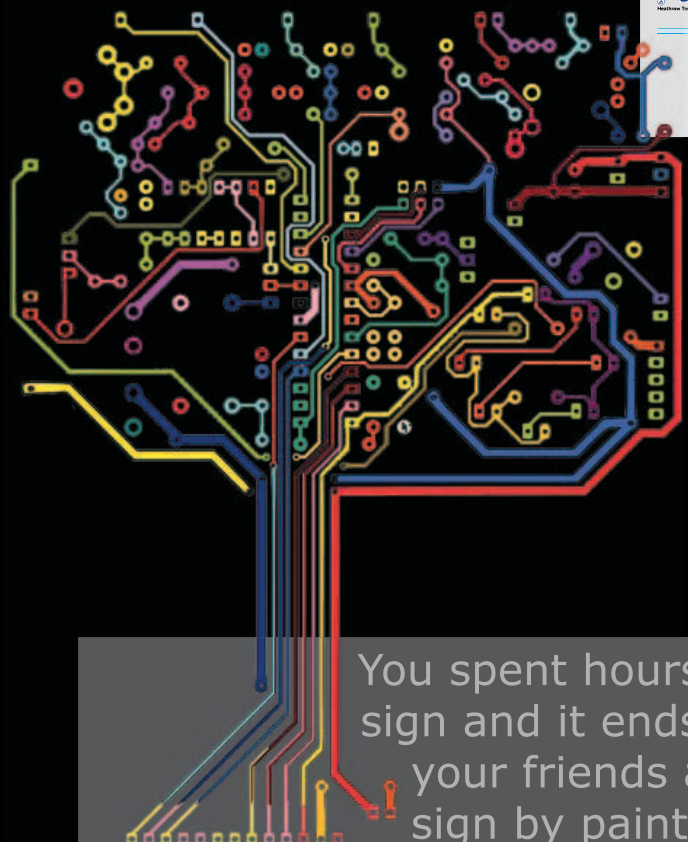
(120141)

[1] http://en.wikipedia.org/wiki/555_timer_IC

HACK THE TRACK

Weird PCB design

Not everything you see is an electronic design, but sometimes it gets close to it. Take the famous London Tube map – can you drop a few components at selected points and make a small amplifier? Or a 'Bakerloo' oscillator?

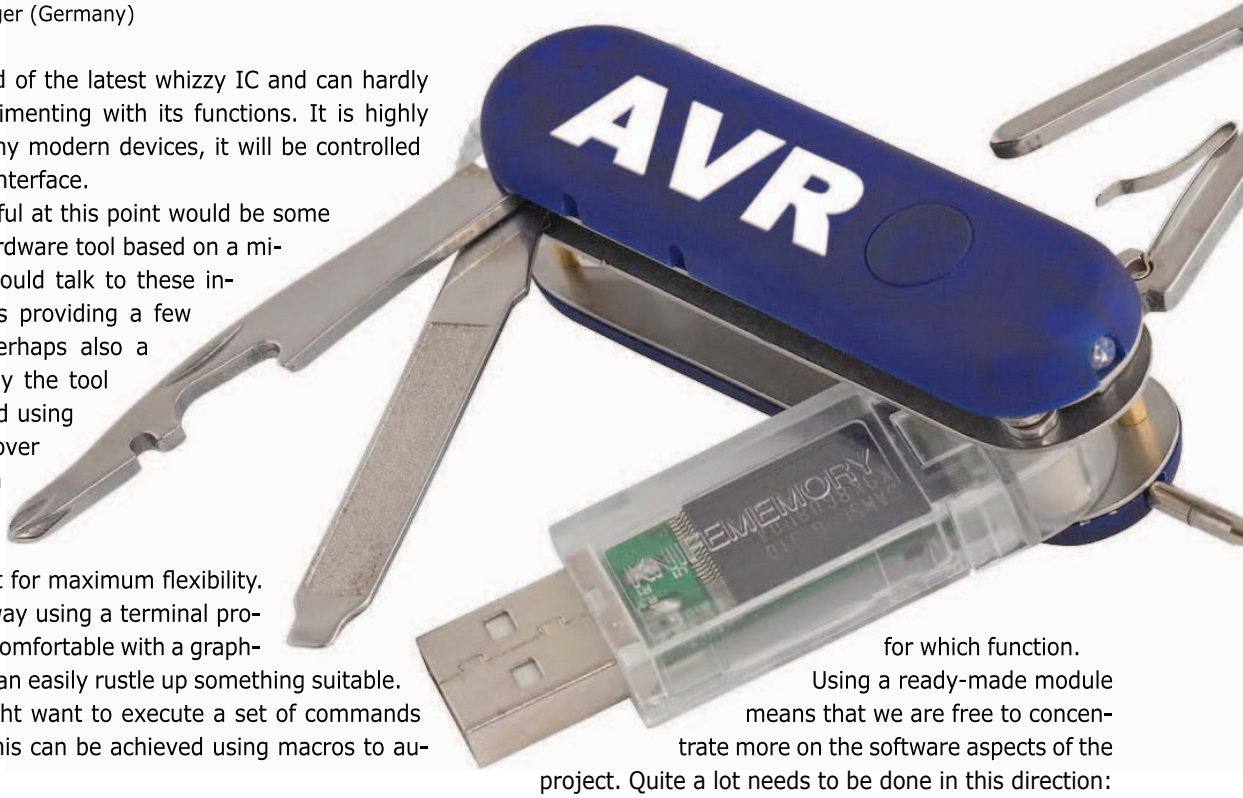


You spent hours designing the ultimate PCB design and it ends up in a box well out of sight of your friends and relatives. Show off your design by painting it and print it on poster format or wallpaper. How about this PCB TREE?

AVR MultiTool

Measure, control, experiment

By Dr Andreas Eppinger (Germany)



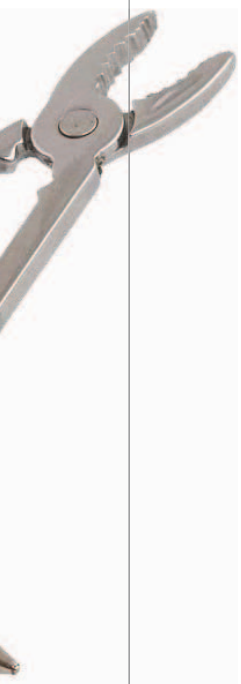
You've just got hold of the latest whizzy IC and can hardly wait to start experimenting with its functions. It is highly likely that, like many modern devices, it will be controlled over an I²C or SPI interface.
What would be useful at this point would be some kind of versatile hardware tool based on a microcontroller that could talk to these interfaces, as well as providing a few digital I/Os and perhaps also a PWM output. Ideally the tool should be controlled using a simple protocol over a serial port, which would allow a PC to be used to issue commands to it for maximum flexibility. Purists can hack away using a terminal program; those more comfortable with a graphical user interface can easily rustle up something suitable.
In principle we might want to execute a set of commands in sequence, and this can be achieved using macros to automate things.
Most modern microprocessors, such as AVR microcontrollers, already include the peripheral interfaces needed to carry out such experiments. A ready-made processor board with all the required pins brought out on header strips would make a good basis for all-singing-all-dancing hardware for measurement, control and experimenting. For the 'AVIOM' (*A*VR *V*ersatile *I/O M*odule) the author chose an Arduino Nano board (see photograph). This board basically consists of an ATmega328P and a USB interface for talking to a PC. In the lab we have also successfully tested the design using an Arduino Uno board. Alternatively, it is easy enough to construct a compatible module with an ATmega328P and a few support components. If a ready-made USB-to-serial TTL-level cable is used, the corresponding converter chip on the board can be dispensed with. The do-it-yourself approach is made possible by the fact that Arduino hardware and software is all open source: the hardware reference design, the programming environment and a wealth of software examples are available for free download from the Arduino homepage [1]. The large figure shows which pin on the board is responsible for which function.
Using a ready-made module means that we are free to concentrate more on the software aspects of the project. Quite a lot needs to be done in this direction: the firmware running on the Arduino needs to configure the Timer/Counter/PWM, I²C, SPI and UART modules, as well as set up the four analog channels and eight digital ports.

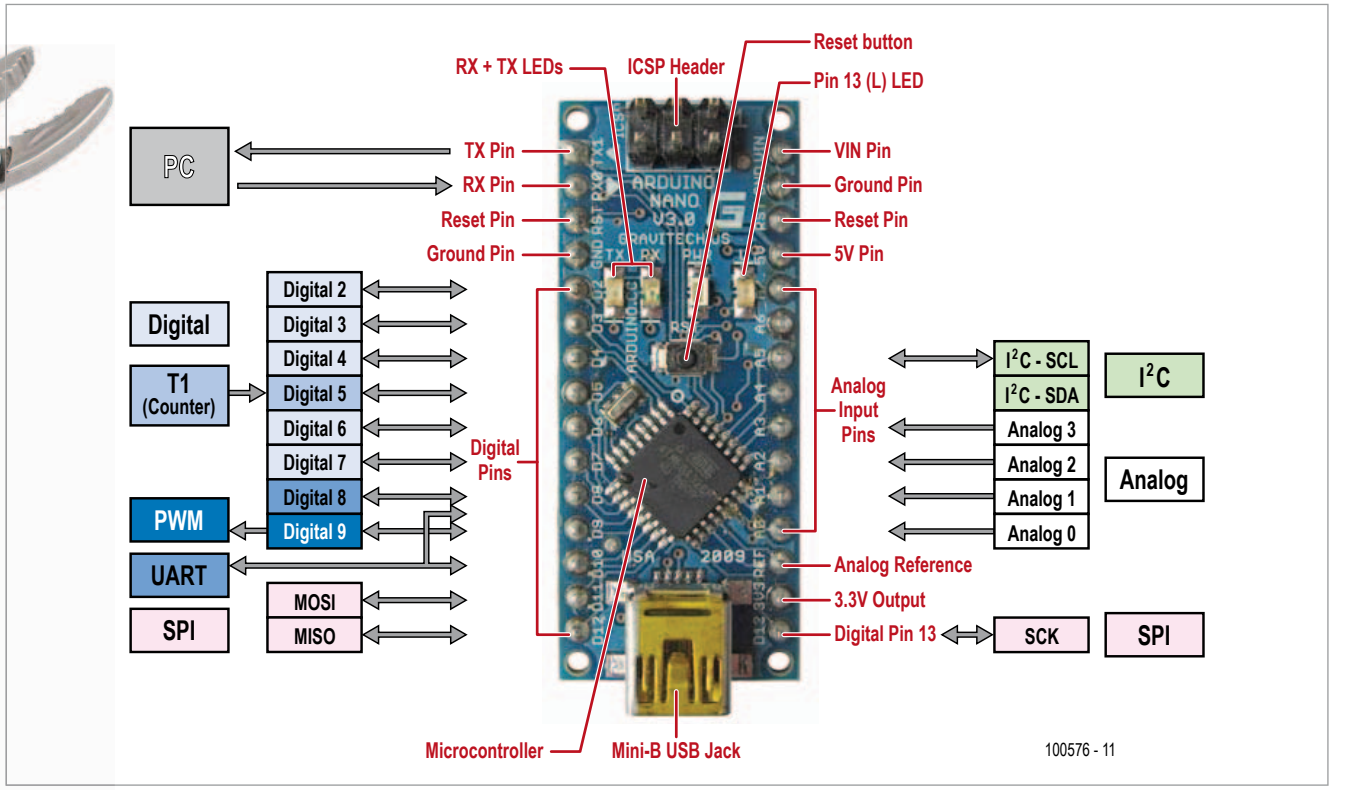
There are two ways in which the device can be controlled from a PC.

- Use a terminal. A simple terminal emulator program suffices, and the short commands make interactive control of all functions easy. Sequences of commands can be defined as macros, stored and then subsequently played back.

- Write a program. The hardware can be controlled using a program written in Visual C# 2010 with a graphical user interface, written specifically for this project by the author. The user interface even allows Python scripts to be created and executed to automate the operation of the hardware.

We will now look at the various parts of the software one by one. For simplicity the AVIOM operates in one of a range





of different modes, such as 'analog', 'digital' and 'wait'. The operating mode is selected by sending a full stop character '.' followed by a single letter abbreviation as follows.

.a	Analog
.d	Digital
.c	Configuration
.e	EEPROM access
.i	I²C
.l	System LED
.m	Macros
.r	SRAM access
.t	Timer/Counter
.u	UART
.w	Wait

In each mode there are three basic commands available: help ('?'), status ('#') and command line ('%'). The help command '?' causes the built-in help system to list the available commands. The '#' command displays status information. The percent character '%' introduces a command line: this means that subsequent characters are collected until the end of the line (indicated by a CRLF) and then executed.
Within the commands themselves capitals are distinct from lower-case letters. Each command consists of letters, numeric values, or a combination of the two. A complete list of commands would occupy more space than we have available here, but is available for download from the Elektor website [2]. As a taster will we show here some of the commands available in analog, system LED and wait modes.

Analog mode (.a):

'1'	Display the value read from ADC channel 1
's'	Read all four of the ADC channels and display their values

System LED mode (.l):

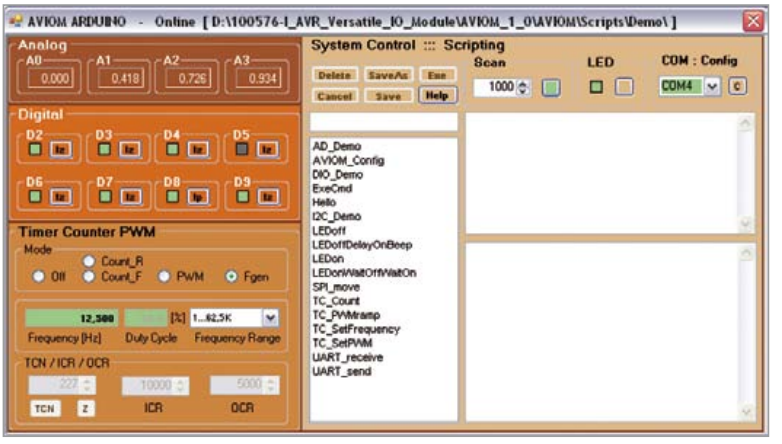
'h'	Switch system LED on
'l'	Switch system LED off
's'	Read system LED status

Wait mode (.w):

hhh	Wait for hhh (hex) milliseconds (hhh = 000 to FFF)

Commands (and this goes also for mode-changing commands) can be strung together into sequences, as hinted at above. For example, the following sequence switches on the system LED and then reads analogue channel 3: '.lh.

a3;'. A semicolon can be used to mark the end of a command sequence.
The sequence '.mdA .ll.w100.lh.m' defines a macro called 'A' which turns the system LED off for 256 ms and then turns it on again. The macro can be executed using the command '.mA'.
On reset, the system automatically executes the macro called '0'. This macro can therefore be used to store all the commands and settings that need to be executed whenever the AVIOM system is booted.
As mentioned above, the 'multi-tool' can also be controlled by a program running on a PC, written by the author using Visual C# 2010. The screenshot shows the graphical user interface in action.
The ADC values are shown at the top left under 'Analog'. Pressing the 'Scan' button starts a cyclic reading of ADC values: below to the left the cycle timing can be set in milliseconds.



connection has been successfully established the field turns green and the rest of the user interface is activated; otherwise the field remains gray.
The C# software uses the 'ALab' framework developed by the author, which offers a very wide range of basic functions for using a PC to control operations in a microprocessor network. Communication between the PC and network nodes is done using messages which are kept in queues. Replies received are processed and displayed in the AVIOM user interface. The whole thing is of course written with a little help from threads.
One of the most important features of the PC software is scripting. Scripts, written in the Python programming language, can be entered in the script text window. To do this, the AVIOM system uses the freely-available IronPython ('Python for .NET') implementation [3].
The scripts are stored as text files in a workspace directory. A complete list of the script files found there is shown in the list

Automation using macros and scripts

The area marked 'Digital' shows the current state of the digital pins. Clicking on the relevant button switches a pin between output, high-impedance-input, and input-with-pull-up-resistor modes. Clicking on the display (when in output mode) changes the state of the output.
Radio buttons are used to change settings in the area marked 'Timer Counter PWM'. In 'Count_R' mode the counter counts rising edges, while in 'Count_F' mode it counts falling edges. Clicking 'TCN' reads the current value in the counter and clicking 'Z' resets it.
In PWM or frequency generator mode ('Fgen') the 'Frequency' and 'Duty Cycle' fields are enabled. Since only integer values are allowed in the AVR's ICR and OCR registers, the actual frequency and duty-cycle values are displayed, which may differ somewhat from the values the user has entered.
The COM port that is used for communication with the AVIOM module is set under 'COM:Config' at the upper right. Once a box in the middle of the screen. The working directory can be changed by clicking on the 'C' button.
If a script is selected in the list box, the name of the file will appear in the text box above it and can be edited there if necessary. A copy of an existing script with a new name can be created by editing the filename suitably and clicking on 'SaveAs'.

If you have entered or edited a script in the large window at the bottom right, you can try it out using 'Exe' or by double-clicking the script name in the list box. The file will automatically be saved first. Text output from the script (from 'print' commands) and error messages appear in the window above. Make sure that 'scan' mode is not active when executing scripts.
User script files are automatically provided with a header that imports a few handy name spaces and defines two special

objects: 's' for system functions and 'a' for AVIOM functions. The AVIOM object 'a' is an essential part of any script file. All AVIOM commands that can be executed by a Python script are implemented as methods of this object. (A click on the 'Help' button lists the built-in functions.) In many cases the methods return 'true' or 'false' to indicate whether the command was successful or not. A complete list of the AVIOM script commands can be found in the document available from the Elektor website.
The following example shows how commands can be executed.

```
#
# Demo: TIMER COUNTER
# set pwm
#
f = 1.0
dc = 7.0
res = a.TCPpwm(f, dc)
print "PWM f = ", res, "  DutyCycle = ",dc,"%"
```

Further examples can be found in the 'Demo' workspace. Note that the 'I2C_..._PCA8581' demonstration scripts only work when a suitable EEPROM device is connected.

You will doubtless now want to try the system out for yourself. The first step is to install version 1.0 of the Arduino development environment [1].
The download from the *Elektor* website includes a directory 'AVIOM_1_0' which should be copied to any convenient place on the computer. It is now a good idea to create a shortcut to the file '..\AVIOM_1_0\AVIOM\AVIOM\bin\Release\AVIOM.exe".
The next step is to launch the Arduino IDE and set the 'sketchbook' location to point to the directory '..\AVIOM_1_0\ARDUINO'. Connect the Arduino board and select the 'sketch' 'AVIOM_Arduino_1_0', compile the program and load the hex file into the microcontroller.
A first test can be carried out using a terminal emulator program (with settings 115200 baud, 8N1) or using the author's dedicated program, which can be run by clicking on the shortcut. The demonstration scripts should appear in the script list. And away you go!

(100576)

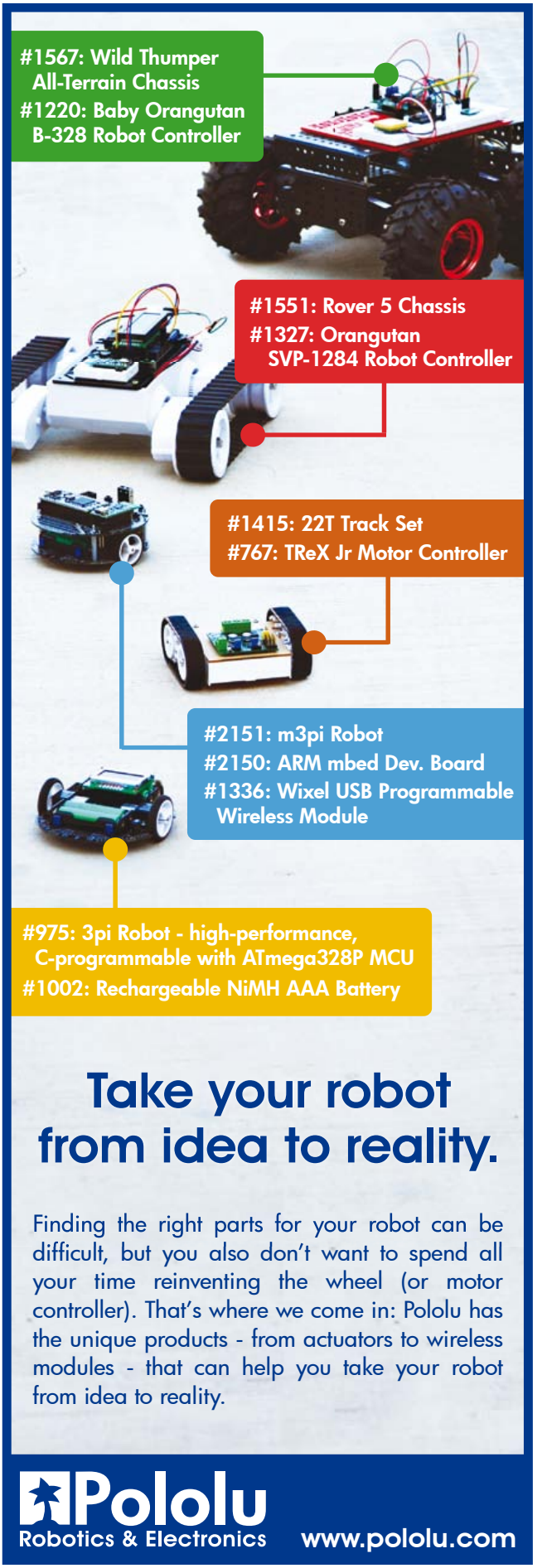
Internet Links

[1] www.arduino.cc

[2] www.elektor.com/100576

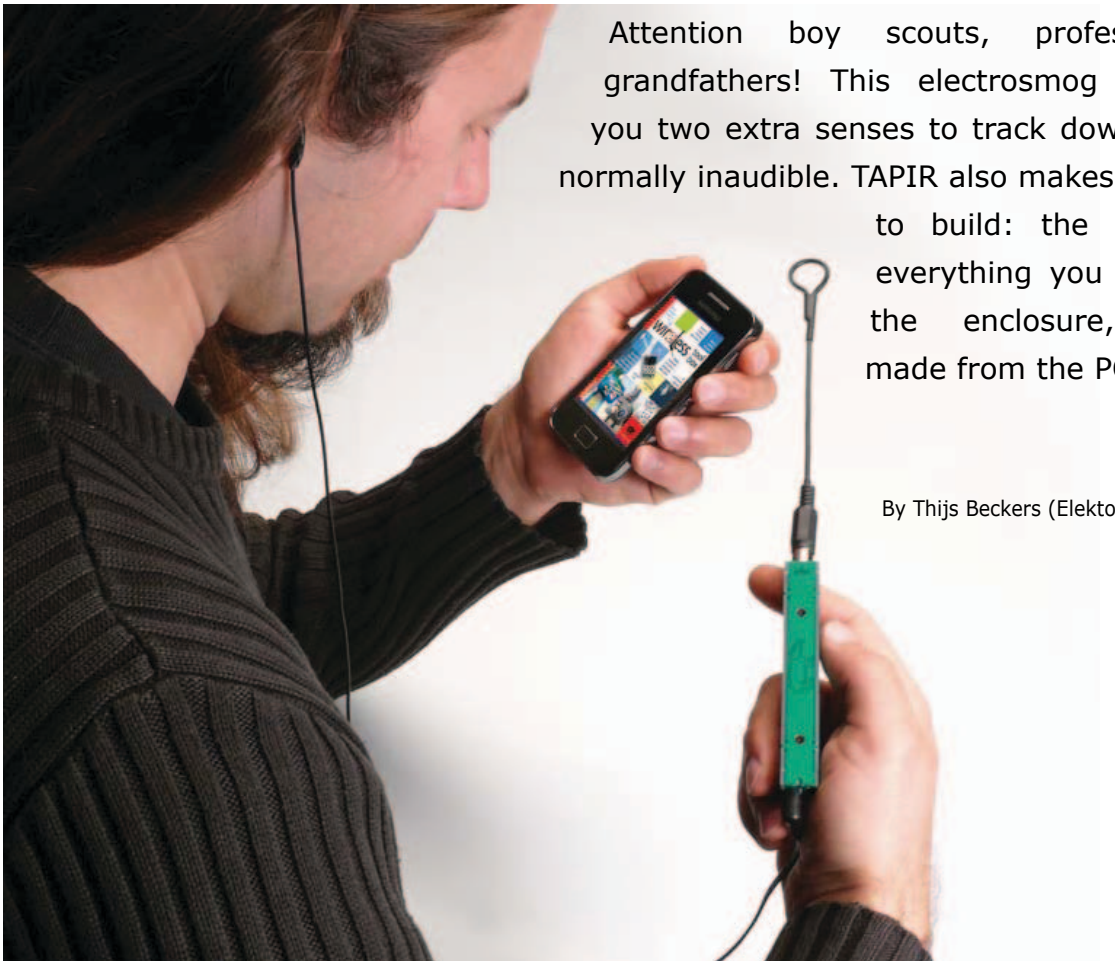
[3] http://ironpython.net

Advertisement



TAPIR Sniffs it Out!

Ultrasensitive wideband E-smog detector



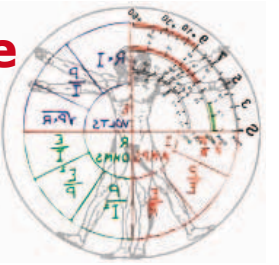
Attention boy scouts, professionals and grandfathers! This electrosmog sleuth offers you two extra senses to track down noise that's normally inaudible. TAPIR also makes a nice project to build: the kit comprises everything you need — even the enclosure, ingeniously made from the PCB proper.

By Thijs Beckers (Elektor UK/INT Editorial)

Why build an electrosmog ('E-smog') detector? The answer is quite simple. More and more of our everyday objects are based on some sort of electrical 'core': your toothbrush, camera, cellphone, TV set, and so on. Each and every one of these devices generates electrical radiation in some way. There are of course rules manufacturers should abide by, but that doesn't mean that devices are completely free from electrosmog.

In fact, even with the widespread 'CE' certification stamped onto your device, it is not certain that a device complies with all the rules and doesn't interfere with other electronic devices. Ever tried calling someone (or, when receiving an incoming call) holding your mobile phone close to a cheap alarm clock radio, or a set of low-end PC speakers? (your guitar amp probably loves those cellphones too…)

An E-smog detector is designed to detect the 'radiant misbehavior' of near-by electronics. The TAPIR — short for *Totally Archaic but Practical Interceptor of Radiation* — is a simple design capable of detecting, and audibly pinpoint, any source of electric or — with the appropriate antenna — magnetic field. Its application area extends from home use (*"Where can I sit without being microwaved?"*), to practical use (*"Where's that Wi-Fi-antenna aimed at?"*), to professional use (*"Who the devil is jamming me?! I'm trying to do some sensitive measurements here!"*).



It's even suitable as a first SMD soldering project — with your (grand)child — since it's so easy (and fun!) to assemble.

Different fields

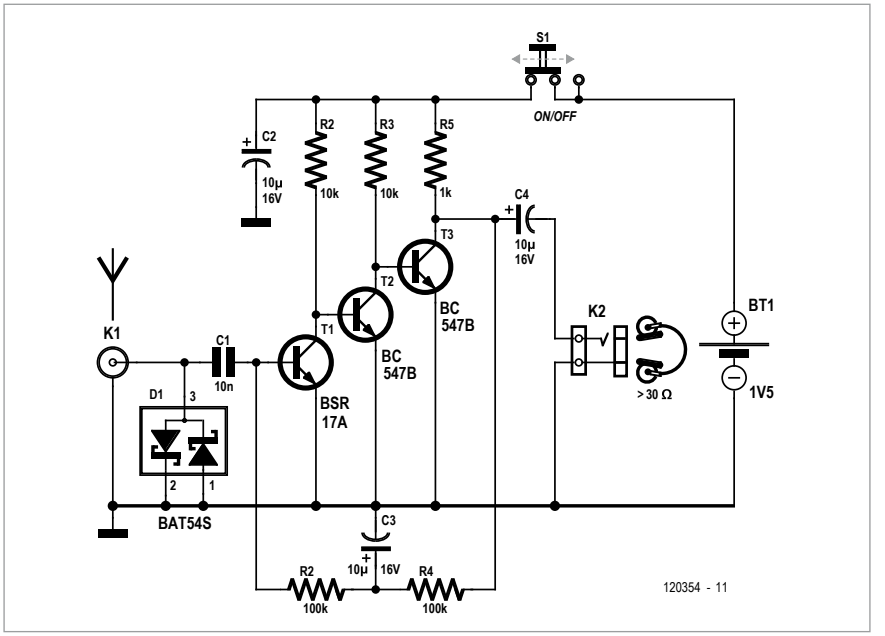
TAPIR is able to detect electric as well as magnetic fields of high frequencies. Magnetic fields are mostly generated by transformers and loop antennas, while electric fields are emitted by high voltage transmission lines, EL backlights and old mopeds passing by. Electromagnetic fields are a combination of both fields, mostly occurring in the 'far field' at a larger distance from the generating object.

Two different antennas can be connected to TAPIR, each optimized for one type of field. Magnetic fields are detected with a ferrite cored coil, while electric fields are detected with a rod antenna, which can be constructed very easy from a piece of installation wire.

How does it work?

The schematics show the simplicity of the design and are very similar to an Elektor circuit published in 2005. Basically it consists of a three-stage low-frequency amplifier with high gain. There is no low-pass filter in the circuit, consequently high frequencies are passed on to the gain stages. This way the non-linear characteristics of the transistors have a demodulating effect on these high frequency signals, so they can also be heard via headphones. The bias point of the gain stages is automatically adjusted via a DC feedback path from the output through R4 and R1. To suppress the AC component C3 is added, which shorts this part of the signal to ground.

The output voltage level has an offset of about 0.7 volts, hence C4 is added to remove this offset and protect any connected headphones (or other devices). The total gain is high enough to be able to 'hear' the intrinsic noise of transistor T1, so it's best to pick a low noise transistor for this. We went for the BSR17A, which has far better noise figures at high frequencies than a BC847B. Signals of mere microvolts are audible via headphones connected to the output.



teries). Worried about soldering those tiny SMD components? No need! Even though there are some components with the '0805' shape, it can all be done with your standard tools, provided you have a reasonably small soldering tip at hand for your soldering iron, and a pair of precision tweezers.

Listen in on electromagnetic pollution

First, clean up your desk! You might drop an SMD component from your tweezers in which case you want to be able to find it again... Assuming the light conditions on your desk are optimal, you may begin with opening the first bag and sorting the components, with or without the help of our online assembly manual [1]. Now you're ready to start soldering.

To get the hang of it, start with some larger components, switch (S1) and the headphones jack (K2). Be frugal

Don't flee 4 the SM-Dee

This E-smog detector is available as a low-cost kit [1] with the PCB and all the components included (except the bat-

with the solder on K2, otherwise you may have some trouble assembling the PCBs together into the housing. When finished, remove PCB #2 and #4 from the panel and flatten the sides where it used to be held into place. Now you're ready to start with the 'real deal'.

A convenient way to solder SMDs is to 'wet' *one* pad first. Hold the end of the solder wire (thin wire is preferred) onto the pad and *shortly* touch it with the solder tip. A thin layer of solder should now cover the pad with some flux from the core still active. Now use tweezers to align the component onto the PCB, holding it down while you gently touch the lightly tinned soldering pad with your soldering iron again, reflowing the solder. The flux now helps the tin to flow, creating a solid connection between the component and the pad. You may even reheat the pad to position the component better.

When the component is in position, solder the other pad by pushing the solder wire onto the pad and shortly touching it with your soldering iron. The flux should work its magic and evenly spread out the solder onto the pad and the solder connection of the component.
Short soldering actions create the tidiest connections. But do make sure you're actually soldering and not only wetting the pad or the component. Adding some fresh solder to the first pad while shortly reheating it can tidy it up if you made it a little messy.
Now you're ready to proceed with the rest of the components.

Cubism, it's a work of art

When finished, remove PCB #3 from the panel using a fretsaw. Make sure there's a small ridge left. This is needed to put the PCBs together forming its housing. Solder the RCA connector (K1) onto the PCB.

Now we're going to solder PCBs #5, 6 and 7 onto PCB#3. Remove the PCBs from the panel, leaving a short pin in place where it used to be connected to the panel. Place PCB #3 in front of you with K1 pointing away. Now put PCB #5 in its place, making sure it's perpendicular and the soldering pad for the PCB pillar is at the RCA connector side pointing upwards. Solder the pad on the right corner only, so adjustments are easier later on.

Put PCB #6 in place, again making sure it's perpendicular. The PCB pillar pad should be pointing upwards and away from the RCA connector. Solder the right corner pad only. Finally put PCB #7 in its place and solder all three pads.

Continue sliding PCB #4 into its place. K2 should be right through the hole in PCB #7. The small ridges on PCB #5 and 6 should enter the cut-outs on PCB #4. Now solder the 'lower' PCB pads of PCB #4 to PCBs #3, 5 and 6, starting from the middle, pressing the PCBs together tightly. Don't forget to solder the 'normal' pads between PCB #3 and 4 next to K2. Put PCB #4 down and solder the RCA connector onto PBC #4. Also solder the 'upper' PCB pads to the rest of the PCBs.
Put PCB #2 in place and solder it to the rest of the PCBs, making sure it all stays nice and square. Make sure all pads are soldered! Solder the two M2×6 PCB pillars in place. They should be flat on the PCB and right in the middle. Bracket tweezers can be helpful with this. Use a sharp drill to countersink the screws into PCB #1 and check if the last PCB (#1) fits nicely. If needed, correct the position of the PCB pillars. Place the spring and a battery (AAA type) and close the lid. Your TAPIR is now ready for use.

Track down wretched interference sources

Constructing antennas

To detect electric fields, a simple rod antenna can be constructed using an RCA connector and 20 cm (8 inches) of electrical installation wire (or any type of wire, but installation wire is quite stiff and can be bent the way you like).

Strip 3 mm (0.1 inch) off the isolation and solder the wire to the center pin of the RCA plug. When locating interference on circuit boards a small loop at the end of the rod could prove useful. Magnetic fields are picked up by an inductor-based antenna. This antenna is constructed using a piece of installation wire as a frame to hold the coil, while one end of the coil is connected to the center pin of the RCA plug and the other to the outer connection. Make sure the 'ground' (outer connection) is securely connected to the TAPIR, otherwise the inductor acts as an electric field antenna. More detailed information about the construction can be found on our website [1].

COMPONENT LIST

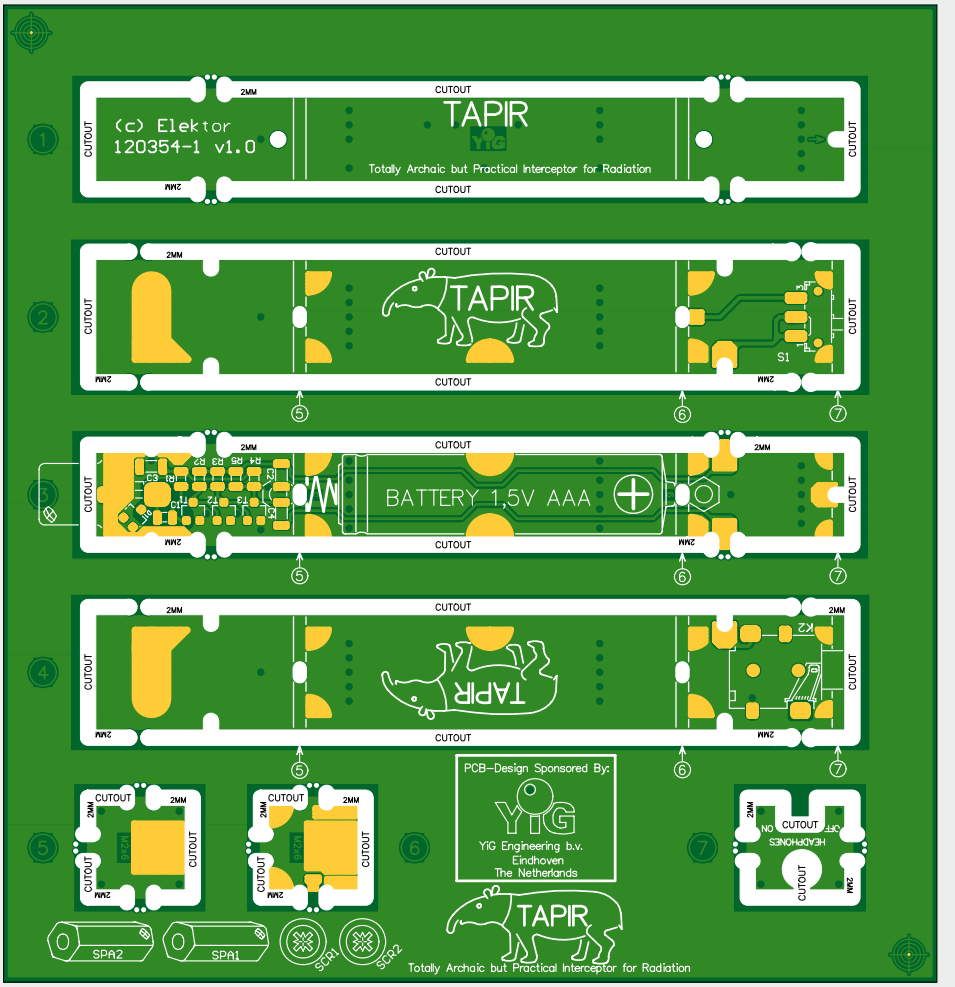
Resistors (SMD 0805)
R1,R4 = 100kΩ
R2,R3 = 10kΩ
R5 = 1kΩ

Capacitors
C1 = 10nF 50V, SMD 0805
C2,C3,C4 = 10µF 25V, SMD 1206

Semiconductors
D1 = BAT54S
T1 = BSR17A
T2,T3 = BC847B

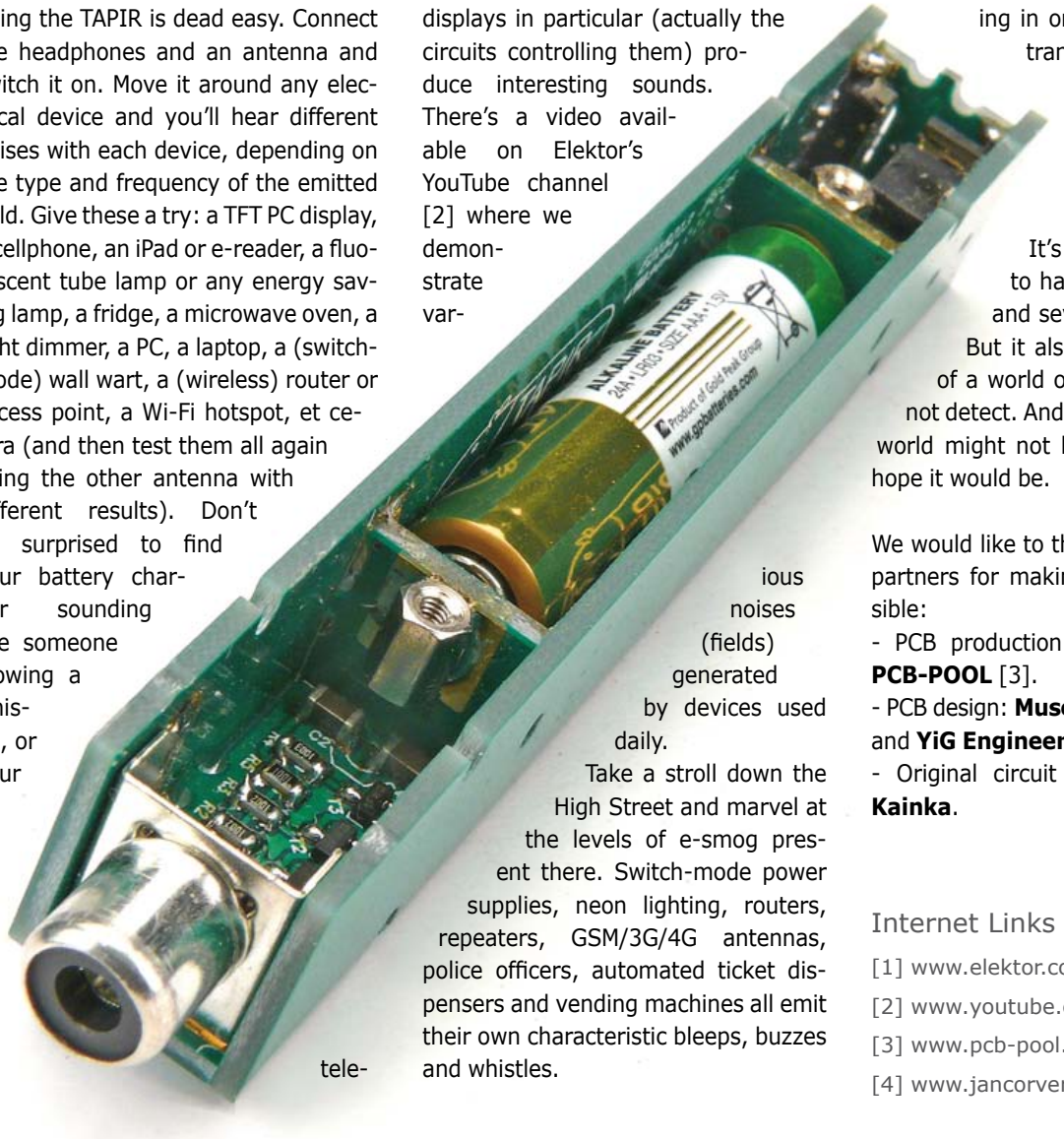
Miscellaneous
K1 = RCA socket, SMT
K2 = mini jack SMT, CIU
S1 = switch, JS102011SAQN
PCB #120354-1, see [1]
Battery spring
Two PCB pillars, M2×6
Two Phillips screws, M2×6
Two RCA connectors
Two pieces of installation wire, approx. 20 cm (8 inch)
One inductor coil (H-field antenna)

A kit consisting of the PCB and all the needed parts (AAA cell excluded) is available from Elektor [1] order no. 120354-71.



TAPIR in use

Using the TAPIR is dead easy. Connect the headphones and an antenna and switch it on. Move it around any electrical device and you'll hear different noises with each device, depending on the type and frequency of the emitted field. Give these a try: a TFT PC display, a cellphone, an iPad or e-reader, a fluorescent tube lamp or any energy saving lamp, a fridge, a microwave oven, a light dimmer, a PC, a laptop, a (switch-mode) wall wart, a (wireless) router or access point, a Wi-Fi hotspot, et cetera (and then test them all again using the other antenna with different results). Don't be surprised to find your battery charger sounding like someone blowing a whistle, or your telephone tap dancing through TAPIR. LC displays in particular (actually the circuits controlling them) produce interesting sounds. There's a video available on Elektor's YouTube channel [2] where we demonstrate various noises (fields) generated by devices used daily.



Take a stroll down the High Street and marvel at the levels of e-smog present there. Switch-mode power supplies, neon lighting, routers, repeaters, GSM/3G/4G antennas, police officers, automated ticket dispensers and vending machines all emit their own characteristic bleeps, buzzes and whistles.

You can also use TAPIR for listening in on the inductive loop transmission system frequently present in museums and other public places.

It's actually quite fun to have access to a sixth and seventh set of senses. But it also makes one aware of a world our own senses cannot detect. And what goes on in this world might not be as nice as you'd hope it would be.

We would like to thank all contributing partners for making this project possible:
- PCB production: **Beta LAYOUT / PCB-POOL** [3].
- PCB design: **Museum Jan Corver** [4] and **YiG Engineering**.
- Original circuit design: **Burkhard Kainka**.

(120354)

Internet Links

[1] www.elektor.com/120354
[2] www.youtube.com/ElektorIM
[3] www.pcb-pool.com
[4] www.jancorver.org/en/index.htm

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Elektor have teamed with **Beta LAYOUT** to manufacture the PCBs required for this project.

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The PCB design was generously donated by the **Museum Jan Corver Foundation** and **YiG Engineering**. Visit www.jancorver.org/en/index.htm for more information.

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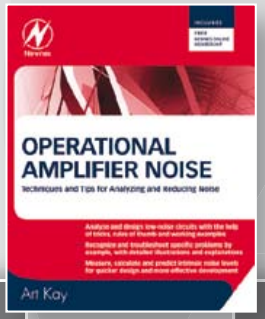

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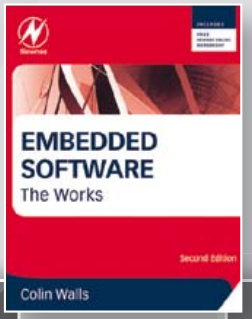

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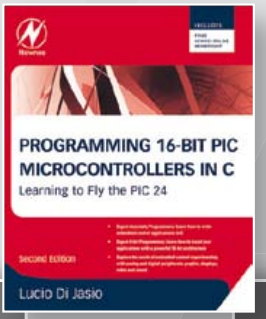

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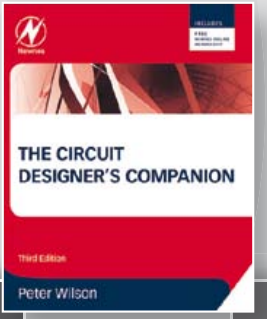

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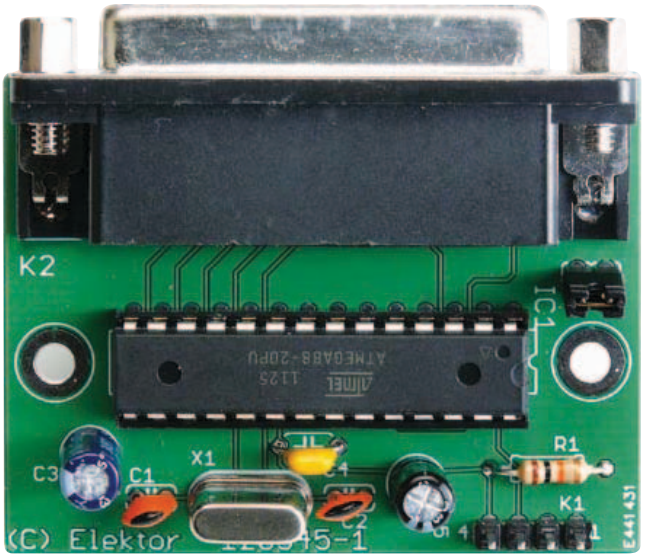
USB Control Board

USB-to-LPT bidirectional adapter

By Abraham Vreugdenhil (Netherlands)



There's still a lot of electronic hardware around that's designed to be operated from the legacy printer port (LPT) of a PC, but this port is virtually extinct on modern PCs. With the aid of an ATmega88 and associated firmware and software, a relatively fast link can be implemented between the PC and an LPT port via the USB port.

In the past the LPT (or Centronics) port was often used to drive a wide variety of stepper motors, lamps and relays, detect the positions of limit switches, and read other types of signals. It provided a fast and versatile interface. Modern PCs (both desktop and laptop) no longer have this port. It has been replaced by the USB port. For control or measurement tasks, you can use devices such as the well-known LabJack or the Velleman K8055D board. These are both nice devices, easy to use and easy to control from your own application software. However, they have one major shortcoming: speed. These devices work with USB 1.1, which means that every command or measurement takes 20 ms. This may not seem like much — until you want to do something that requires short latency, such as driving a stepper motor. Here you need three commands per step, so each step takes 60 ms. This limits the maximum speed to 16 steps per second, which is much too slow.

Options

There is another option: you take a USB/serial adapter cable and connect it to a microcontroller. The microcontroller then receives data from the PC at high speed (using USB 2.0) and uses this data to perform control and measurement tasks. A variety of USB/serial conversion ICs are commercially available. The best known ones come from FTDI, but suitable devices are also available from Silicon Labs (CP210x) and Prolific (PL2303). The latter device is often used in a wide variety of commercial USB/serial adapter cables, which are sold under various names. It is probably the most widely used converter.

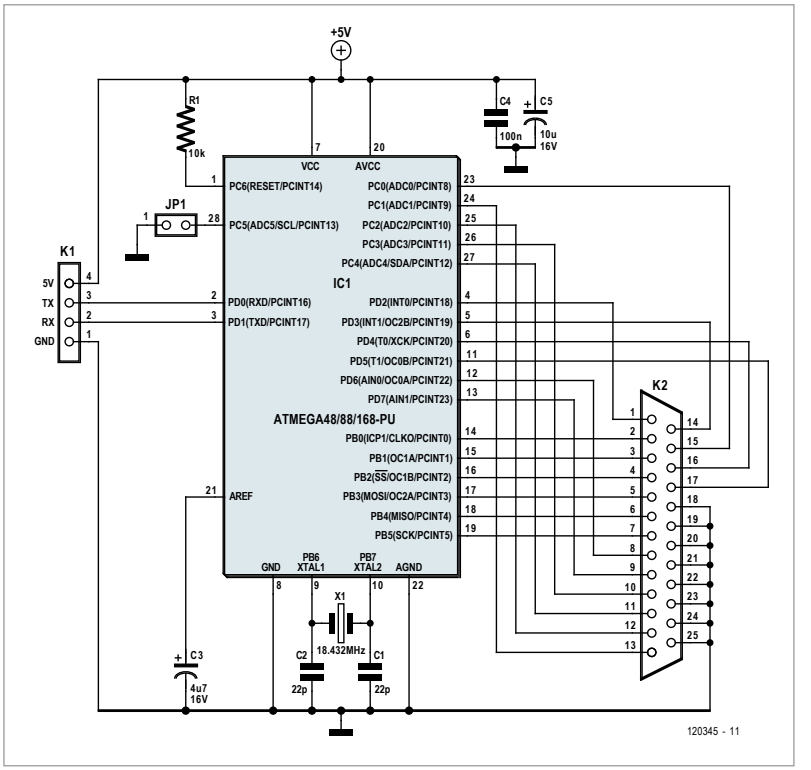
If you look at the differences between these converters, you discover a few surprises. When you use a test program to transmit a large number of individual bytes, the FTDI converter tops out at only 340 bytes per second, while the Prolific and Silicon Labs converters can handle 1000 bytes per second. This makes a considerable difference when you want to drive a stepper motor in real time. Unfortunately, the Prolific and Silicon Labs ICs are very difficult to obtain in small quantities for hobby use. However, complete USB/serial cables based on the PL2303 or the CP210x are available on eBay with prices in the range of 3 to 10 dollars. They output TTL-level signals, which can be connected directly to a microcontroller.

Hardware

For this project we chose a USB/serial adapter cable with a Prolific IC (PL2303) and connected it to an ATmega88. These two devices communicate with each other at a rate of 115,200 baud. This allows you to send something from the PC in just 1 ms. The author also selected a Conrad stepper motor board (SMC1500/800) to drive the stepper motor. In

addition to the 8-bit data bus, this board uses the Enable signal to put data on the board's output. To make our USB control board as general-purpose as possible, we decided to add a jumper to allow selection of either fast SMC mode or normal LPT mode.

The hardware is straightforward. The USB/serial converter is connected to the Rx and Tx pins of the ATmega88 (or ATmega88P). The clock rate is set by an 18.432 MHz crystal, which is a good choice for serial communication at 115,200 baud. The jumper for selecting the two modes is connected to microcontroller I/O pin PC5, and the other I/O pins are routed to the LPT connector. This gives us a fully wired LPT port, so the full range of functions of this port can be implemented.



Software

The software for the ATmega88(P) is written in Bascom AVR (Prog 1). When the program starts up, it check whether jumper JP1 is present.

If it is, the program jumps to SMC mode. When a character is received on the serial port, it is placed on the 8-bit output of the LPT port and the Enable/Strobe pin is briefly pulled low. If a limit switch is connected to the SMCxx board and its status changes, the result is sent back to the PC.

If jumper JP1 is not present, the program jumps to LPT mode. Here it looks for incoming data. The response varies, depending on the second character of the received data string. If it is '1' or '3', the value of the next character in the string is placed in register 1 (data bus 8-bit output) or register 3 (data bus 4-bit output) of the LPT port. If the second character is '2', register 2 (5-bit data bus input) is read and the resulting data is sent back to the PC via the serial interface and the USB/serial converter. The data can then be processed in the PC.

Control from the PC

The PC sees the USB control card as a normal COM port, but usually with a high number. Visual Basic 6.0 can only handle COM port numbers from 1 to 9, so you have to use Device Manager to change the COM port number to something lower than 10.

In Visual Basic, place a COM object on your form. You can then use it to send and receive serial data.

First you have to configure the COM port with the right settings:

```
MSComm1.CommPort = COM port number (see Device Manager)
MSComm1.Settings = "115200,N,8,1"
MSComm1.RThreshold = 1
MSComm1.PortOpen = True
```

In SMC mode you only have to send a data byte; the USB control card generates the Enable/Strobe signal automatically:

```
transmit = Chr(DataByte)
MSComm1.Output = transmit
```

In LPT mode you can access several registers corresponding to the registers of the legacy LPT port. They can be read or written individually:

```
transmit = "#1" & Data & Chr(13)        ' 8-bit data bus OUT
MSComm1.Output = transmit
```

```
temp = "?2" & Chr(13)          ' 5-bit data bus IN
MSComm1.Output = temp

transmit = "#3" & Data & Chr(13)       ' 4-bit data
bus OUT
MSComm1.Output = transmit
```

The USB control card sends a response to the second command above. It can be handled by the following bit of Visual Basic code:

```
Private Sub MSComm1_OnComm()  ' for incoming data
Dim indata As String
Dim Info As byte

If MSComm1.InBufferCount > 2 Then
MSComm1.InputLen = 0
indata = MSComm1.Input
indata1 = Mid(indata, 2, 1)
Info = Asc(indata1)
End If

End Sub
```

Things to watch out for

The PL2303 (built into a USB connector with attached cable) is readily available on eBay at prices in the 4 dollar range, including shipping costs. Make sure you are getting a four-pin cable. The 5 V pin is necessary for supplying power to the circuit.

When programming the ATmega88(P), make sure you get the fuse bit settings right (see the screen dump in the download file for this project [3]).

If you connect the USB control board to a different USB port, the computer may assign a different COM port number to the board. Check for this, or always use the same USB port.
The supply voltage for the microcontroller and the operating voltage for the LPT port are taken from the USB/serial converter. Only a limited amount of power is available with this arrangement, so you should restrict yourself to driving a few ICs (e.g. buffers) or LEDs. In other words, you can't drive a motor or other power device this way.

The free version of Bascom AVR, which you can use to compile the software and program the ATmega88, can be downloaded from the website [1].

Final remarks

The USB control card was developed for a hobbyist club, to allow a small lathe to be controlled in real time using Visual Basic and the SMC1500/800 driver board. The successful results can be seen in a YouTube video [2].
The source code for the ATmega88 firmware, a program for testing data transmission rates, and a program for bit bashing via the USB port are collectively available in a free download zip file on the Elektor website [3].

(120345)

Internet Links

[1] www.mcselec.com

[2] http://www.youtube.com/watch?v=maxNgXApeOQ&feature=channel

[3] www.elektor.com/120345

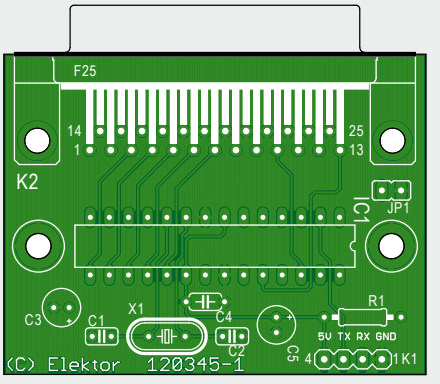
COMPONENT LIST

Resistors
R1 = 10kΩ

Capacitors
C1,C2 = 22pF
C3 = 4.7µF 16V radial
C4 = 100nF
C5 = 10µF 16V radial

Semiconductors
IC1 = ATmega88(P), DIL-28 case

Miscellaneous
X1 = 18.432MHz quartz crystal



K1 = 4-pin pinheader, pitch 2.5mm
K2 = DB25 socket, right angled pins, PCB mount
JP1 = 2-pin pinheader with jumper
PCB # 120345 (see [3])

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- Visconti2 - A Heterogeneous Multi-Core SoC for Image-Recognition — **Toshiba**

Integration
- Centip3De: A 64-Core, 3D Stacked, Near-Threshold System — **U. Michigan**
- FPGAs with 28Gbps Transceivers Built with Heterogeneous Stacked-Silicon Interconnects — **Xilinx**

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Marcus Weldon, CTO — Alcatel-Lucent

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- An IA-32 Processor with a Wide Voltage Operating Range in 32nm CMOS — **Intel**
- Taking Advantage of SuVolta DDC Technology to Lower Power in Chips — **Suvolta**

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- High Performance and Efficient Single-Chip Small Cell Base Station SoC — **Cavium**
- FSM: a Highly-Integrated Chipset Solution for the Small Cell Market — **Qualcomm**
- Medfield Smartphone - Intel's ATOM Z2460 Processor — **Intel**

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Pat Gelsinger, COO Infrastructure Products — EMC

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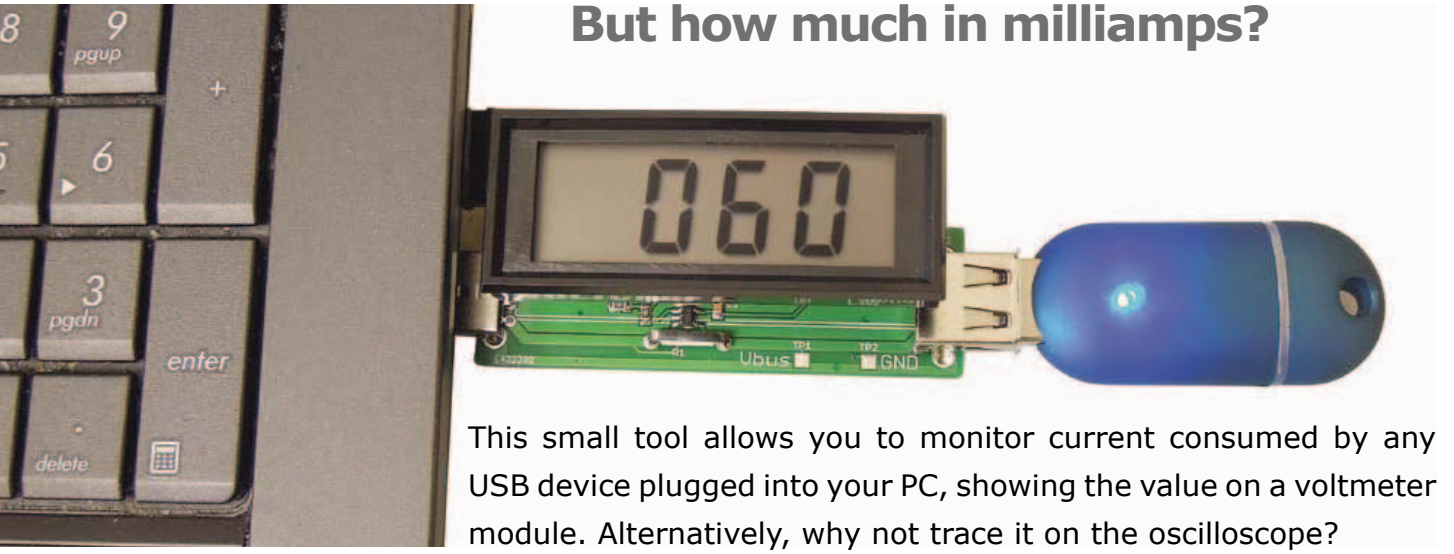
SSCS

A Symposium of the Technical Committee on Microprocessors and Microcomputers of the IEEE Computer Society and the Solid state Circuits Society in cooperation with the Association of Computing Machinery

I’ve Got the USB Power

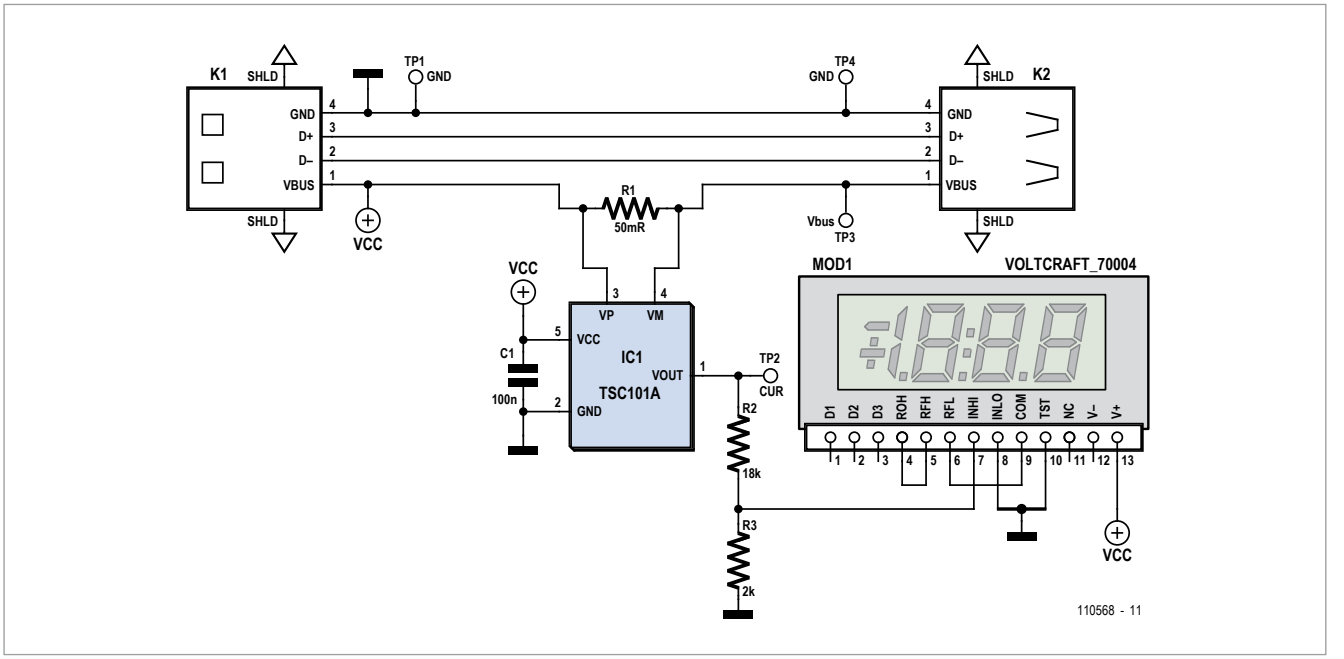
But how much in milliamps?

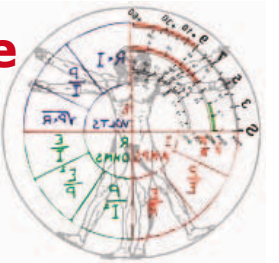


This small tool allows you to monitor current consumed by any USB device plugged into your PC, showing the value on a voltmeter module. Alternatively, why not trace it on the oscilloscope?

By Miroslav Batěk (Czech Republic)

More and more devices have USB connectivity and many engineers design devices which are powered by the USB port. However if you want to measure the current drawn from the USB port you’ll soon find that’s not a simple affair. You have a few choices though like disconnecting the circuit and connecting the ammeter in series with your device, or insert series resistors in the Vbus line and measure voltage across them.
Both solutions are quite simple but have disadvantages. Your ammeter or series resistor could introduce a considerable voltage drop, causing problems to the





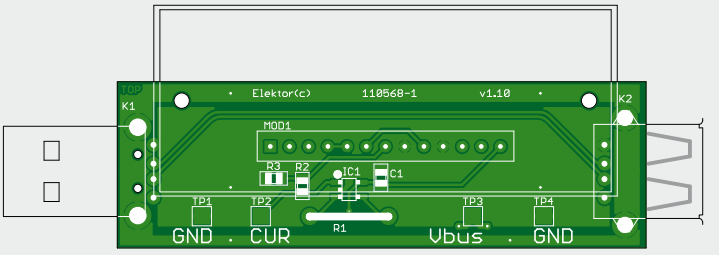
COMPONENT LIST

Resistors
R1 = 0.05Ω 1W 1%, Welwyn OAR1-R050FI (Farnell # 1200363)
R2 = 18kΩ (SMD 0805)
R3 = 2.00kΩ (SMD 0805)

Capacitors
C1 = 100nF X7R (SMD 0805)

Semiconductors
IC1 = TSC101A, TSOP-5 case

Miscellaneous
K1 = USB-A male connector (plug), PCB mount, through hole



K2 = USB-A female connector (socket), PCB mount, through hole
MOD1 = Voltcraft 70004 LCD panel meter module; Conrad-Uk.com # 121065-89

PCB # 110568-1 from www.elektorpcbservice.com

USB device. Moreover if you want to watch the current on your 'scope you have to use a differential probe, or two probes, because the current is not measured relative to ground. In case you insert the series resistor in the GND line, the voltage levels for the USB device and the USB host will be different as a result of the voltage drop.

The small tool presented here solves the problems by incorporating a high-side current sense circuit. There are a few methods of making a high-side current sense circuit, like a standard opamp or instrumentation amplifier with a few resistors. Here we went for an integrated circuit type TS101, which is basically a high-side current monitor [1]. This IC doesn't need any external components except the current sensing resistor.

The schematic of the USB Power Monitor shows two USB (type A) connectors. One is male (plug type) and the other, female (socket type), meaning our little circuit is connected in series with the USB device whose current consumption you are keen to know. Data lines D+, D– as well as GND are passed 'straight through'. Shunt resistor R1 sits in the Vbus line, turning the current through it into a corresponding voltage (drop). This gets amplified by IC1 and converted such that it exists relative to ground. C1 is the supply decoupling capacitor for IC1. Components R2, R3 are a voltage divider to match the TSC101A's output voltage to the input of the Voltcraft 70004 voltmeter module. Note that there are three versions of the TSC101, suffixed A, B and C, each having a different gain. The A version used here has 20 V/V. Each version also has a slightly different bandwidth. In practice, you'll notice that the resolution of the proposed meter is limited at low currents and that's why a separate current test point, TP2, is available. The millivolts measured on TP2 equate to milliamps of current consumed by the USB device. Sticklers for precision may measure the Vbus voltage on TP3.

At 500 mA theoretical maximum current from the PC the voltage drop of our circuit is just 25 mV which is negligible for most if not all USB devices.

The circuit is built on a double-sided PCB shown here and it's available ready made [2]. USB connectors K1, K2 and shunt resistor R1 are through-hole components. R1 is a 1% precision 4-wire connection shunt resistor type OAR1-R050FI specially designed for this purpose. The rest of the parts are surface mount. The TSC101A comes in a TSOP-5 package which is not too difficult to solder if you use a fine tipped soldering iron.

If you mount a 13-pin 0.1 inch pitch socket strip on the converter board, the Voltcraft module may be plugged on top of it.

The monitor should work first time and there are no adjusting points. Simply connect it between your PC or charger and your USB device, and read the current from the display.

Elektor Flash drive	32 mA (Idle)		58 mA (Copy files)
USB Hub	100 µA (standby)	45 mA (idle)	75 mA (Flash drive connected)
USB Flashlight	7 mA (Battery check)		55 mA (Charging)
HTC Legend	430 mA (initial charging current, from PC)		560 mA (initial charging current, from AC line charger)
Ipad 2	570 mA (charging current at 30% from PC with Asus Ai Charger tool)		

To close off, here are some results from measurements carried out by the author:

(110568)

Internet Links

[1] www.st.com/internet/com/TECHNICAL_RESOURCES/TECHNICAL_LITERATURE/DATASHEET/CD00153725.pdf

[2] www.elektor.com/110568

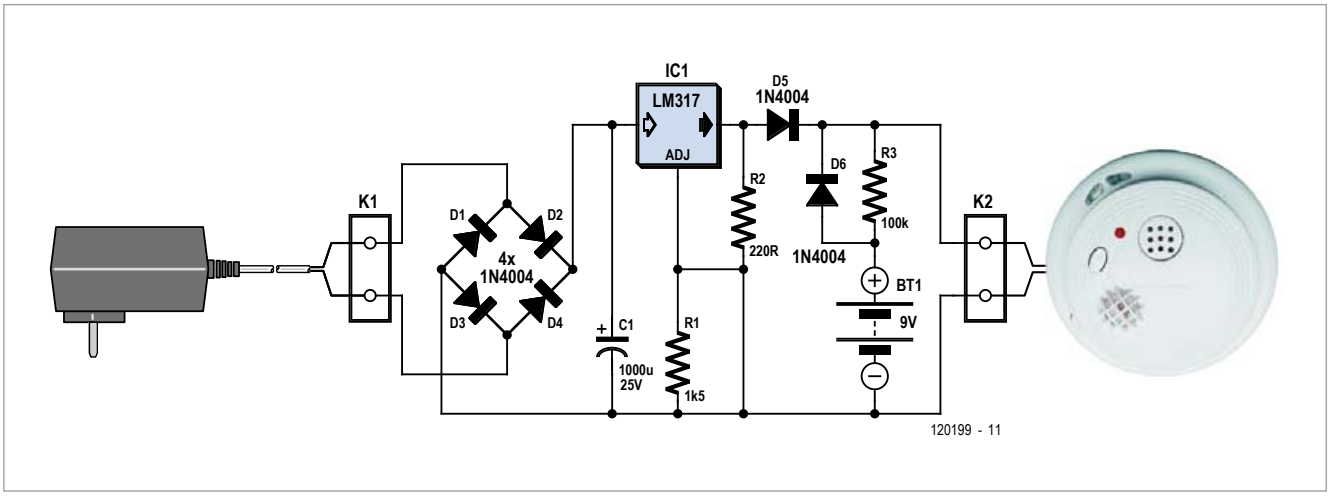
Smoke Alarm Power Supply

Simple but effective

By Jacob Gestman Geradts (France)

Smoke alarms are extremely useful devices, but they suffer from one significant disadvantage, which is that they're battery powered. This can't really be avoided, since a smoke alarm should still function when the AC grid cuts out. Unfortunately, it still runs off the battery even when the AC line supply is present, with the result that for some types of smoke alarm you need to replace the batteries at an alarming rate. This circuit lets the smoke alarm run off the AC grid normally, and only switches to the battery when it is really necessary, in other words, when there is a power cut.

The circuit itself is fairly simple, but as is often the case, the circuit's strengths are in its simplicity. In this instance an AC power adapter is used to power the smoke alarm. The circuit has been designed such that just about any type of adapter can be used. The polarity of the power plug isn't important and it doesn't matter if the power adapter outputs an alternating or direct voltage, thanks to the presence of a bridge rectifier (D1 to D4). The only thing to watch out for is that the output voltage of the adapter should be 9 V or more. After the bridge rectifier and smoothing capacitor is voltage regulator IC1 (an LM317), which keeps the voltage constant. The output voltage of the IC can be varied by adjusting the value of resistor R1. D5 and D6 make up an 'electronic switch' that automatically selects the highest supply voltage for the smoke alarm, so either the AC line supply or the battery supply. R1 has to be chosen such that there is a reverse voltage of about half a volt across diode D6 (with a full 9 V battery) when the smoke alarm is switched on. This prevents the battery from discharging, unless



the AC power fails. To mitigate the self-discharge of the 9 V battery, resistor R3 has been added, which delivers a minute current that can somewhat compensate for the self-discharge of the battery. This will keep the battery in a charged state for as long as possible. (Note from the editors: this method is usually not recommended with normal (i.e. non-rechargeable) batteries, as it can sometimes result in battery leakage. However, due to the very high value of R3 it's very unlikely to happen. For those of you who want to be absolutely safe, you can just leave out R3.

The diodes aren't critical and have been selected from the 1N4000 series, in this case with a larger than required 400 V rating. The electrolytic capacitor may also be larger, both in value and in voltage. AC power adapters often output a somewhat higher voltage than is stated, which should be taken into account when choosing the electrolytic capacitor.

The condition of the battery can easily be tested (once a week) by switching off the AC adapter and running the self-test of the smoke alarm whilst it is being powered only by the battery.

(120199)

COMPONENT LIST

Resistors

R1 = 1.5kΩ
R2 = 220Ω
R3 = 100kΩ

Capacitors

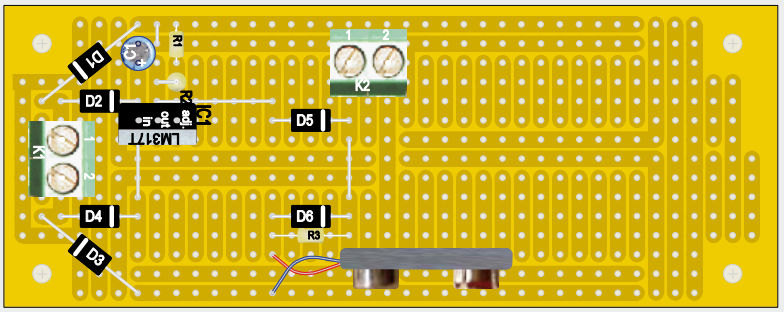
C1 = 1000µF 25V

Semiconductors

D1–D6 = 1N400x
IC1 = LM317

Miscellaneous

K1,K2 = 2-way PCB terminal block, pitch 5mm
'Elex' prototyping board



Equipment 'ON' Counter for 68 Years Max.

By Vladimir Mitrovic (Croatia)

Have you ever wondered how long a piece of electric equipment has been switched on and consuming AC power? The simple circuitry shown here counts the seconds of the ON time periods and keeps the total accumulated time in the EEPROM inside the ATtiny13 microcontroller. Just read the EEPROM with the help of an appropriate ISP programmer or the dedicated readout circuit and you will know how "old" the equipment really is!

The watchdog

It is supposed that the equipment is AC-outlet powered because the microcontroller counts cycles of the AC grid voltage. The input terminals should be connected after the equipment Power (On/Off) switch (or relay) or to the secondary winding of a power transformer. Any voltage upwards of about 4 VAC, 50 Hz or 60 Hz, will be appropriate if resistor R1 is chosen correctly.

Returning to the schematic of the pulse counter, zener diode D2 limits the AC voltage to 4-5 V_{pp} square-wave(ish) pulses which are used not just for the system timing, but also to power the circuit via D1/C1. Soon after the (AC) power is switched on, the voltage

Stop! Calculate R1 first

The microcontroller needs less than 1 mA to function properly, and at least 1 mA should flow through D2 for it to do its stabilizing act. Therefore, at least 2 mA should flow through R1. Its maximum permissible value can be calculated with the following formula:

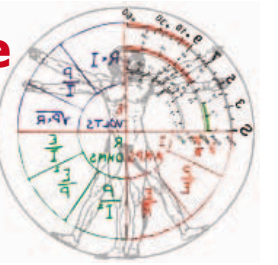
$$R1 = \frac{V_{AC} \times 1.4 - 3.5}{2} [k\Omega]$$

The 3.5 constant in the formula comes from the estimated voltage across D2; at such low currents, you should expect a slightly lower voltage across a zener diode than rated. Some experimentally proven values for R1 are given in the table below. You can always use a smaller value for R1, at the cost of higher power consumption. With values for R1 as given in the table, the total power consumption of the circuit is 10-50 mW depending on the input voltage.

If you experiment with values for R1, be sure that the DC voltage across C1 is not lower than 3 V, and not exceeding 5 V.

R1 as a function of input voltage

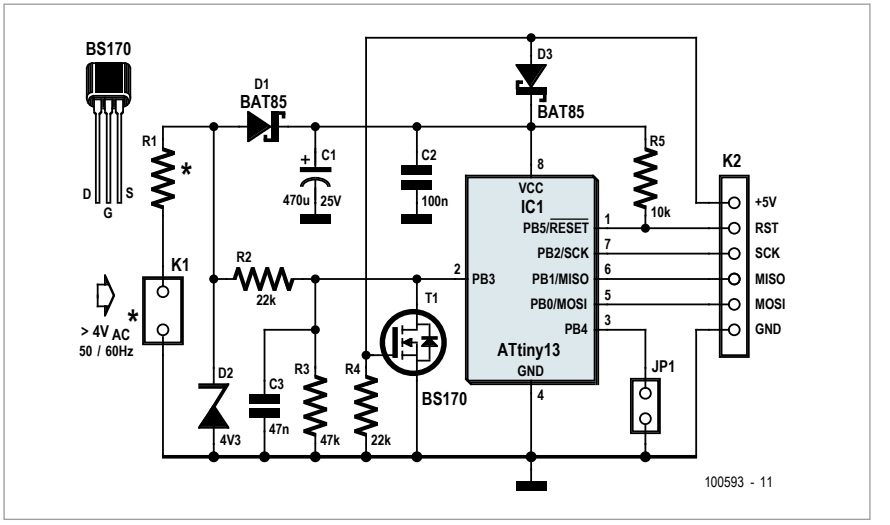
Input voltage	R1
4–5 V AC	1 kΩ
5–6 V AC	1.5 kΩ
6–8 V AC	2.2 kΩ
8–10 V AC	3.3 kΩ
10–12 V AC	4.7 kΩ
12–15 V AC	6.8 kΩ
15–18 V AC	8.2 kΩ
18–22 V AC	10 kΩ

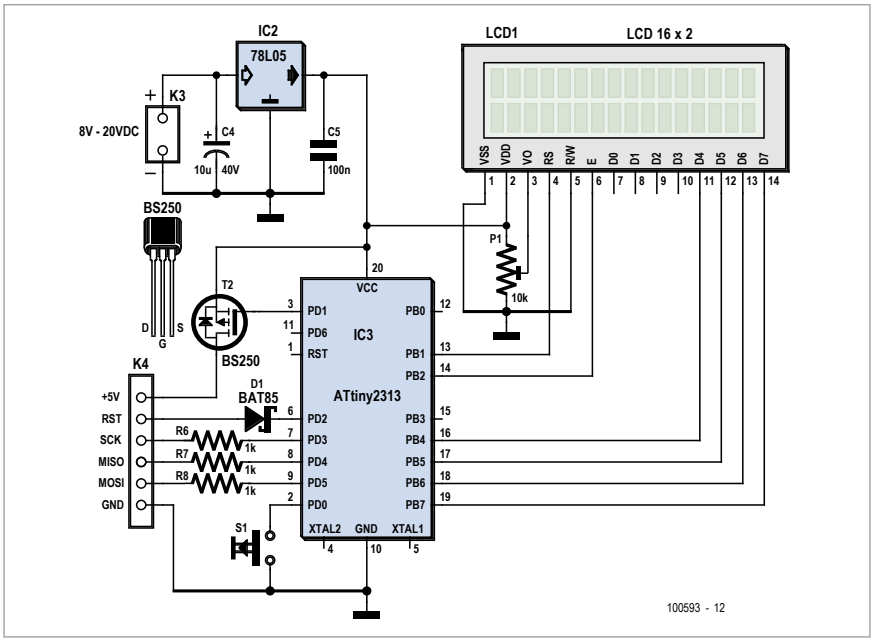


across C1 rises to a value at which the microcontroller starts to execute the program inside its memory. Initially the program reads the previously accumulated time from the internal EEPROM and starts to count pulses at the ATtiny13's PB3 input. Every level change at this input is recognized, so there will be 100 or 120 transitions per second depending on the grid frequency (50 Hz or 60 Hz). As soon as a single transition is counted, the microcontroller enters Idle mode. This way, the average consumption of the microcontroller is kept under 0.5 mA.

Simultaneously, Timer0 counts clock pulses. Once started, it will count to the top value, overflow and cause an interrupt. This would happen after some 50 ms in the absence of input pulses. However, the input pulses are not just being counted. They also repeatedly reset the Timer0, preventing it from reaching the top value. Therefore, as long as the input pulses are present, Timer0 will not overflow and the associated interrupt will not execute.

When the input voltage is switched off, the voltage across C1 starts to decrease. The capacitance of C1 is sufficient to keep the microcontroller working for at least one second. However, if the input voltage is switched off, the pulses at PB3 disappear abruptly. Without being reset, Timer0 will cause an interrupt some 50 ms after the last transition at the PB3 input has occurred. The interrupt wakes up the microcontroller from Idle mode and causes the associated interrupt subroutine to be executed. This effectively writes the second counter back to the EEPROM. This way, the counter state gets preserved when the supply voltage drops under the safe level. The EEPROM writing procedure lasts takes about 10 ms and then the microcontroller enters Idle mode again and waits for one of the following events to happen:





- If the power is switched on again within a short period of time, i.e. before the voltage across C1 drops significantly and still is within the safe operating area, the microcontroller will wake up and start to count input pulses as soon as they occur.

- If the voltage across C1 drops below 2.7 V, which happens a few seconds after switch-off, the ATtiny13's on-chip Brown-out Detection (BOD) circuit will reset the microcontroller.

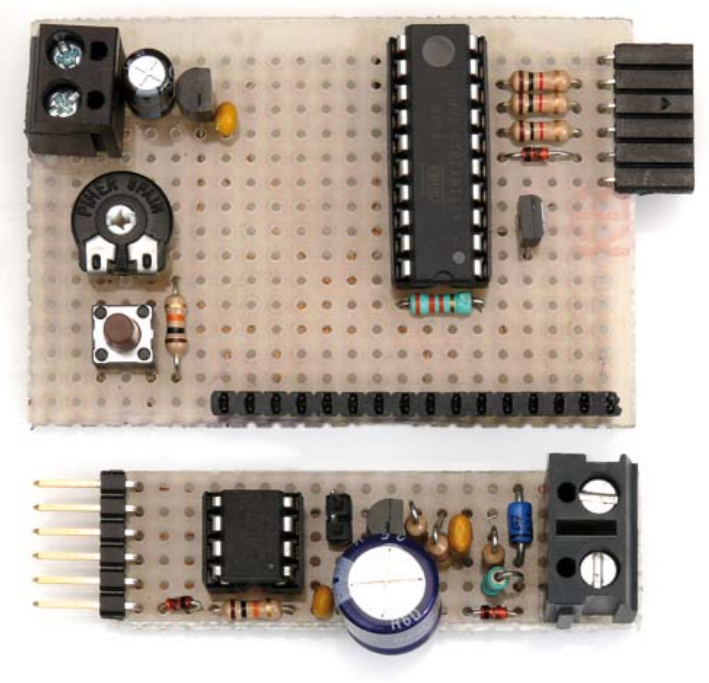
The BOD circuit should be activated during the programming session, and the BOD trigger level should be set at 2.7 V (BODLEVEL fuse 1 = 0, BODLEVEL fuse 0 = 1). This will ensure that the microcontroller stops running before the supply voltage drops under the safe level, when the RAM contents would be corrupted as well. When activated, the BOD circuit constantly monitors the V_{CC}

level during operation by comparing it to the fixed trigger level. If the supply voltage drops below 2.7 V, BOD will reset the microcontroller and keep it in this state as long as the supply voltage does not reach the safe value again. Waking from reset, the microcontroller will read the accumulated time from the EEPROM, and continue to count from that value.

Back at the input of the circuit, the value of R1 should be chosen according to the input voltage, as its purpose is to limit the input current — see the text box on R1.

Readout circuit

For sure you'll want to read the counter value from time to time. In order to keep the circuit as simple as possible, no display was provided initially, and readings were taken using a low-voltage in-system programmer (ISP). Eventually a dedicated reading tool was developed and its schematic is shown here. The heart of this circuit is an ATtiny2313 microcontroller that produces all control signals required to read the contents of the Watchdog's EEPROM, converts them to a readable form and displays them on a 2x16 characters alphanumeric LC display. If you use the proposed readout circuit, you can connect it to the Watchdog circuit regardless whether the equipment in which the Watchdog is embedded is powered or not. Be very careful if the Watchdog is connected directly to the AC line voltage! If the Watchdog is active (i.e. if the equipment is switched on), the readout circuit should be switched on before it is connected to the Watchdog. This ensures well defined logical levels on all of the connecting lines, which will not disrupt the Watchdog operation. Failing to switch on the readout before connection to the working Watchdog might reset the Watchdog and cause a loss of time accumulated after the last switch-on. If the Watchdog is not active (i.e. if the equipment is switched off) it is irrelevant if the readout is switched on or off at the moment of connection.



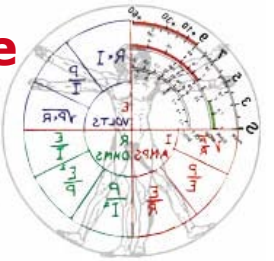
To read and display the measured time, just press the S1 pushbutton on the readout board for a short time. The readout will first activate the +5 V voltage, with the following consequences on the Watchdog:

- If the Watchdog was inactive, the +5 V signal from the readout will power-up the ATtiny13 microcontroller and simultaneously switch transistor T1 in the Watchdog on, which in turn disables the program in ATtiny13 from running.
- If the Watchdog was already powered up and active, the +5 V signal from the readout opens T1 only. This will short-circuit the PB3 input to ground and prevent pulses from D2 from reaching PB3, forcing the ATtiny13 to write the counter to the EEPROM.

In other words, whatever state the Watchdog was in previously, the +5 V signal will ensure that the ATtiny13 microcontroller is switched on and that the data in its EEPROM are up to date. Shortly after switching the +5 V signal on, the readout starts to communicate with the Watchdog and read the contents of its EEPROM. As soon as the reading is done, the readout switches the +5 V signal off, recalculates the data and displays the time in the "ddddd:hh:mm:ss" form (days, hours, minutes and seconds). However, bear in mind that the overall accuracy depends on the power grid frequency stability and long time intervals will not be accurate to a second!

Besides reading, the readout can also erase the Watchdog's EEPROM if necessary. The erasing procedure is similar to the reading procedure, except for one detail: you should press S1 and keep it depressed for at least 3 seconds in order to erase the counter in the ATtiny13 microcontroller.

If you use an ordinary ISP programmer to read the Watchdog EEPROM, be sure to switch off the equipment in which the Watchdog is embedded before the programmer is connected to the Watchdog! The ISP programmer



should provide a 5 V supply for the Watchdog. The counter is written in the EEPROM starting from the address 0, in the form of a 4B variable (type Long), LSB first, and represents the ON time measured in seconds. It will be necessary to do some calculations to decipher it (the readout does it for you!). The counter can be erased with an ISP programmer as well — if you erase the EEPROM memory. Note: erasing the EEPROM memory will write binary 1s in the whole memory. This will set –1 instead of 0 as the starting counter value, but such inaccuracy may be totally neglected.

Programs

Two Bascom-AVR programs were written for the project:

EE_T_on.bas is a program for the ATtiny13 micro in the Watchdog. Be sure to set the CKSEL fuses for: calibrated internal RC Oscillator running at 9.6 MHz, and to set BODLEVEL fuses as explained before. Erase the EEPROM during the programming session to reset the counter before first usage.

EE_T_on_reading_tool.bas is a program for the microcontroller in the readout circuit. Set the CKSEL fuses for: calibrated internal RC Oscillator running at 8 MHz.

Now get on the Internet! Both programs are in archive file 100593-11.zip for free downloading from [1], which is also the place for ordering ready-programmed micros for the project. Burn-a-Chip@Home fans: a free demo version of Bascom-AVR is available from [2], and Elektor also has books in its portfolio on this wonderful little compiler [3].

(100593)

Stop Again! Electrical safety!

Should the circuit be connected directly to an AC outlet, consider replacing R1 with a series connection of:

- a 2.2-kΩ / 1-watt resistor and a 100 nF capacitor (for 115 VAC/60 Hz grids) or
- a 4.7-kΩ / 1-watt resistor and a 68 nF capacitor (for 230 VAC / 50 Hz grids).

In both cases, the capacitor should be rated for direct connection to the AC line voltage (for example, WIMA MKP-X2, WIMA MP3-X2, Epcos MKP X2 or similar).

Caution.

The entire circuit is at Live AC potential and potentially hazardous to touch. Never work on the circuit while it is connected to the AC power outlet. The circuit must be enclosed in an approved enclosure preventing any part of it from being touched. When in doubt, ask for the assistance of a qualified electrical engineer.

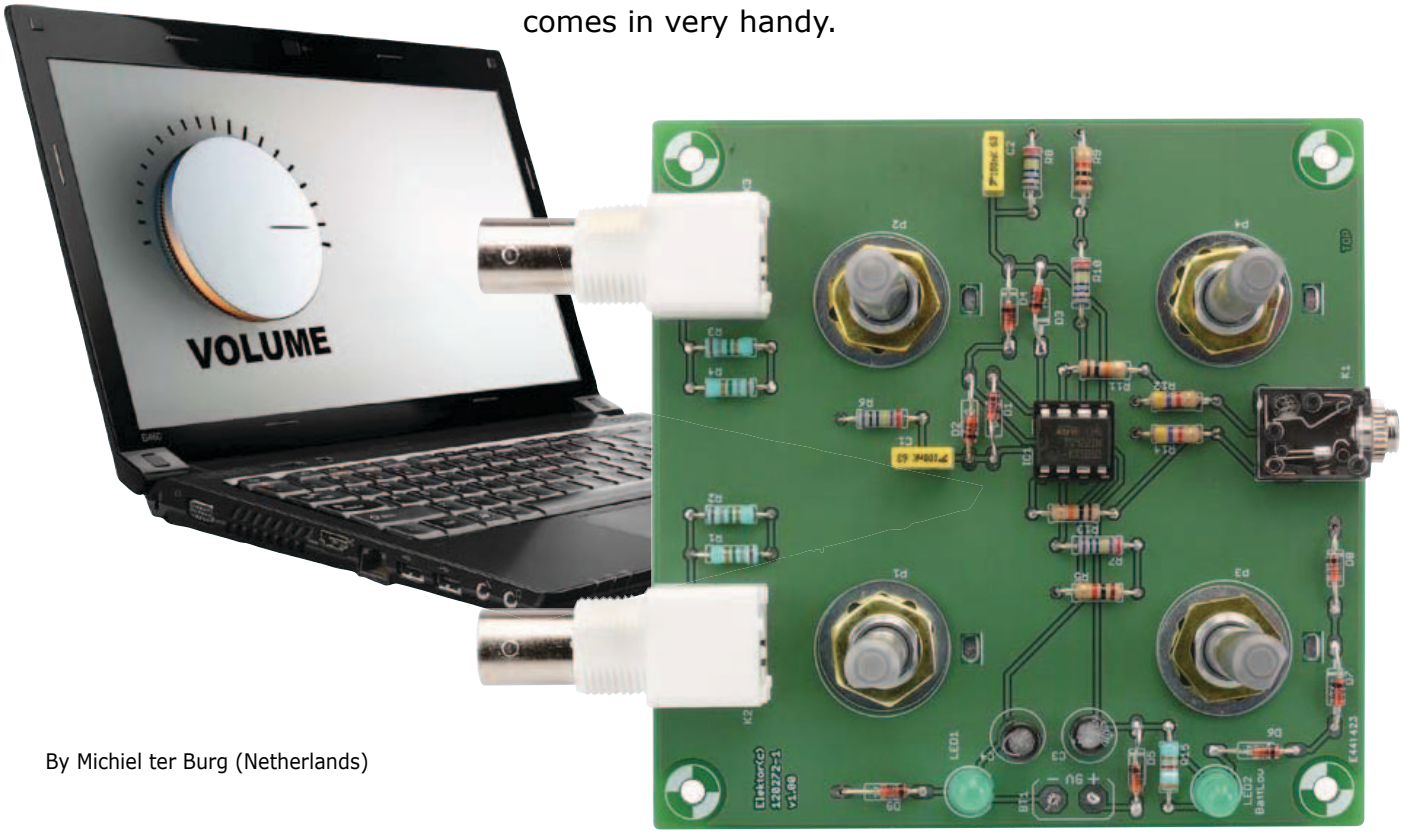
Internet Links

1. www.elektor.com/100593
2. www.mcselec.com
3. www.elektor.com/products/books.255.lynkx

Universal Measurement Amplifier/Attenuator

For laptop or PC

A computer is very suitable for making (audio) measurements thanks to the sound card that is usually built in. Unfortunately, the audio input on laptops is usually too sensitive to measure somewhat larger AC voltages. A small amplifier/attenuator circuit then comes in very handy.



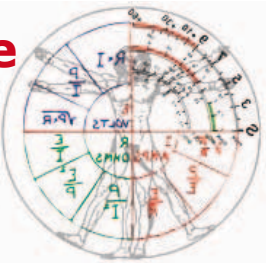
By Michiel ter Burg (Netherlands)

If you build or repair audio equipment yourself, you don't always need an oscilloscope. Any direct current or voltage can be measured with a multimeter. You can do a lot more if you happen to have a better model that can also measure (small) AC voltages.

For more advanced measurements such as the frequency response or the distortion it is very handy to use the sound card in a computer combined with some software. A laptop or notebook can also function without an AC outlet, which means you'll avoid earth loops and hum during measurements. However, a laptop often has just an oversensitive (microphone) input, so that you need to make a range of voltage dividers for your measurements.

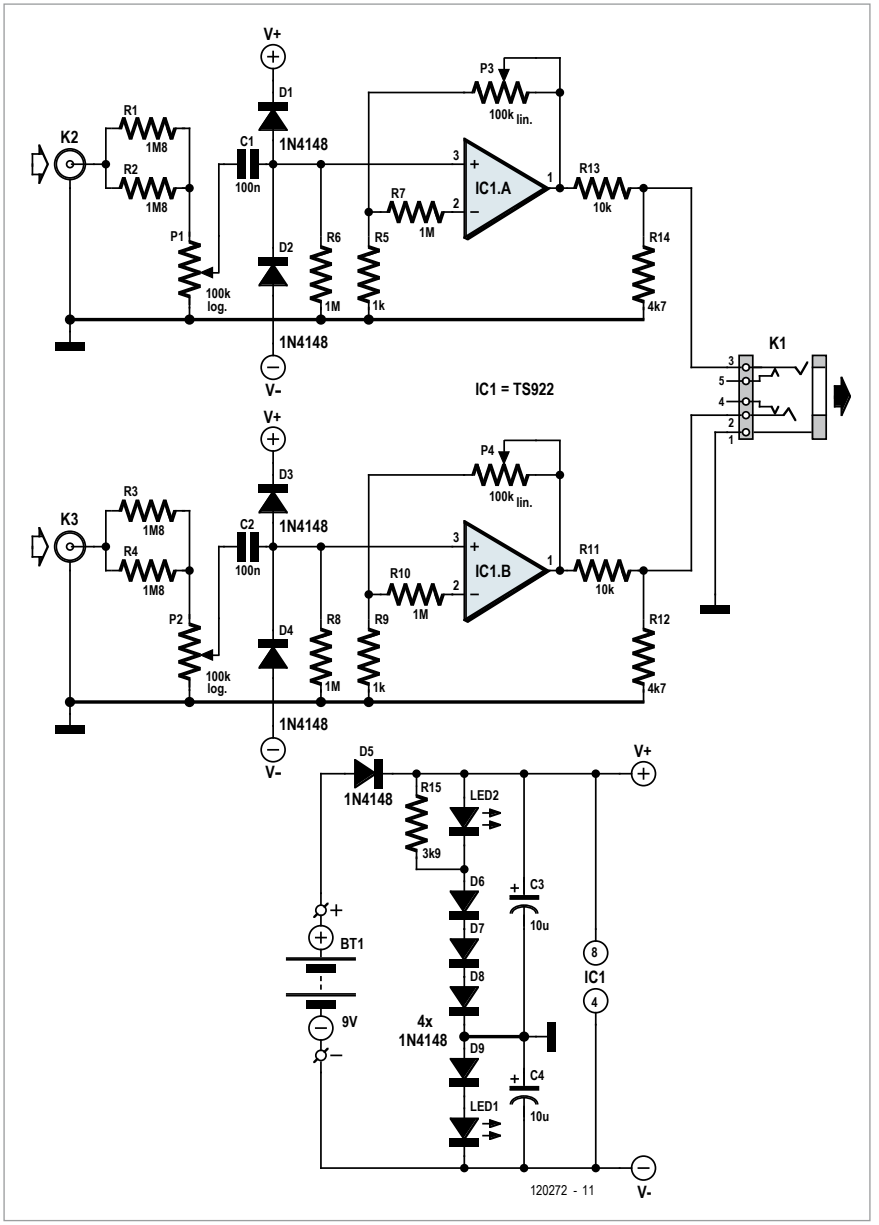
This measurement amplifier has been designed especially for these situations. It has an adjustable input attenuation and an input impedance of 1 MΩ, so that standard scope probes with built-in attenuators can be used for even larger AC voltages.

The input signal is first attenuated and then amplified to get the required



transfer function. The input is DC coupled. The input signal is attenuated by at least a factor of 10; with the help of logarithmic potentiometers P1 and P2 the signal can be attenuated further. C1 and C2 provide DC decoupling after the input attenuators to prevent irritatingly large time-constants caused by high-impedance probes. This is followed by an amplification stage (built round IC1.A and IC1.B). Potentiometers P3 and P4 are used to vary the gain of this stage between 1x en 100x. Bear in mind what the value of the GBP (Gain Bandwidth Product) is for the opamp used. The author first tried an LM258 and a TS912, which should have a GBP of about 1 MHz (typical). In practice a bandwidth of 15 kHz was measured with the gain set to 30x and a 9 V supply voltage. This means that the GBP was 450 kHz, although that can be compensated for by the measurement software. The best opamp is a TS922 (GBP of 4 MHz), which managed the complete audio bandwidth at a gain of 100x. This is also the type that was used in the prototype built at Elektor Labs.

The power is supplied by a 9 V battery that has its voltage split into a negative and positive component with a Ground in between. LED2 functions as a Low-Battery LED (it has to be a type that lights up at 2.5 V); the addition of R15 makes it light up when the battery voltage is above 7 V, which is high time to replace or recharge the battery!



a computer sound card running measurement software makes a useful tool

The inputs of the opamps are protected by diodes against very high input voltages or electrostatic discharges, since you can never be sure what voltages you'll find in (switched off) audio circuits, especially when valves are used!

A printed circuit board has been designed for this project, which has room for all components, including the connectors and potentiometers. The layout can be downloaded freely from the usual place [1]. Standard through-hole components have been used throughout, which makes the construction very easy. The potentiometers are put through the solder side of the board and screwed into place, after which the solder tags are bent onto the pads on the board and subsequently soldered.

COMPONENT LIST

Resistors

R1–R4 = 1.8MΩ
R5,R9 = 1kΩ
R6,R7,R8,R10 = 1MΩ
R11,R13 = 10kΩ
R12,R14 = 4.7kΩ
R15 = 3.9kΩ
P1,P2 = 100kΩ potentiometer, logarithmic law
P3,P4 = 100kΩ potentiometer, linear law

Capacitors

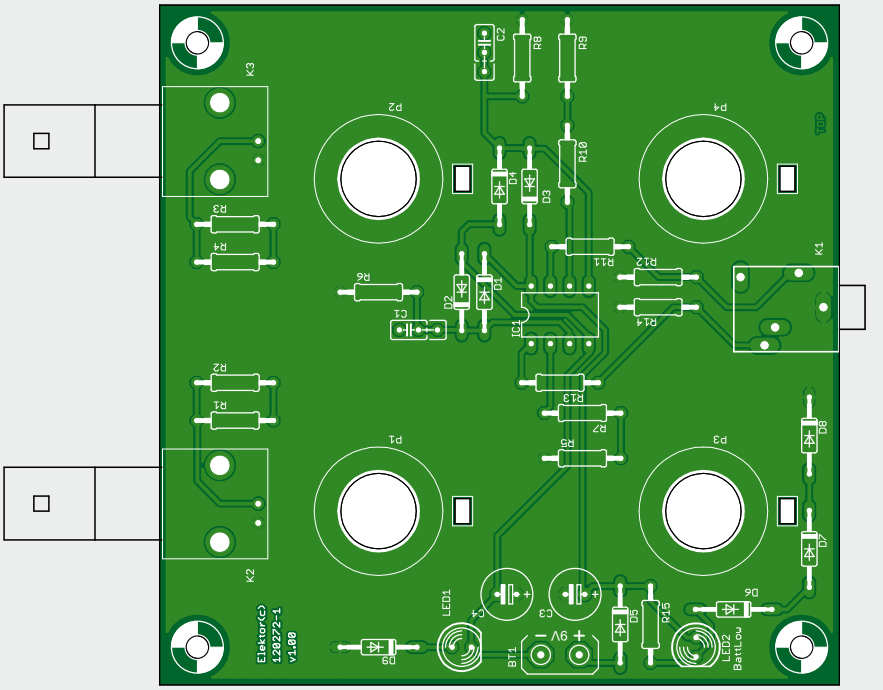
C1,C2 = 100nF MKT, pitch 5mm
C3,C4 = 10µF 16V, 6mm diam., pitch 2.5mm

Semiconductors

D1–D9 = BAT48 (DO-35 case)
IC1 = TS922IN (dual opamp, DIP-8 case)
LED1,LED2 = LED, green, 5mm

Miscellaneous

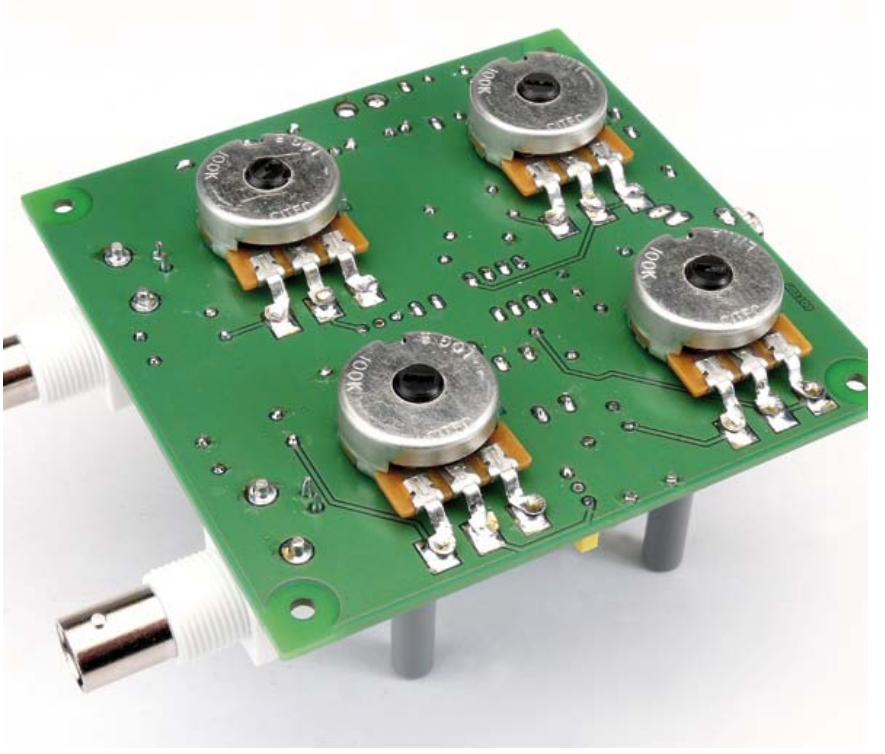
K1 = 3.5mm stereo socket (e.g. Lumberg 1503-09)
K2,K3 = BNC connector, right angled pins, PCB mount (e.g. TE connectivity 1-1337543-0)
BT1 = 9V battery clip
PCB # 120272-1 (www.elektor.com/120272)



Since logarithmic input potentiometers can deviate by as much as ±20% it is best to calibrate them after they have been mounted in the box. The calibration should be carried out in steps of 10 dB (= a factor of 3.1623) using the measurement software. First mark out the calibration points on a piece of paper placed over the potentiometer, then scan this into the computer and use a drawing package to create a professionally looking scale.

During the calibration P3 and P4 should be set to a gain of 1x, which is normally only used with very small input signals that still need some amplification.

(120272)



Internet Link

[1] www.elektor.com/120272

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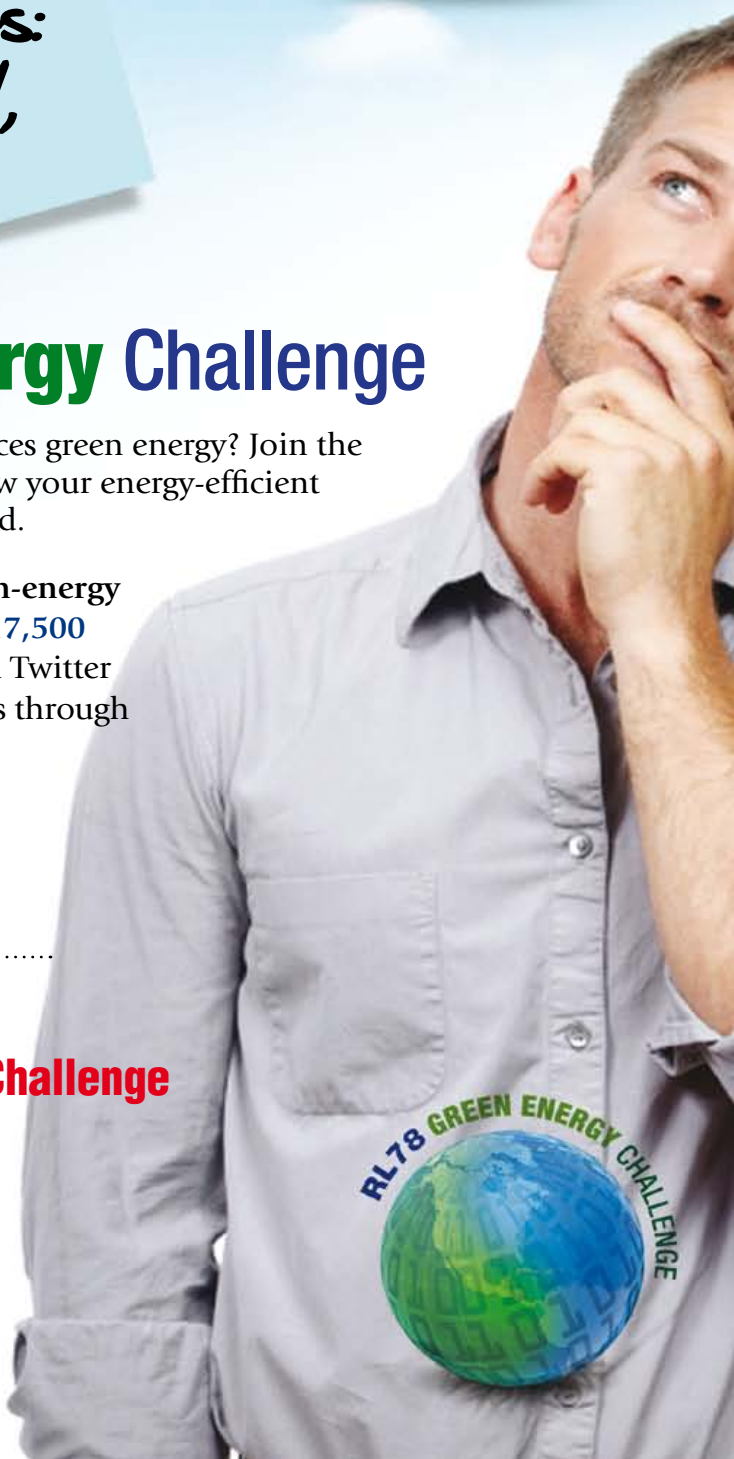


Loudspeaker Resonant Frequency Meter

By Jac Hettema (Netherlands)

This system is designed to facilitate the determination of loudspeaker resonant frequencies. What components do you need for this? A good variable oscillator, an amplifier, and meters for reading the frequency and the voltage. The oscillator here is based on the function generator described in the April 1995 issue of *Elektor Electronics*. Only the sine-wave function is used here. The main advantage of this oscillator is that it can be adjusted over a wide frequency range with a single potentiometer. If you use a ten-turn potentiometer for this, you can set the frequency very precisely. The sine-wave signal also has a very stable amplitude and low distortion.

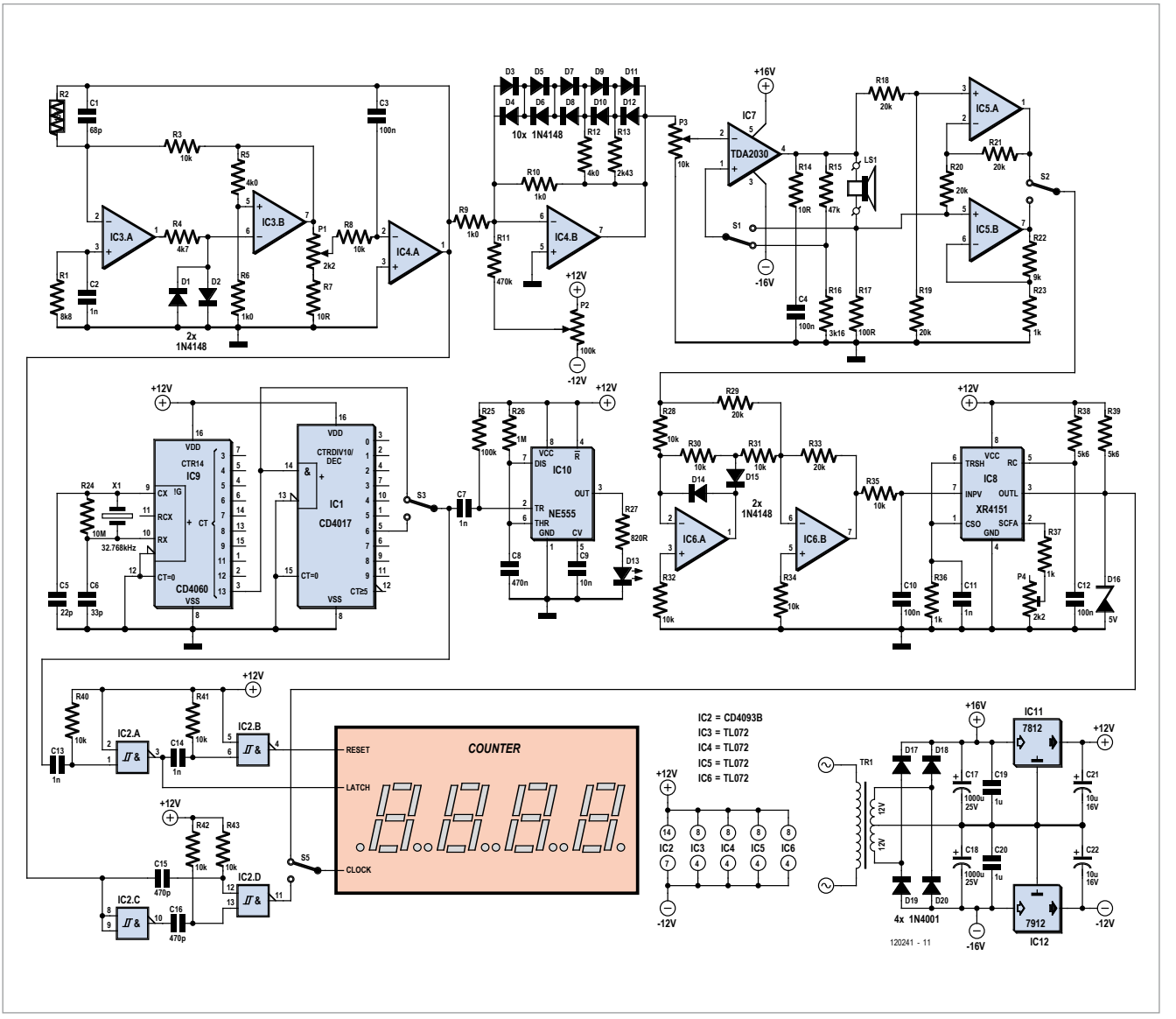
The sine-wave signal generated by IC3 and IC4 is fed to the output amplifier (TDA2030) via potentiometer P3. Switch S1 allows the amplifier to be operated in two different modes: constant voltage and constant current. The latter option is helpful for determining the position of the peak amplitude at the resonant frequency, since this can best be seen with constant-current drive.

The loudspeaker voltage is measured by IC5a, which is wired as a differential amplifier with a gain of 1. IC5b converts the loudspeaker current into a voltage. Switch S2 selects one of these two outputs, and the selected measurement signal is fed to an active rectifier built around IC6a and IC6b. The rectifier output is fed to IC8, a voltage to frequency converter (type XR4151). Its output signal is routed via S5 to a frequency counter. Switch S5 selects either the frequency or the loudspeaker voltage or current.

The author used a type 74C925 IC as the frequency counter for frequency measurement, along with a time base and the necessary peripheral circuitry.

Although this IC is no longer available, the associated devices (IC1, IC2, IC9 and IC10) have been included here for completeness. The time base uses a crystal oscillator with a watch crystal to generate a 10-second counting window, and the counter allows the frequency to measured with a resolution of 0.1 Hz. The above-mentioned ICs can be omitted if you use a frequency counter module.

Power is supplied by a mains



transformer rated at 2 × 12 V, followed by a pair of voltage regulators. The output amplifier is powered from the unregulated supply voltage.

When making measurements, take care that the measuring voltage does not become too high. If the loudspeaker has a nominal impedance of 4 Ω, the impedance at the resonant frequency can easily be a factor of 10 greater. If you measure with constant current, this will cause the voltage on the loudspeaker at the resonant frequency to be 10 times the normal value. The loudspeaker voltage must always be well below the clipping voltage of the output amplifier. A clipping indicator could be a useful addition.

Before starting to make a measurement, ensure that the level control P3 is set to zero. Then increase the level until the loudspeaker generates a barely audible tone. Set switch S2 to voltage measurement mode and adjust the frequency with P1 to maximize the measured voltage. The measured current at this point should not deviate from the initial value. If it does, repeat the measurement with a lower setting of P3.

At the maximum loudspeaker voltage, read the frequency from the counter. This is the resonant frequency of the loudspeaker.

(120241)

Shoo Heron!

Outsmart a clever bird

More and more pond owners suffer from herons that help themselves to the fish in the pond. Although several devices are for sale in the trade to scare away herons, they are often not completely effective. The 'perfect' heron scarer doesn't exist, unfortunately. These birds have a justified reputation for their intelligence! Even electric wire fencing doesn't work, as the heron just steps over it. However, the system described here was found to work very well.

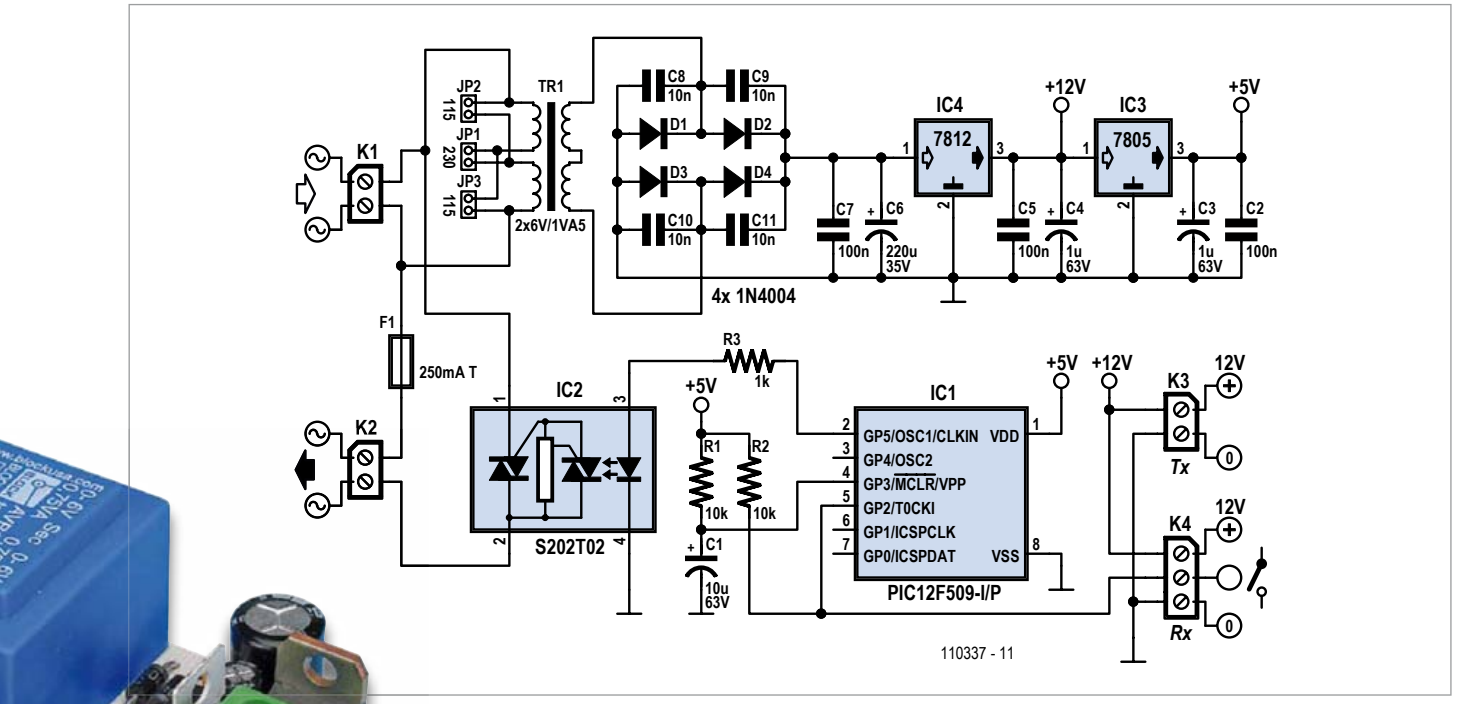
By Will J.B. Hus (Netherlands)

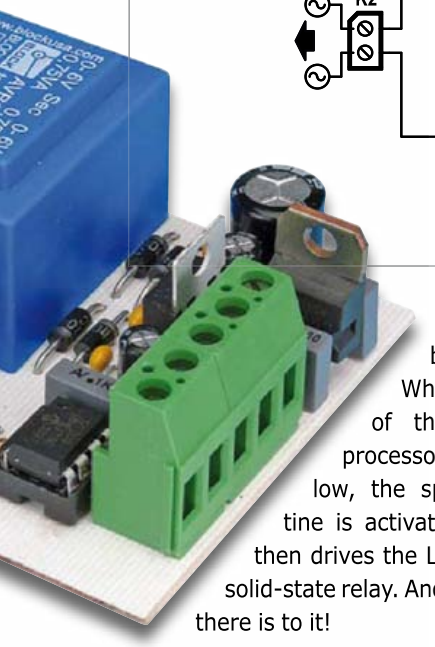
If you have ever observed herons, you will have noticed that they always approach a pond from some distance. The idea is to protect the pond with an invisible barrier that is connected to a powerful water spray. Herons dislike being sprayed and will leave. Furthermore, they can't easily determine what causes the spray to start.

The protection consists of an infrared transmitter and receiver that are mounted close to each other. The beam is made to go round the object to be protected (the pond) by means of a series of mirrors. Should the infrared beam be broken, it causes an electromagnetic valve to open, which causes the spray of water to start. The heron definitely doesn't like this! For the mirrors you could use rear-view mirrors, for example, mounted on a small post. The best height is about 20 to 30 cm (8 to 12 inches).

The infrared transmitter and receiver used in this project came as a set and are widely available (e.g. from Conrad). The receiver has a 'normally open' (NO) contact. The rest is taken care of by a simple microprocessor that drives a solid-state relay (IC2). The relay of the receiver module is closed when the

This setup should also fit other types of surveillance systems





beam is broken.

When pin 2 of the microprocessor goes low, the spray routine is activated. Pin 5 then drives the LED of the solid-state relay. And that's all there is to it!

The extremely simple program turns on the sprayer three times for five seconds. To avoid that the sprayer is turned on continuously, when the beam is permanently broken for example, the routine has a loop that is only exited when the beam is restored again. As usual, the program for the microprocessor can be downloaded from the Elektor website [1].

A PCB has been designed for this circuit, which contains the power transformer, voltage regulators, microcontroller and solid-state relay. The infrared transmitter and receiver and the electromagnetic valve are easy to connect to the board, using screw terminals.

To set up the system properly requires a high level of precision. The transmitter, receiver and the mirrors have to be

COMPONENT LIST

Resistors

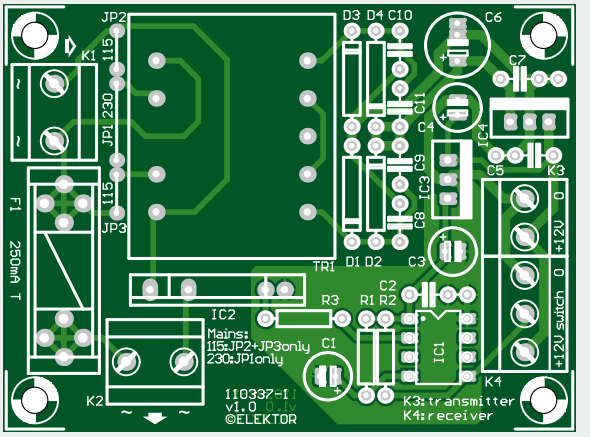
R1,R2 = 10kΩ
R3 = 1kΩ

Capacitors

C1 = 10µF 63V radial, pitch 2mm
C2,C5,C7 = 100nF, pitch 7.5mm
C3,C4 = 1µF 63V radal, pitch 2mm
C6 = 220µF 35V radial, pitch 3.5 or 5mm
C8–C11 = 10nF, pitch 5mm

Semiconductors

D1–D4 = 1N4004
IC1 = PIC12F509-I/P, programmed



IC2 = S202T02F
IC3 = 7805
IC4 = 7812

Miscellaneous

F1 = fuse, 250mAT, w. PCB mount holder and cap
K1,K2 = 2-way PCB terminal block, pitch 7.5mm
K3 = 2-way PCB terminal block, pitch 5mm
K4 = 3-way PCB terminal block, pitch 5mm
TR1 = power transformer, secondary 2x6V, 1.5VA (e.g. Block AVB1,5/2/6)
PCB # 110337-1

lined up exactly. This is best done using a simple laser pointer. First, the laser pointer is put in front of the transmitter and pointed at the first mirror. A piece of masking tape on the mirror can make it easier to see the laser light. From then on, you follow the same procedure for all successive mirrors until you get to the receiver. This is something best done at dusk or at night!

Once that is done, the transmitter and receiver have to be aligned as well as possible with the first and last mirrors respectively.

If possible, you should use twin beam modules for the transmitter and receiver. This will prevent smaller birds or even a falling leaf from breaking the beam.

With only minor modifications, this system can also be used for other security purposes. The output is capable of switching all kinds of AC line powered devices.

(110337)

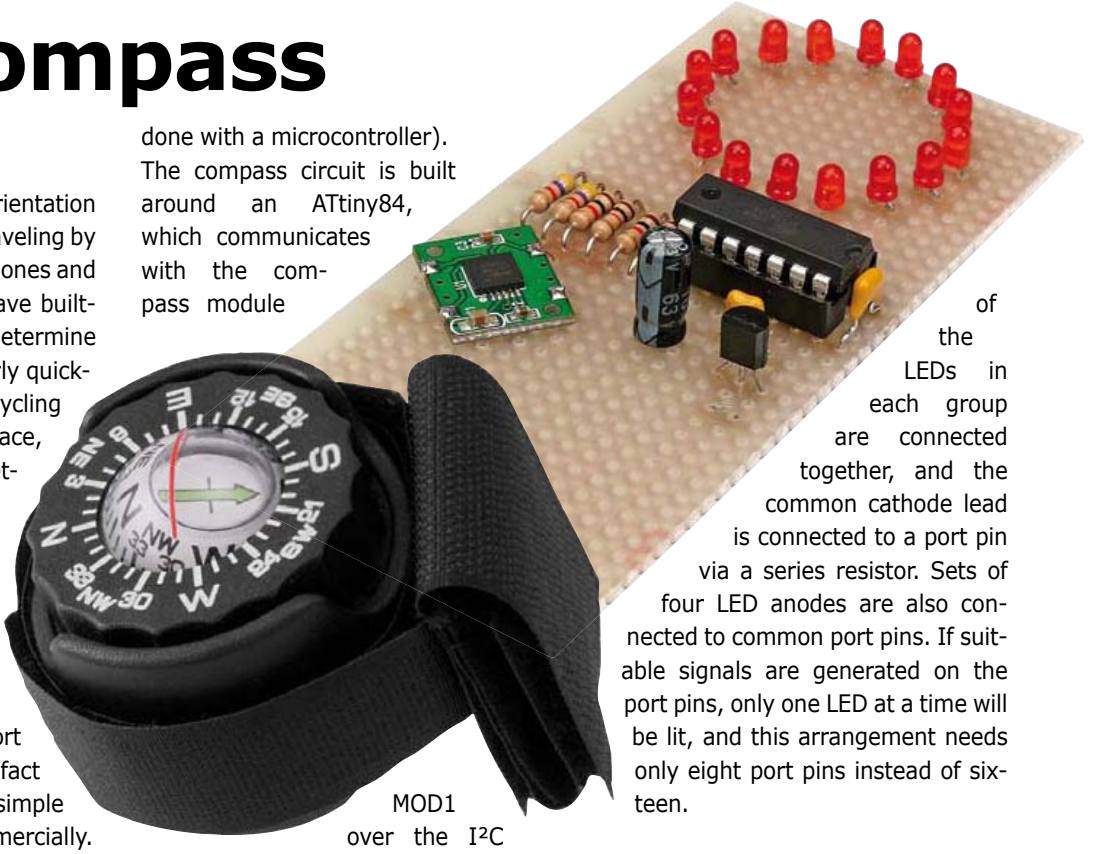
Internet Link

[1] www.elektor.com/110337

Tiny Compass

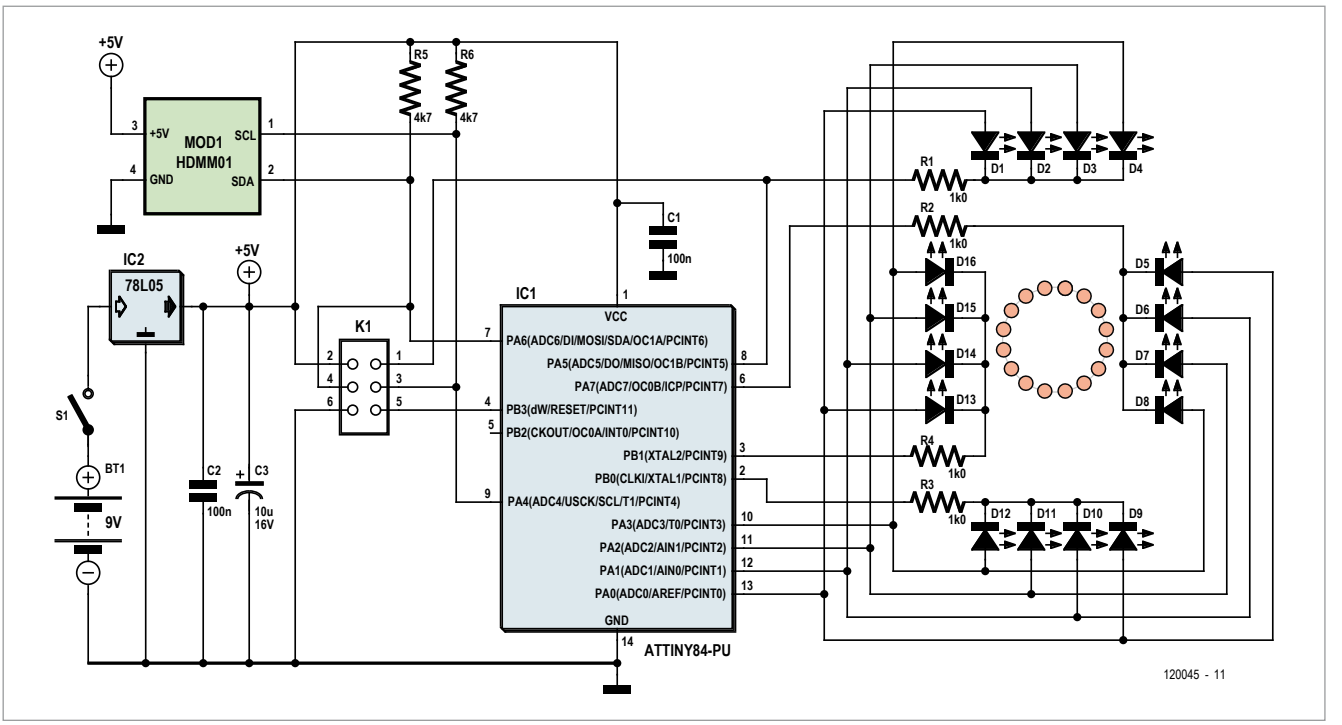
By Wilfried Wätzig (Germany)

A compass is an invaluable orientation aid, especially when you're traveling by foot or bicycle. Some smartphones and navigation systems do not have built-in compasses, so they can determine direction only if you move fairly quickly. Old-fashioned hiking or cycling maps also still have their place, since they provide a much better overview than any display. Accordingly, the author went looking for a robust compass, and it quickly became clear that what he wanted was an electronic model — and of course, of his own design. The implementation of this sort of project is simplified by the fact that compass models with simple interfaces are available commercially. The author decided on a module with the designation HDMM01, which can be obtained from Pollin Electronic [1]. It incorporates a type MMC2120MG two-axis magnetic field sensor from Memsic. All you need to do is provide the module with a 5 V supply voltage, and you can read out the compass data from a two-pin I²C port (most easily done with a microcontroller). The compass circuit is built around an ATtiny84, which communicates with the compass module MOD1 over the I²C bus. The two pull-up resistors R5 and R6 have standard values. The circuit can be powered from a 9 V battery, among other options. The voltage regulator reduces the input voltage to 5 V.



The compass direction is indicated by a set of 16 LEDs, divided into in four groups of four LEDs each. The cathodes of the LEDs in each group are connected together, and the common cathode lead is connected to a port pin via a series resistor. Sets of four LED anodes are also connected to common port pins. If suitable signals are generated on the port pins, only one LED at a time will be lit, and this arrangement needs only eight port pins instead of sixteen.

The intelligence of the circuit is vested in the microcontroller firmware, starting with the I²C interface. This is necessary because the ATtiny84 does not have a hardware I²C interface (which Atmel calls 'Two Wire Interface' or TWI), but instead only a 'Universal Serial Interface' (USI). The I²C functionality must therefore be emulated using



the USI, in the manner described in an Atmel application note [3].

The compass module supplies the X and Y components of the magnetic field as signed numbers. The corresponding quadrant can be determined from the signs of the numbers, and the angle within the quadrant can be obtained using the expression *Angle = arctan(abs(Y/X))*, where the function *abs()* returns the absolute value of the quotient of *Y* and *X*. The average values of *X* and *Y* are calculated from a set of eight samples in an endless loop in the main routine of the firmware and are used to compute the angle. From this the LED that points to the north can be determined. To allow the direction to be indicated with sufficient precision, the LEDs should be arranged in a circle with equal spacing and in the same sequence as shown on the schematic diagram. LED D1 must be aligned to the top edge of the module (oriented so that the IC marking can be read normally). For best results, you should use another compass to calibrate the assembly and adjust the orientation of the module (connected to the circuit by loose wires) accordingly. Then secure the module to the PCB with a drop of heat-melt glue.

The firmware (source code for WinAVR and hex code) can be downloaded from the Elektor website. The main routine is contained in the file tiny_compass.c; the routine USI_TWI_Master.c handles I²C communication and the routine led_driver.c drives the LEDs. The microcontroller can be programmed directly on the PCB via connector K1. The fuse bits must be configured as follows: EXT = 0xFF, HIGH = 0xDF, LOW = 0xE2. If you don't want to program the microcontroller yourself, you can buy a pre-programmed device from the Elektor Shop [4] (order number 120045-41).

(120045)

Always on the right path

Internet Links

[1] www.pollin.de

[2] www.pollin.de/shop/downloads/D810164D.PDF

[3] www.atmel.com/Images/doc2561.pdf

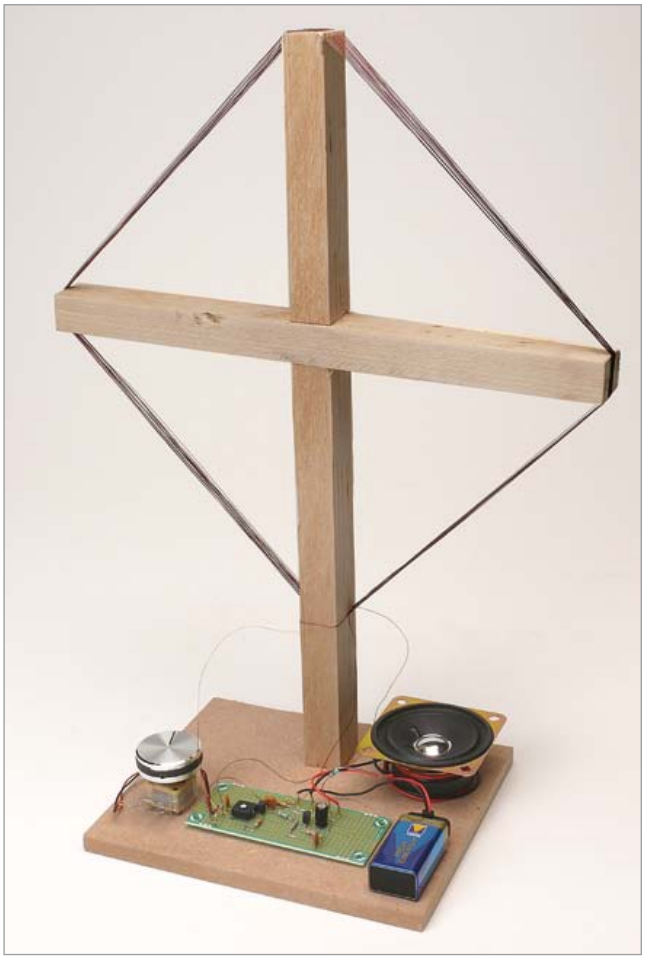
[4] www.elektor.com/120045

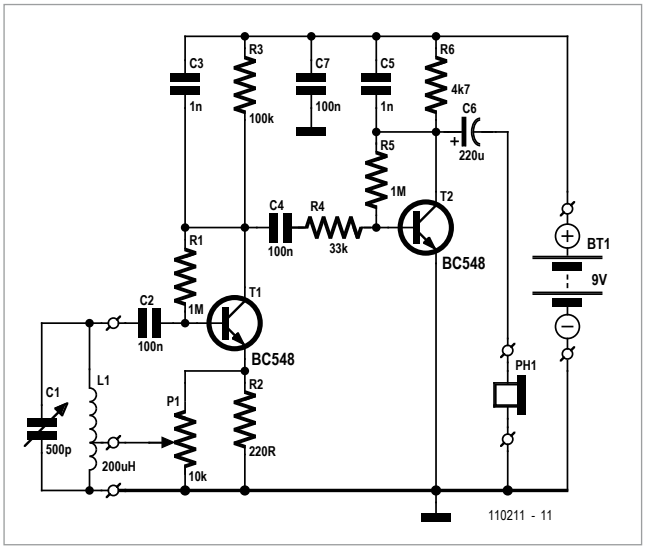
Elektor Products & Services

- ATtiny84 microcontroller (pre-programmed): # 120045-41
- Free software download: 120045-11.zip

All products and downloads are available from the web page for this article: www.elektor.com/12004

Two-Transistor Regenerative Receiver





By Frank de Leuw (Germany)

Regenerative? What's that? In the age of Twitter and smartphones, you can't assume that things not related to the Internet are still generally known — or maybe they are? Amazingly, Google delivers nearly 80,000 hits for the search term 'regenerative receiver' and much more for the German name Audion, even though it lacks a lower-case i as a prefix ('iAudion' also exists, but it yields only 12,000 hits). From this we can conclude that this type of receiver is not entirely unknown nowadays, even if some of the search results have nothing to do with radio circuits.

In any case, it's a reasonable assumption that you all have idea of what 'regenerative' means. If not: it's a super-simple but nevertheless sensitive type of radio receiver. If you want to know more, check the references. The Wikipedia entry on this topic [1] is also quite extensive. The author is a fan of the many HF experiments and projects dreamed up by the well-known Elektor author Burkhard Kainka. Based on Kainka's regenerative receiver circuit, the author developed an especially simple but high-performance version using

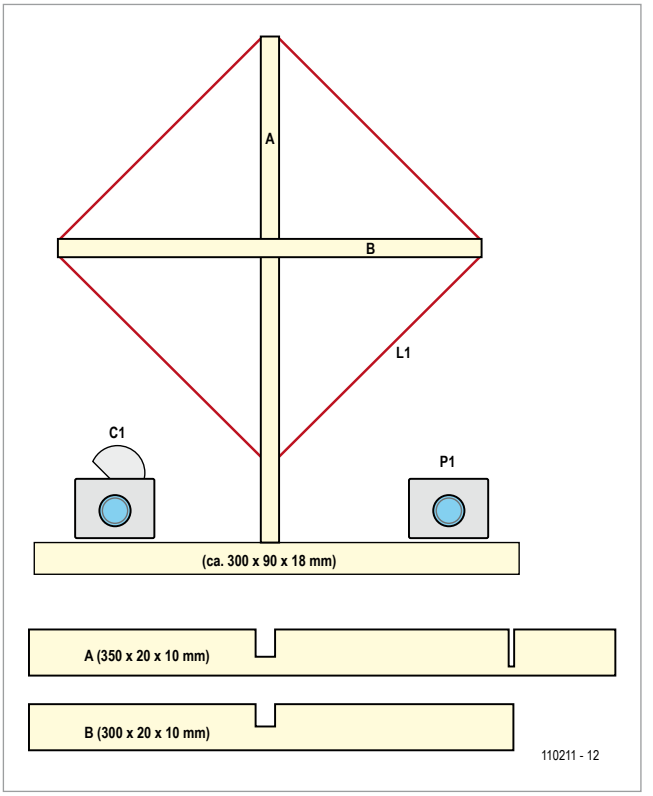
DIY Retro Radio

modern components — a regenerative receiver using only garden-variety transistors, but with good reception characteristics. The author has published a version of this design on his website [2].

The Elektor version, which is perhaps a bit easier to build yourself, is described here. Instead of breadboard construction, which was common in the days before PCBs were invented, the component layout of the design presented here has been optimized with the Lochmaster 4 program for assembly on an Elex prototyping board (a.k.a. UPBS-1 and available from the Elektor Shop).

First a few words about the circuit. A noteworthy feature is that both transistors are type BC548 in the 0815 package. Apparently types that are actually designed for audio use are adequate for use with HF signals in the medium-wave broadcast band from 0.5 to 1.6 MHz, which is what we're interested in here.

Variable capacitor C1 and coil L1 form the usual parallel resonant circuit that determines the receiver frequency. The special feature of a regenerative receiver is that an active component, or more precisely the gain of an active component, is used to implement a form of feedback that is adjusted to the point where the circuit is just on the edge of oscillation. This reduces the load on the resonant circuit and increases its selectivity, and the high gain makes the receiver fairly sensitive. The active component in this case is T1. The feedback is provided by P1 and the tap on L1. Here T1 does double duty: it provides HF gain and (thanks to the nonlinear characteristic of the BE junction) it demodulates the AM signals commonly transmitted in the MW band.
T2 provides additional gain for the audio signal. A small loudspeaker or (preferably) headphones can be connected to coupling capacitor C6. The headphones should have high impedance to improve matching. For this reason, it's a good idea to connect the two earphones in series.

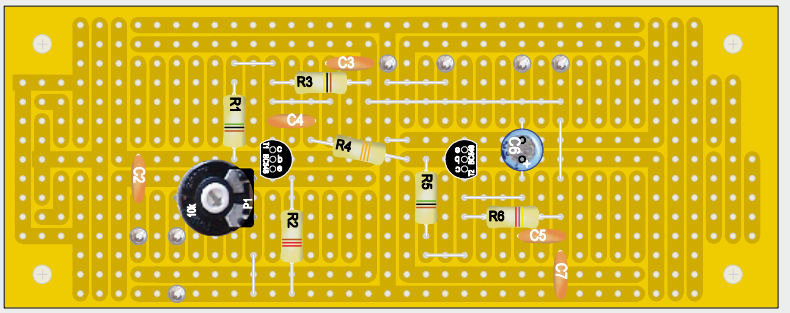


Assembling the circuit is straightforward thanks to the layout for the prototyping board. A bit more dexterity is required for making the aerial, but even here you don't need much more than the usual hobbyist tools. You can have planks and laths sawn to the dimensions given in the components list in any home improvement shop for a small charge.
Fit the PCB in the middle of the baseboard between the variable capacitor on the left and the potentiometer on the right. Screw the lath cross to the baseboard behind the PCB as shown in the photo of the prototype (note: in the prototype the author fitted a trimpot directly on the PCB instead of using an external potentiometer; this is also shown in the component layout for the Elex board). Wind 20 turns of enamelled copper wire on the cross, with a tap at the end of the fifth turn. The exact arrangement is not as critical as it might appear to an HF novice.
The prototype built in the Elektor lab drew 1.4 mA from a 9 V battery. The measured frequency range with this construc-

COMPONENT LIST

Resistors
R1,R5 = 1MΩ
R2 = 220Ω
R3 = 100kΩ
R4 = 33kΩ
R6 = 4.7kΩ
P1 = 10kΩ potentiometer, linear

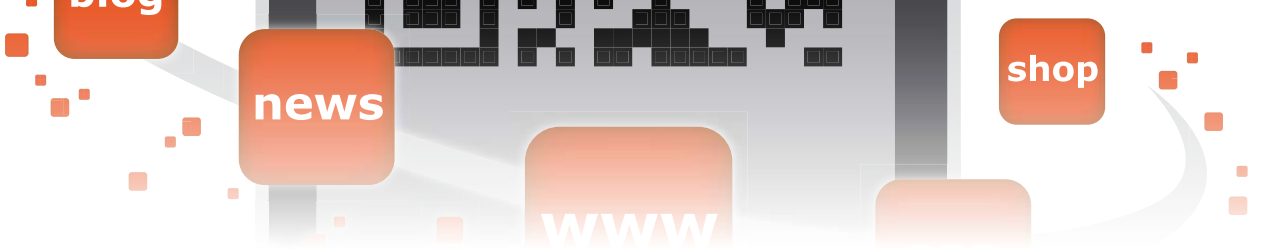
Capacitors
C1 = 500pF tuning capacitor, see text
C2,C4,C7 = 100nF ceramic, pitch 2.5mm
C3,C5 = 1nF ceramic, pitch 5mm
C6 = 220µF 16V, radial, pitch 5mm



Inductors
L1 = loop antenna, 20 turns ECW, tap at 5 turns (see text)

Semiconductors
T1,T2 = BC548

Miscellaneous
Prototyping board type Elex-1
9V battery w. clip
Small loudspeaker or headphones (see text)



tion was 0.4 to 1.4 MHz. The reception quality is surprisingly good, once you get the hang of adjusting the feedback with potentiometer P1. In terms of reception, the regenerative receiver can hold its own against superheterodyne receivers. If you want to connect an amplifier instead of headphones, you can replace R6 by a potentiometer with the positive end of C6 connected to its wiper.

If you can't scare up a suitable variable capacitor rated at 500 pF or so, you can purchase the VCAP4 from [3] and connect the two 265-pF gangs in parallel. Incidentally, in the Elektor lab it was necessary to reduce the turns count of the aerial loop by three in order to roughly match the receiver frequency range to the MW band. In our opinion this regenerative receiver is not only a good example of a loop aerial receiver, but also a good candidate for a 'father and son' project where you can try out lots of things and learn from them. And don't forget that a loop aerial receiver is a directional receiver!

(110211)

Internet Links

[1] en.wikipedia.org/wiki/Regenerative_circuit

[2] www.elektronik-radio.de/39994.html (in German)

[3] www.ak-modul-bus.de/ (in German)

Same PCB Shoots Again!

A thermometer with an unusual readout

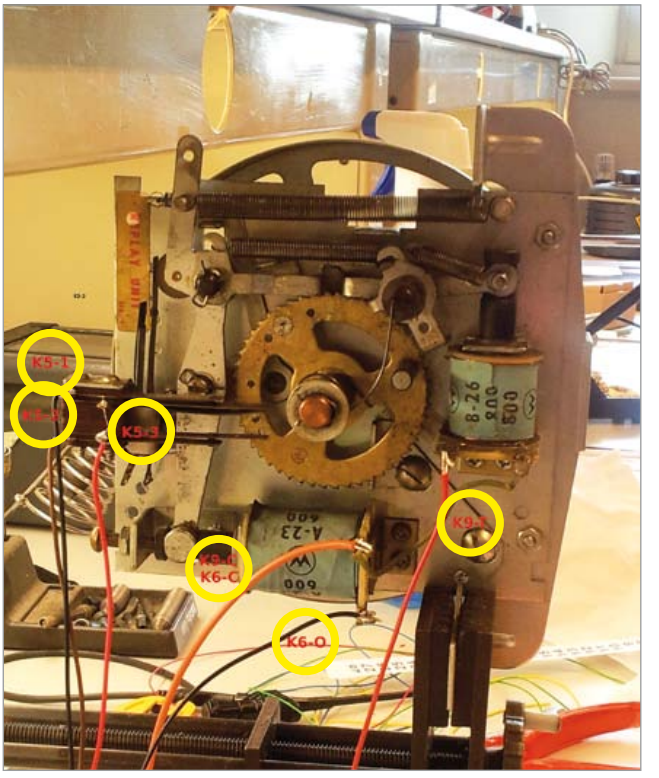
By Luc Lemmens (Elektor Labs)

In the April 2012 edition of Elektor we published a design for a thermometer that uses two counter wheels from a 1960's pinball machine to display the temperature. With few minor modifications to the firmware, a credit unit from a pinball machine can also be used as a display device.

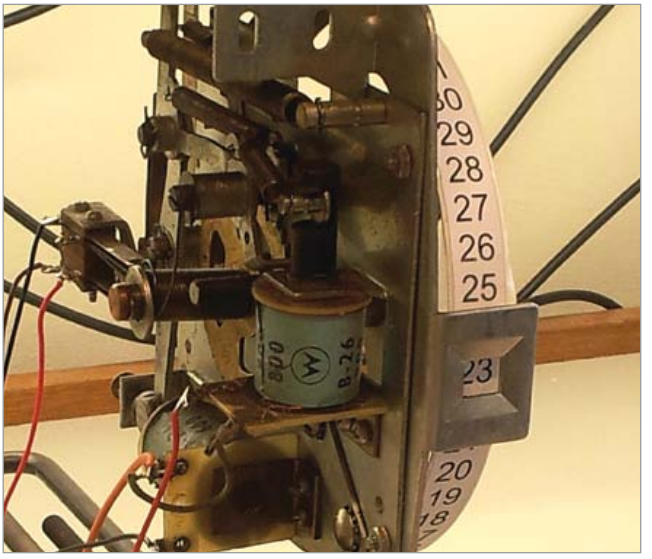
The counters used in the original design are a pair of modules normally used in a pinball machine to show the player's score. Each module can display a number from 0 to 9. These modules can only count up, which means that a change from 2 to 1 requires spinning the counter wheel all the way around to reach the new position.

EM pinball machines contain another type of counter called the credit unit, which shows how many games the player can still play before inserting more coins in the machine. It has a wheel that can display a number from 1 to 20. Some credit units can even go as high as 37 (the experts in this area disagree on the highest number ever). Unlike score counters, credit units can count down because they have a dual mechanism and two actuator coils. These units also have contacts to indicate the zero and maximum positions of the wheel. The numbers are smaller than those on score counters, and the available range of numbers is usually not especially large — but this can be taken as a challenge for developing version 2.0 of the thermometer.

Two contacts, two coils and two digits; what can we do with



that? The readout is a bit different, but the circuitry for the previous version of the thermometer has everything we need for driving this unit as well. With a few changes in the con-



nections and of course a few modifications to the firmware, it should certainly be possible.

The vast majority of the original firmware is unchanged; only the readout routine has changed. The algorithm for this is not difficult. After power-up, the microcontroller pulses the counter until it reaches the zero position. This position is signalled by the opening of the zero contact. Next, the temperature is measured and a pulse is sent to the counter for each measured degree Celsius to increase the indicated number. The circuit waits 15 minutes before making a new measurement. The new value is compared with the previous value and the difference between the two is translated into the number of steps up or down that are necessary to show the right temperature. That's all easy enough, but with a 20-credit unit — such as we had here in the lab — the range is rather limited and not even sufficient for measuring the room temperature.

The wheel has enough room for more numbers, and in principle the unit could certainly make more steps; if necessary it could even turn the wheel in a full circle with a modified mechanism. Our credit unit came from a pinball machine made by Williams, but a unit from another brand is equally suitable (just like the counters for the previous version), such as Bally or Gottlieb. Credit units also differ somewhat from one brand to the next, and some manufacturers occasionally make changes to their own modules, but the connections and operation are always the same. A bit of exercise with a graphic design program on the computer delivers a nice strip of paper with a series of numbers from 0 to 48, which can be taped onto the original wheel. However, there's a bit more to be done. As already mentioned, the unit has a contact that indicates when the wheel has reached its maximum count. On the photo you can see the contact for the 0 position at the left, and to the right of it a ratchet wheel with two pins fitted to it. The upper pin opens the zero contact when the wheel has been rotated far enough anti-clockwise, and the lower pin opens the maximum-position contact when the wheel reaches the maximum position in the clockwise direction. We removed the second pin to make the range as large as possible. In the worst case the pin intended to operate the contact for the zero position will also operate the contact for the end position. If this happens, the firmware prevents the wheel from stepping any further.

The new firmware for the ATtiny2313 used in the original circuit published in the April 2012 edition (PCB # 110673-1) is available on the web page for this project [1].

(120251)

Internet Link

[1] www.elektor.com/120251

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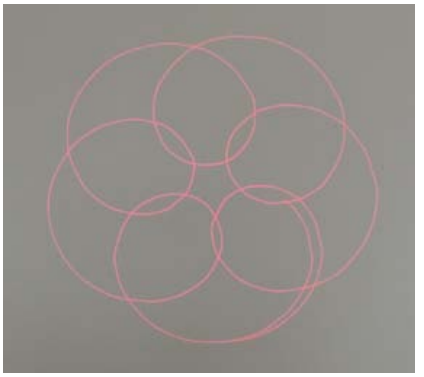
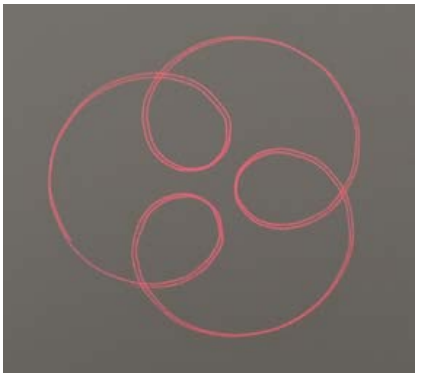
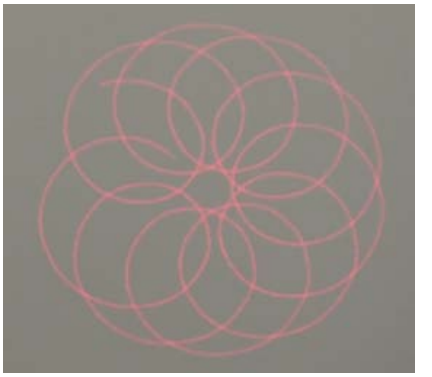
Laser Projection with Arduino

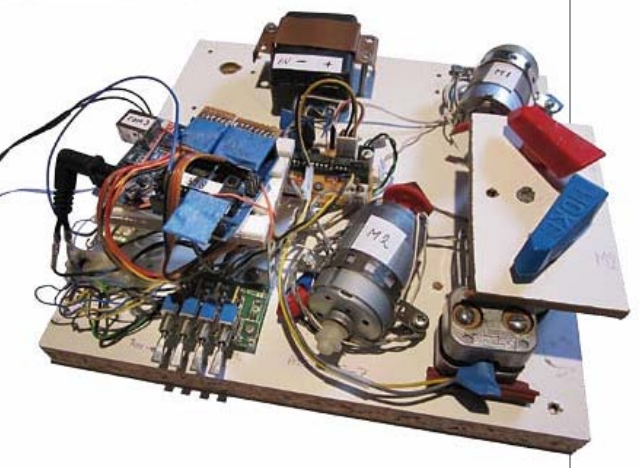






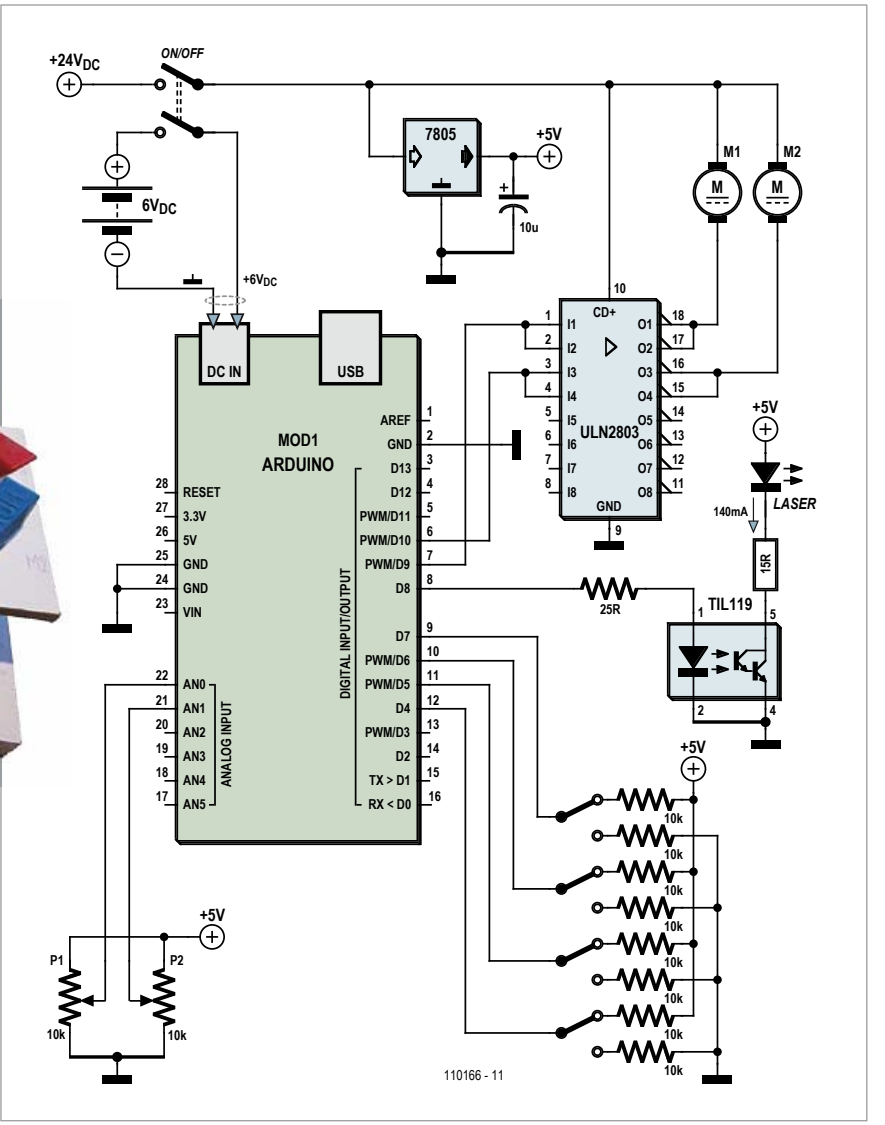
By G. van Zeijts (The Netherlands)

This device can project attractive laser beam patterns on virtually any desired surface. The basic idea is to manipulate the path of a laser beam from a source such as a laser pointer. The beam is deflected by a small mirror fitted to the end of a motor shaft. The mirror is not



perfectly perpendicular to the axis of the shaft, so the originally linear beam path is converted into a cone. This cone strikes a second mirror on end of the shaft of a second motor. The beam from the second mirror goes to the projection surface.

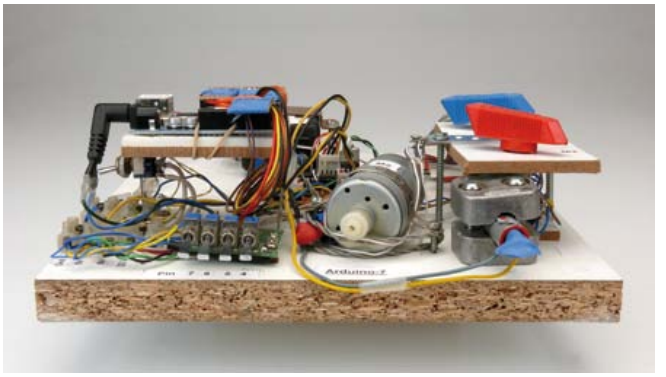
The motor speeds are high enough that viewers see a stationary figure instead of a moving point of light, thanks to the

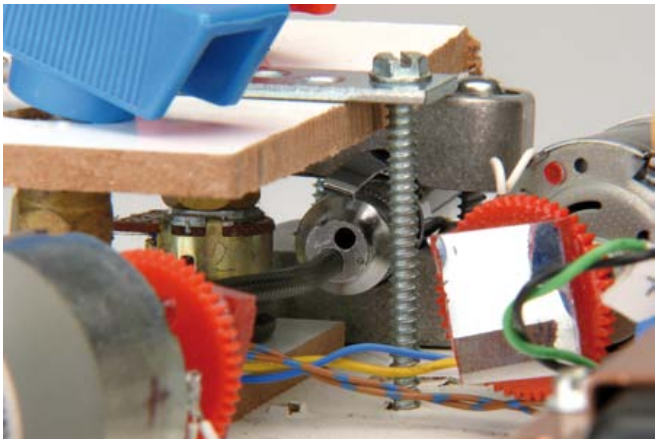


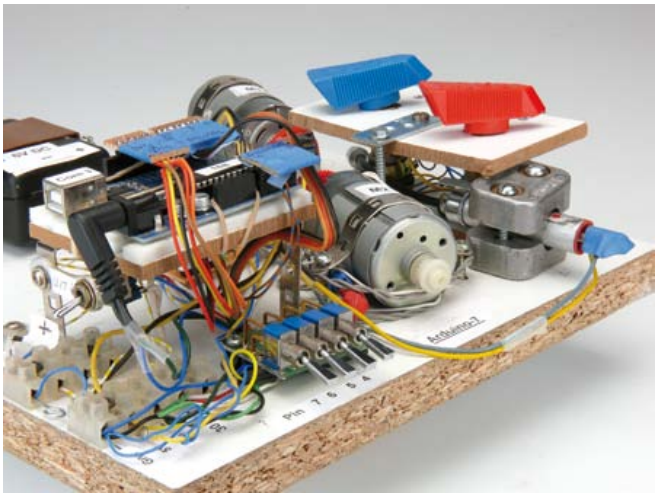
persistence of human vision. A wide variety of fascinating figures can be created by varying the speeds of the motors.

All of this is controlled by an Arduino microcontroller, using a program written in C. The software can be downloaded free of charge from the web page for this article [1].

The speeds of the two motors are set by potentiometers P1 and P2 (which are fitted with the red and blue knobs in the photo), whose positions are read by the microcontroller. The microcontroller converts these two input signals into PWM outputs that determine the speeds of the motors.
The rest of the circuit diagram is simple. The outputs of the Arduino MCU are fed directly to the ULN2803 driver IC, which can handle up to 500 mA per channel. The two motors (scavenged from printers) operate at 24 V with current consumption well below 500 mA. To be on the safe side, two channels of the ULN2803 are wired in parallel for each motor.
The laser diode is energized by the microcontroller immediately after start-up and is always on. It is powered from a 5-V supply voltage. The current is limited to approximately 140 mA by a 15-ohm resistor. To avoid problems with pulse noise from other supply rails, the Arduino is powered from a separate 6 V source, such as a rechargeable battery.







The author used the potentiometers to find various combinations of motor speeds that produce attractive figures. They have been arranged in sequence to provide a show lasting several minutes, with a repeating series of fascinating figures in an automatic loop. This is included in the C code. This loop, as well as other pre-programmed figures, can be selected using a set of four switches. A short video demonstrating the projected figures can be viewed on Elektor's YouTube channel [2].

(110166)

Internet links

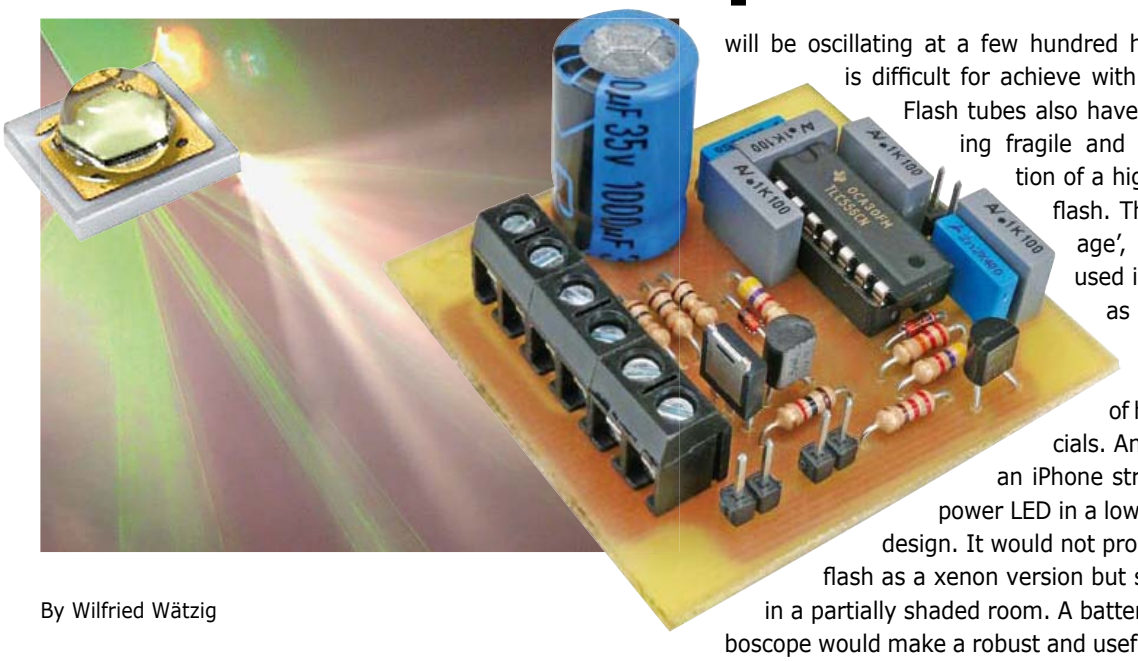
[1] www.elektor.com/110166

[2] www.youtube.com/ElektorIM

Caution: laser beam!

Always be careful when working with laser beams. The light emitted by the laser diode in a laser pointer is relatively harmless and does not cause any problems if the beam passes quickly through your field of vision, but you should **never look directly into a stationary laser beam**, even if the laser power is very low.

Mini Stroboscope

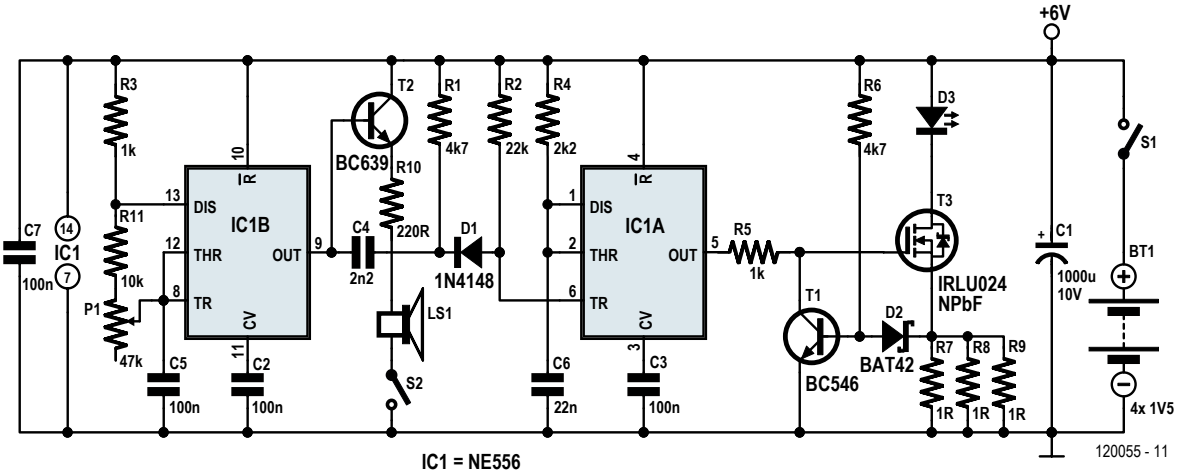


By Wilfried Wätzig

Physics teachers often rely on test equipment to make certain phenomena observable. Stroboscopes are useful for getting a closer look at vibrating strings and rotating motor parts. Conventional stroboscopes however will often not flash at a rate fast enough to 'stop' the motion for observation. The author is of the belief that a hands-on physical demonstration is worth a hundred hours of 'chalk and talk' whiteboard explanations.

Strings vibrating at a frequency high enough to be audible will be oscillating at a few hundred hertz. This flash rate is difficult for achieve with a xenon flash tube. Flash tubes also have a reputation for being fragile and require the application of a high DC voltage for the flash. The words 'lethal voltage', 'fragile' and 'glass' used in the same sentence as 'classroom environment' are likely to arouse the interest of health and safety officials. An alternative (not just an iPhone strobe app) is to use a power LED in a low-voltage stroboscope design. It would not produce such an intense flash as a xenon version but still be bright enough in a partially shaded room. A battery powered LED stroboscope would make a robust and useful teaching tool.

This was reason enough for the author to set about designing and building this mini stroboscope using an LED light source. The design is built around the NE556; the dual-version of the biggest selling chip ever designed. One half of this chip (IC1B) takes care of the flash frequency generation and is therefore configured as a standard astable multivibrator. Variable pot P1 allows the flash rate to be adjusted from around 120 to 650 Hz. The design includes a switchable loudspeaker in the emitter path of T2 to make the flash



650 Hz LED strobe

frequency audible. Transistor T2 is only necessary if you, like the author, use the CMOS version of the NE556.

The second half of the dual timer chip is configured as a monostable multivibrator to provide a pulse shaping function. The differentiating RC network formed by C4 and R1 produces a 10 µs pulse on the positive and negative edges of the output signal from IC1B. The negative going pulse is transferred to the trigger input of IC1.A via diode D1. R4 and C6 are chosen so that IC1.A gives a 50 µs positive output pulse in response to the trigger pulses.

The pulses are connected to the gate of MOSFET T3 via resistor R5. LEDs are driven by a constant current source, in this circuit the voltage drop across the shunt resistors R7, R8 and R9 is added to the forward conduction voltage V_F of D2 to control transistor T1. When the voltage drop over the shunt resistors reaches 300 to 350 mV T1 begins to conduct the drive voltage of T3 to ground thereby limiting current through the LED to around 1 A. C1 effectively reduces the source impedance of the power supply so that high current pulses can be delivered to the LED even when the circuit is powered by four AA size dry batteries.

The author used an LED 'OSLON SSL LCWCQ7P' type LED from OSRAM. According to its data sheet [1] this small LED can be pulsed with a current of 2 A for 50 ms. Running with 1 A pulses of 50 µs duration neither the LED or T3 will require any additional cooling. This particular LED has an electrically isolated 'thermal pad' between the two power connections which can be used as a heat sink contact point. With a heat sink in place the LED will be able to pass a higher current. IC1.A outputs a constant pulse width so the LED dissipates more power if the value of C5 is reduced to increase the maximum strobe flash frequency. It is of course possible to experiment with more powerful LEDs and to increase the LED current by reducing the size of the three parallel shunt resistors. T3 still has a little more in hand even when running with a pulse current of 3 A in this application. To achieve maximum brightness it is better to avoid warm white LED variants. Higher colour temperatures are perceived as being brighter.

Using the suggested components and a CMOS version of the NE556 the LED current has an average value of around 20 mA when running at 650 Hz. With the speaker switched on this rises to around 40 mA. Using the standard non-CMOS version of the NE556 increases the current drain by about 5 mA.

The author has supplied a PCB layout for this design. It uses standard non-SMD components so assembly is very simple. The PCB can be ordered from the project web site [2] where the layout files are also available for download.

(120055)

Internet Links

[1] http://catalog.osram-os.com/catalogue/catalogue.do?favOid=0000000200002633080300 23&act=showBookmark

[2] www.elektor.com/120055

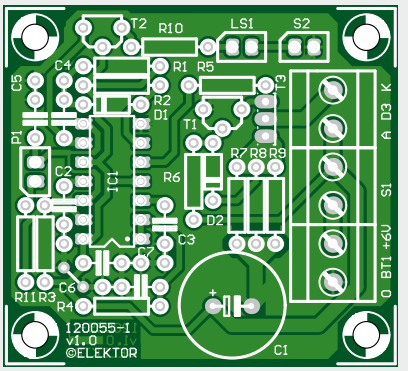
COMPONENT LIST

Resistors
R1,R6 = 4.7kΩ
R2 = 22kΩ
R3,R5 = 1kΩ
R4 = 2.2kΩ
R7.R8.R9 = 1Ω
R10 = 220Ω
R11 = 10kΩ
P1 = 47kΩ, potentiometer, linear

Capacitors
C1 = 1000µF 10V, radial, pitch 5mm, diam. max. 13mm, 1 A ripple current (Farnell # 1165601)
C2,C3,C5,C7 = 100nF, MKT, pitch 5 or 7.5mm
C4 = 2.2nF, MKT, pitch 5 or 7.5mm
C6 = 22nnF, MKT, pitch 5 or 7.5mm

Semiconductors
D1 = 1N4148
D2 = BAT42
D3 = Power-LED, OSRAM type LCW CQ7P. PC-KTLP-5J7K
T1 = BC546
T2 = BC639
T3 = IRLU024NPbF (TO-251AA)
IC1 = TS556 or TLC556 (DIP16)

Miscellaneous
S1 = on/off switch, 1 A
S2 = on/off switch
LS1 = loudspeaker, 8Ω 200mW
BT1 = 4 pcs AA alkaline battery with holder
3 pcs 2-way PCB screw terminal blocks, pitch 5mm, for BT1, S1 and D3
3 pcs 2-way pinheader, pitch 0.1", for LS1, S2 and P1
PCB # 120055-1 (see text)



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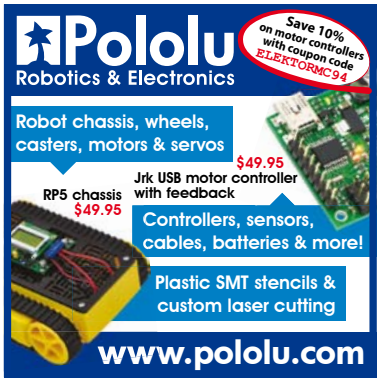

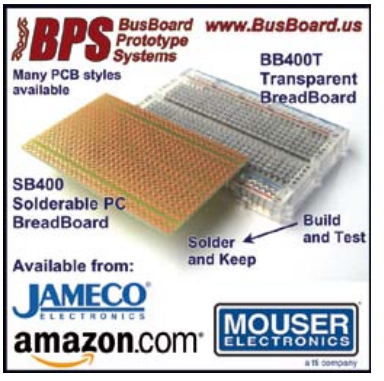

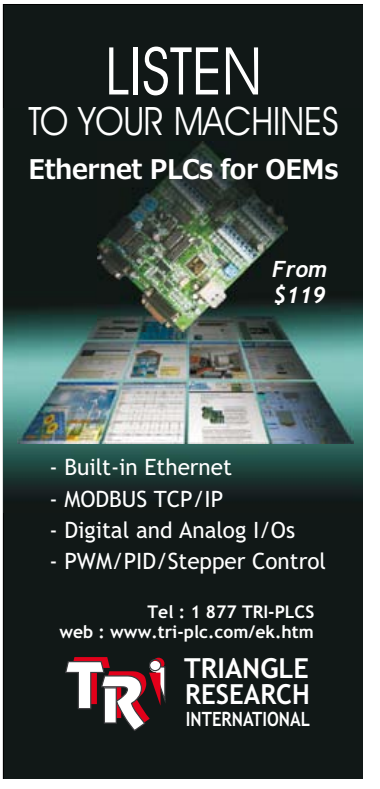

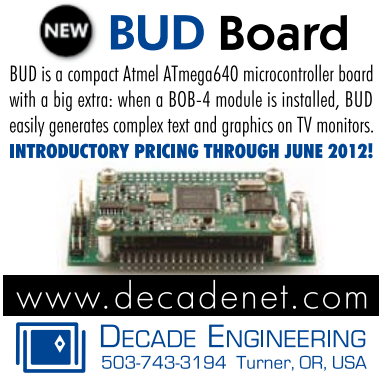

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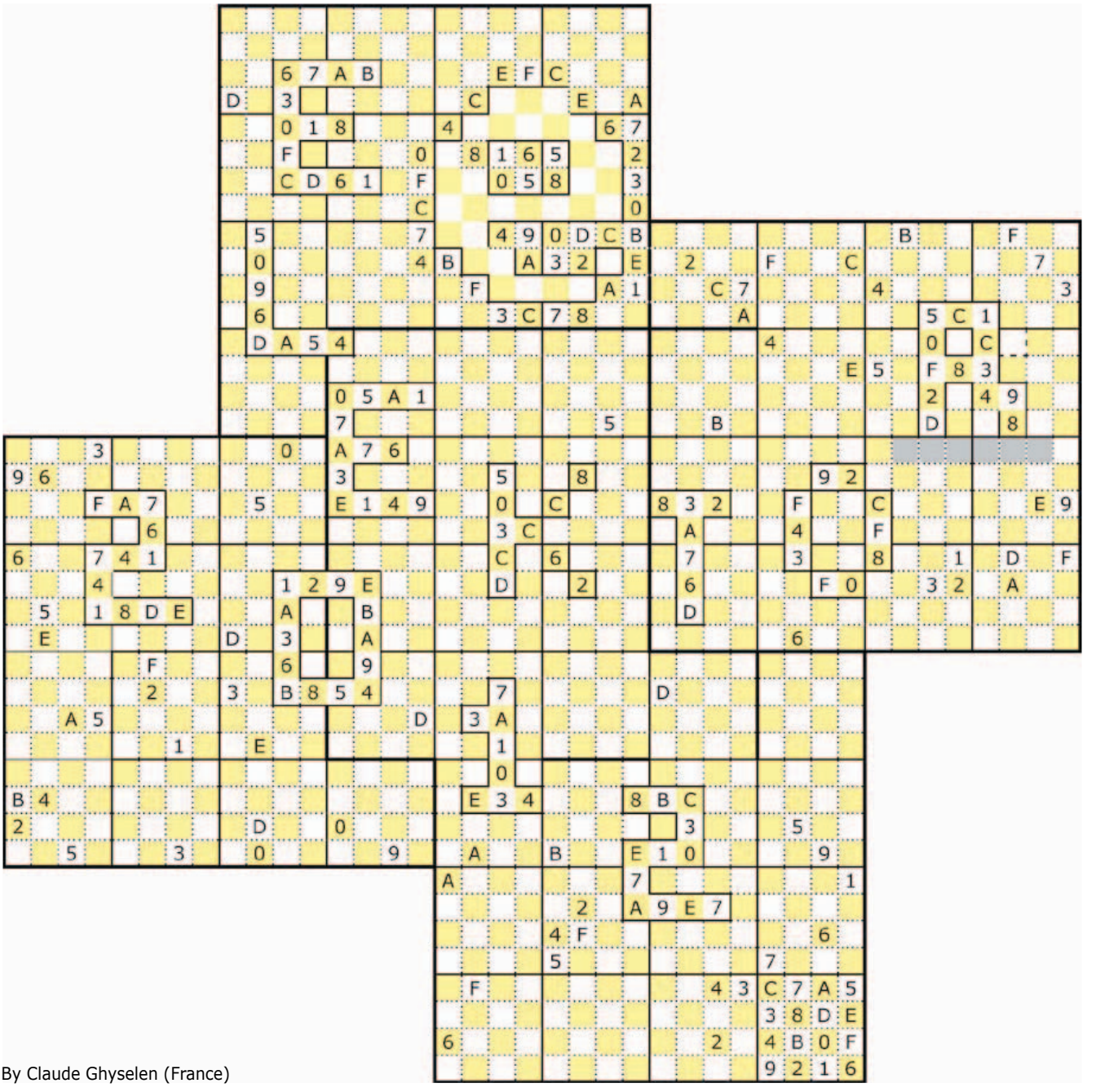

By Claude Ghyselen (France)

Argh, what on earth is this five-headed monster? Has its designer been on hallucinogenic substances?
Or is it a page layout error, a jumble of grids that just seem to have landed up here on top of one another? No such error — take a closer look, there are five interlocking grids, not four. That's why we called it Penta-Hexadoku.

Apart from this rather unusual configuration, this hexadecimal pentagrid uses a checkerboard design not (just) to look pretty, but above all to make the rules of the game harder:

Solve EUC Penta-Hexadoku and win!

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Participate!

Before September 1, 2012,

send your solution by email to hexadoku@elektor.com.

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

an even hexadecimal number must never appear alongside another even number, and an uneven number must never be next to another uneven number. That's why we've called it EUC, for even/uneven checkerboard. This restriction goes very well with the basic Hexadoku rules.

The instructions for solving this puzzle are as follows. Fill in the grid in such a way that all the hexadecimal numbers 0 to F appear only once in each region of the five grids: line, column, 4×4 square (conventional rule) and in addition that the even numbers (0,2,4,6,8,A,C,E) only appear on a colored background, while the uneven numbers (1,3,4,7,9,B,D,F) only appear in white squares.

To make sure there is only one possible solution, certain numbers have already been entered; you're sure to have noticed that these form the words Elektor 2012 and the logo on the blank grid.

A faithful Elektor France reader ever since the very first issue, I tried my luck as soon as the first Hexadoku appeared. Sadly, Fortune has always refused to smile on me. So, to try and win in another way, I've sent Elektor various suggestions for grids, as the inspiration came to me. How pleased I was to see one of my suggestions used in the 2008 annual double edition: the Alphasudoku [1]. Ever since then, I've never stopped researching and suggesting original grids. This is how Hexamurai came about in 2009 [2] and then Hexadocube in 2010 [3], whose complexity I am rather proud of. I've got into the habit of creating grids that will make life difficult for those players who may be tempted to use computer programs to solve the monthly Hexadoku. These won't be any help at all for the EUC Penta-Hexadoku in this year's Project Generator Edition, which got designed during the winter period when my brain cells were in semi-hibernation! Doubtless only every other brain cell was working that day!

Originally trained as a mechanic, I currently work in the Industrial Energetics Laboratory at the Douai Mining & Engineering College. I've always been attracted to electronics, thanks to my father, who was very keen on fault-finding. A railway employee, he spent his leisure time discovering and understanding electronics through practical work. The first TV we had at home, he built himself from a kit that used to be produced by Cibot Radio. He brought the CRT all the way from Lille on the carrier of his moped.

My other passion is solar energy, photovoltaic or thermal. I am working on the construction of garden cooking devices.

The bottom square has already been filled in to illustrate the arrangement of the even/uneven checkerboard (the most anxious of the Elektor editorial staff felt that my explanations are not enough).

(120268)

References

[1] Alphasudoku (2008): www.elektor.com/080463

[2] Hexamurai (2009): www.elektor.com/081169

[3] Hexadocube (2010): www.elektor.com/090724

Prize winners

The solution of the May 2012 Hexadoku is: **4C03E**.

The Elektor $125.00 voucher has been awarded to Betty Brillon (France).

The Elektor $60.00 vouchers have been awarded to Ron Ware (UK), Wolfgang Rossmann (Germany), and Emil Cugini (Switzerland).

Congratulations everyone!

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

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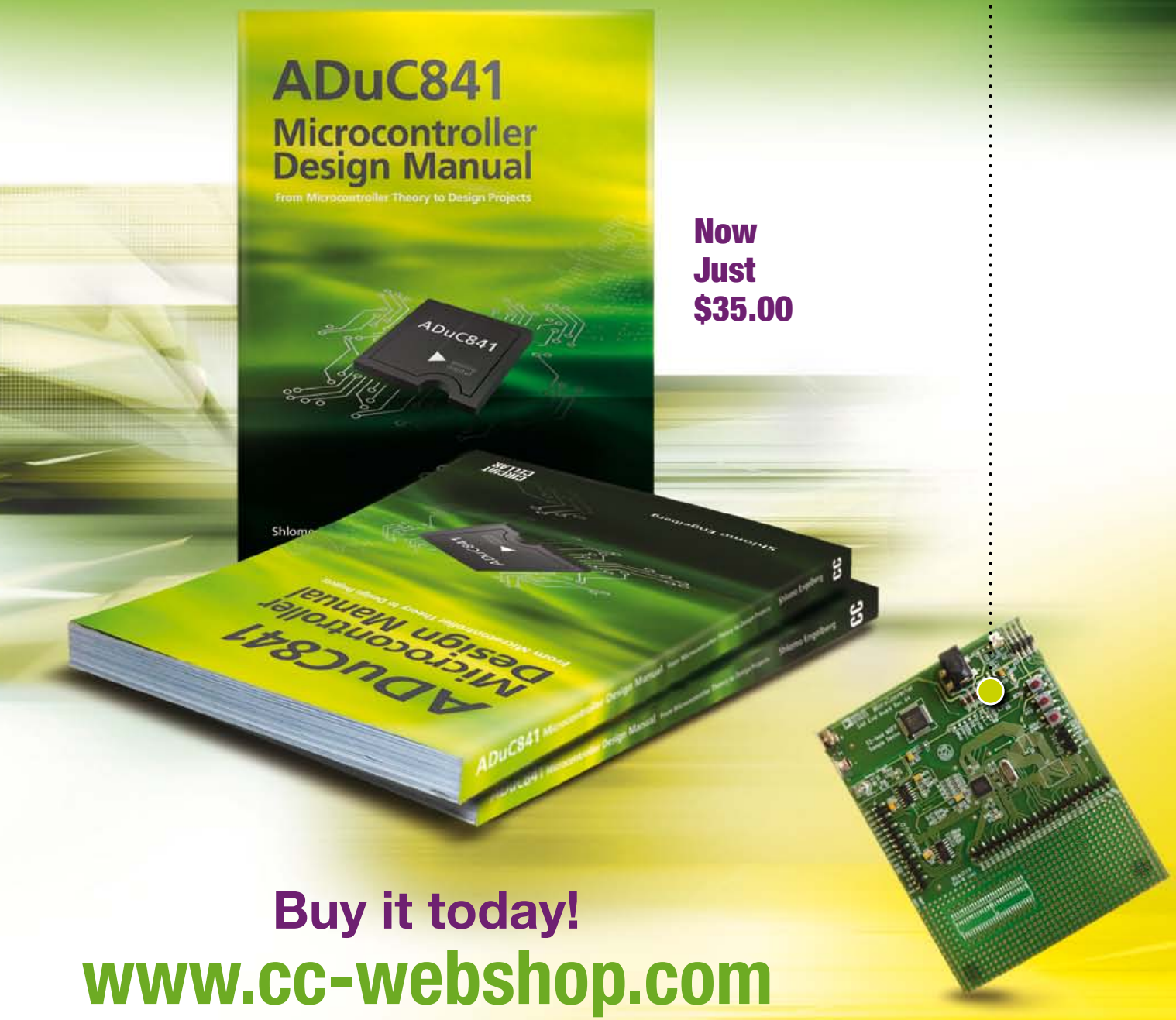

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Stand-alone Model Train Control

Model trains are still popular among young and old. Some operate their trains with mere buttons on a wooden panel, while others are constantly tinkering with comprehensive all-computerised layouts. But there are also middle ground options. Using this stand-alone circuit based on a PIC microcontroller you can make your models do pre-programmed runs on a small layout. There is even a matching PC program supporting scripts that are easy to create and enter.

Nunchuck Gets a USB Interface

The Wii games console is supplied with an accessory called Nunchuk: a second controller that has a 3-axis accelerometer, an analog joystick, and two buttons. All it takes is a PIC18F2550 to communicate with this man/machine interface using the I²C protocol and use it for other applications, e.g. in robotics, modelling, for DMX, etc.

USB Isolator

A USB isolator can be used to electrically isolate a PC from a connected device. By affording electrical isolation it prevents ground loop-noise and helps to avoid measurement errors. This circuit uses an ADuM3160 to isolate the USB data lines. The IC is USB 2.0 compliant, supporting low-and full-speed USB. An LT3575-based flyback converter is applied to ensure isolation of the USB input supply from the PC output port supply.

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

Elektor UK/European September 2012 edition: on sale August 16, 2012. *Elektor USA September 2012 edition: published August 13, 2012.*

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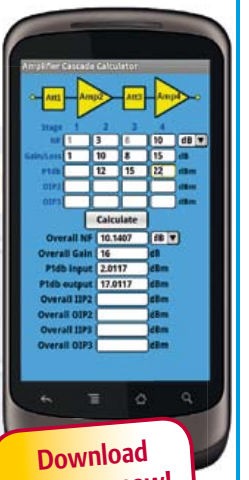

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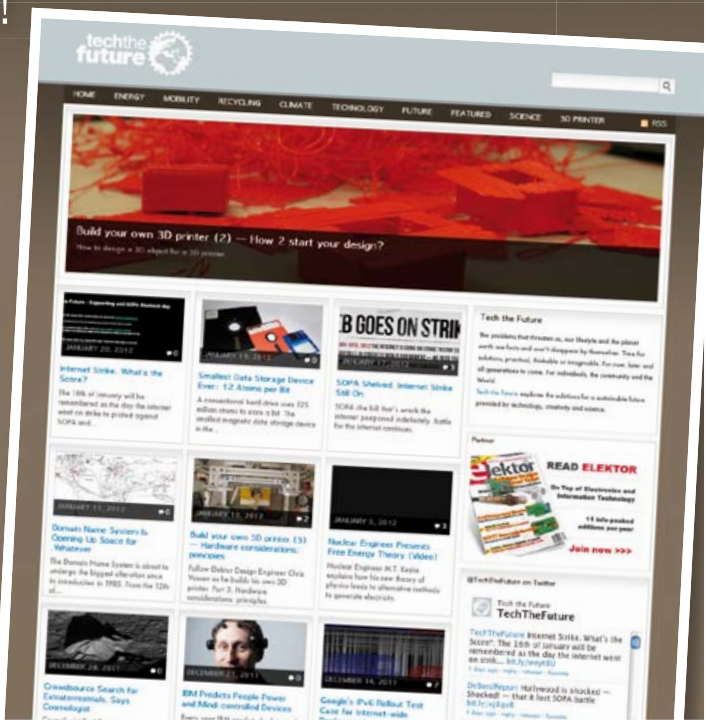

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