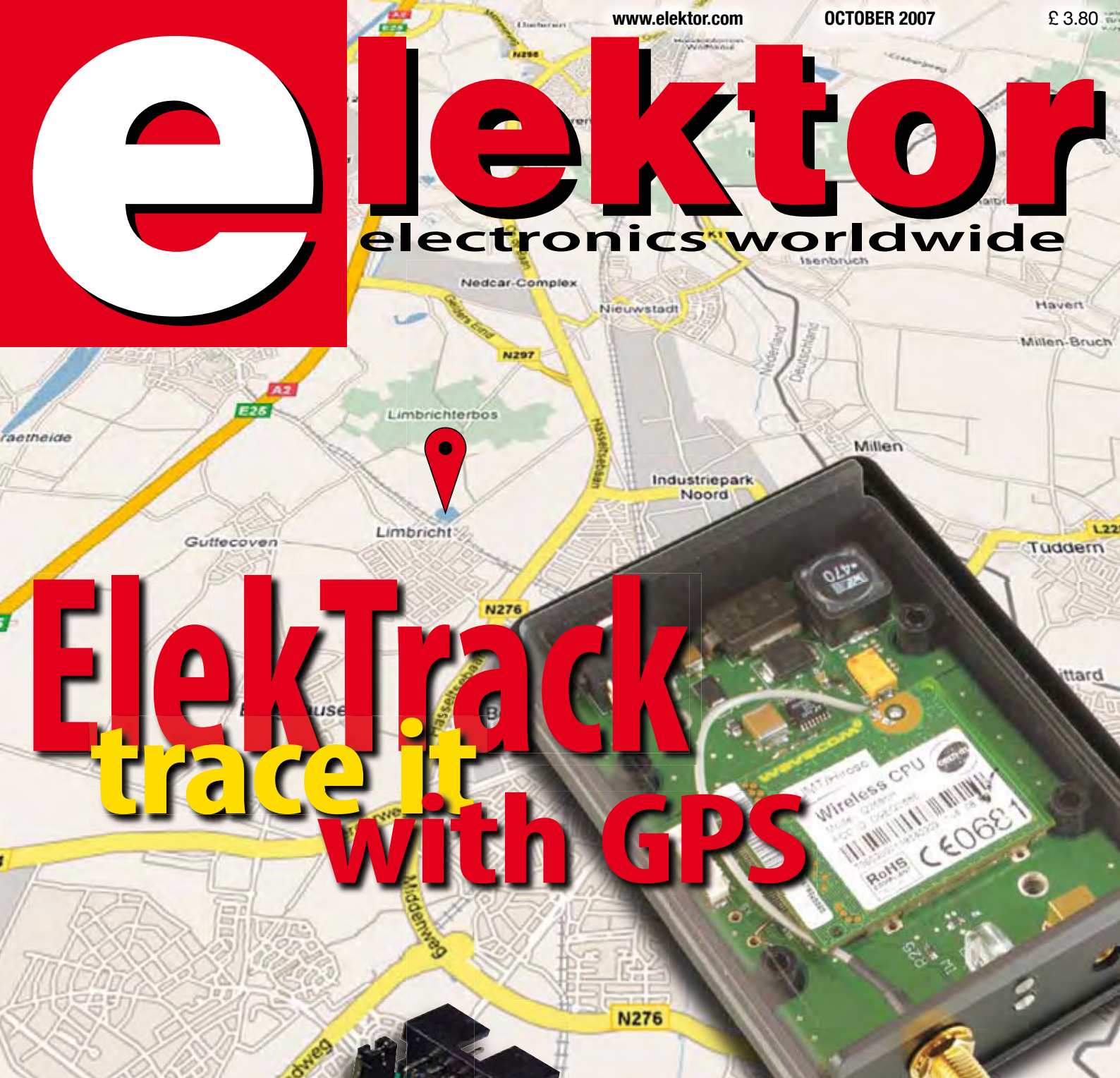


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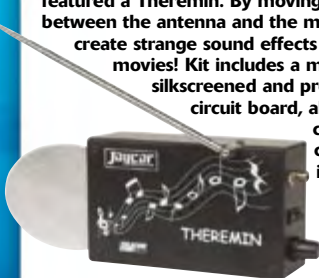
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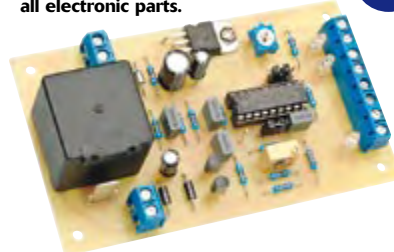
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electronics worldwide

Just in case you did not notice, Elektor has a new subtitle. Half a dozen of these appeared and disappeared over the past 34 years. For the English-language edition, the first subtitle to appear was 'electronics for lab and leisure' and the most recent, 'leading the way'. No different for the other language editions, which now abandon their latest subtitles 'inspiring electronics' (German), 'imaginative electronics' (French) and 'surprising electronics' (Dutch) in favour of the new, unified, 'electronics worldwide'.

The subtitle of a magazine ideally qualifies the content as well acts as an afterburner to the main title — what's the coverage and purpose of the magazine, how does it affect the reader and what's the promise if he or she starts reading it on a regular basis. It's 'electronics worldwide' now and we realise you may not care too much because the contents are more important: new circuits and ideas every month that enable you to experience and enjoy electronics no matter if it's professionally, as an enthusiast or both at the same time. Still, the new subtitle holds good news for you, because it underscores our intention to broaden our horizon. Developments in electronics cannot be stopped at frontiers using red & white barriers. The internet acts as a catalyst, vehicle and medium in this unstoppable trend. That's why Elektor launched new websites for its main European editions recently, with Spanish and Chinese to follow soon. Hence the new subtitle 'electronics worldwide'. Unwittingly, you are part of it all, together with 2 million others we reach every month with our publications and products.

This issue of Elektor also marks our move from rather lacklustre, overcrowded and worn out 1970s style offices to a really 'grand' location — a real castle from the 13th century. Although we're not allowed to paint anything on the façade, or even attach a smallish nameplate (the building is under National Trust protection) we have dubbed the premises 'Elektor House'. See pages 16-18!

Wisse Hettinga

International Coordinating Editor

ElekTrack trace it with GPS

The alarm systems of expensive cars and other vehicles often comprise positioning systems so they can report where the vehicle is located. However, such systems are rather expensive, so we decided to take the DIY approach and develop our own version, dubbed ElekTrack.

46 USBprog



USB-to-serial converters are often slow, especially when it comes to software control of the handshake signals. The delays are particularly irritating when developing and debugging software. Good (i.e., fast) USB to serial converters exist but are dearer than the more general purpose unit we describe here.

52 USB/UART Interfaces

USB bus and asynchronous serial busses (UARTs) appeared in the early 2000s. Now here we are with third, fourth, and even fifth generation circuits: faster, more reliable, and more stable (especially their drivers), and offering improved features.



The amplifier described here uses a mixture of transistors and valves to combine the advantages of both approaches and thus deserves the designation 'hybrid'. The result is an amplifier with audiophile performance.

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62 Astounding Engineering

Solar Team Twente's vehicle built for the World Solar Challenge 2007 in Australia is based on the positively phototropic behaviour of sunflowers. Tilting solar panels with Fresnel lenses aim to maximise the yield of the sun's energy in this solar car.



20 Mugen - a Hybride Audio Amplifier



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Volume 33, Number 370, October 2007

ISSN 0268/4519

Elektor Electronics aims at inspiring people to master electronics at any personal level by presenting construction projects and spotting developments in electronics and information technology.

Publishers: Elektor International Media, Regus Brentford,
1000 Great West Road, Brentford TW8 9HH, England. Tel. (+44) 208 261
4509, fax: (+44) 208 261 4447 www.elektor.com

The magazine is available from newsagents, bookshops and electronics retail
outlets, or on subscription.

Elektor is published 11 times a year with a double issue for July & August.

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

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UK Advertising: Husion International Media, Cambridge House,
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Driving 8, 16, 24 or more servo motors from a single micro

Servo motors require a pulse every 20 ms of which the width varies between 1 and 2 ms. Such a pulse sequence is easily generated using the famous 555 timer IC. A microcontroller, too, has few problems driving one or two servo motors in this way. However, cunning plans are in order if you want to drive (many) more motors. The perennial problem: time! To enable a microcontroller to generate a pulse with a length of 1 to 2 ms at a 20-ms rate you could use its inbuilt timer. This is then programmed to supply an interrupt every 20 ms. The pseudocode shown in Listing 1 is just a suggestion (it's C code for a PIC16F690, but apart from the timing and the ports used, it makes no difference what controller is actually used).

With a small modification, the code can be employed to drive up to 10 servo motors, and it's actually achieved by throwing in an array of servo timers and changing the interrupt rate to 2 ms (Listing 2). This looks nice at first sight but there are a few disadvantages to mention:

- output bits on a controller cannot normally be indexed (minor problem!), but it can be done using a mask over the output port;
- driving more than 10 servo motors is not feasible because we need a 2 ms pulse (max.) (10=20/2) every 20 ms;
- when all 10 servo motors are fully driven (100%), no time remains for the foreground loop. This makes it impossible to adapt the motor positions (major problem!).

Now, instead of generating a separate pulse for each servo motor, we could generate a mask across 8 (or 16, or...) bits and adapt it timewise. So, to begin with we set all servo motor outputs to be driven to 'true', and turn off servo outputs again per delta time (Listing 3). This allows the

Listing 1

```
int servoTime1;           // timeout for servo
1

On_20_milli_Seconds:
    Output1 = true
    WaitMicroSeconds(servoTime1) // wait 1.5 ms
    Output1 = false
    Return                      // from interrupt
routine

OnInit:
    InitTimer()                // set timer to 20 ms and
                                // set interrupt vector

servoTime1 = 1500             // between 1000 and 2000

while( 1 )
    // code to adapt servoTime1
    key = getkey()
    if ( key = KEY_UP && servoTime1 < 2000)
        servoTime1 = servoTime1 + 1
    if ( key = KEY_DOWN && servoTime1 >= 1000)
        servoTime1 = servoTime1 - 1

    // and do other things
    ...
    loop
```

Listing 2

```
int servoTime[10]          // timeout for servos
int currentServo = 0;

On_2_milli_Seconds:
    Output[currentServo] = true
    WaitMicroSeconds(servoTime[currentServo]) // wait
    Output[currentServo] = false
    currentServo = currentServo + 1
    if (currentServo == 10 ) currentServo = 0
    Return                  // from interrupt routine

OnInit:
    servoTime[0] = 1000
    servoTime[1] = 1100
    ...
    servoTime[8] = 1800
    servoTime[9] = 1900

while( 1 )
    // code to adapt servoTimes
    loop
```

Listing 3

```
0 0 0 0 0 0 0 0 all motors off

On_20_milli_Seconds:
1 1 1 1 1 1 1 1 switch all motors on \
    Wait 1000 +d0 microseconds |
1 1 1 1 1 1 1 0 switch motor 0 off |
    Wait d1 microseconds |
1 1 1 1 1 1 1 0 switch motor 1 off |
    Wait d2 microseconds | between
1 1 1 1 1 1 0 0 switch motor 2 off | 1 and 2 ms
    ... |
1 0 0 0 0 0 0 0 switch motor 6 off |
    Wait d7 microseconds |
0 0 0 0 0 0 0 0 switch motor 7 off /
```

micro to handle the delta time and the masks as foreground tasks.

K. Wessing (Netherlands)

Inaccurate DIY shop multimeter (1)

Dear Jan — as an owner of a 'DIY shop multimeter', I was naturally interested in the article in the February issue. My meter looks exactly the same, but it is called 'Digi-tool'. I don't remember any more how long I've had it, but it's probably about two years now. At the time, I was attracted by the accuracy of 1% for a price of (at that time) £ 12. I had to have it! Then I could finally do all those jobs accurately that had been waiting for so long



(and are still waiting). Since I bought the meter, it hasn't seen that much use.

Last week I bought a new power supply for my computer. As the motherboard (also new) didn't want to start up, I began by checking the output voltages of the supply, and to my surprise the 12-V and 5-V outputs were both much too low (10.6 V and 4.6 V), but even so my old motherboard still worked OK. So I got out my old analogue meter, and it knew how to display the right values. Nevertheless, I did a quick check using the battery voltage of my car with the engine running, measured with the analogue meter: 13 V. Conclusion: the analogue meter gives a better indication of the actual voltage than the

meter from the DIY shop. The latter is now sitting in the only place where it is useful: in the caravan as a sort of glorified voltage tester.

The article says that 'the stated specifications are guaranteed for one year, after which calibration may be necessary'. I would suggest changing that to '...after which calibration may still be possible'.

F.R. Goodmans (UK)

The deviations you found are indeed quite large. They can probably not be corrected by recalibration. Naturally, we do not have any experience with the long-term accuracy of such meters, but it is obvious that you can't expect too much from the internal mechanical construction (rotary switch) of a meter that



sells for 5 pounds. In light of the low price, it might not hurt to take the entire meter apart to see whether some of the contacts are oxidised.

Inaccurate DIY shop multimeter (2)

Dear Jan — suspecting massive inaccuracy from a cheap DMM like the one you described in your February edition, I hooked up a 'known-good', digital instrument in parallel for a couple of simple measurements. The differences were considerable and as it turned out, caused by a flat battery in the £ 5 instrument. After replacing the battery, the accuracy was perfectly acceptable again — apparently it's

strongly dependent on the raw supply voltage and I would advise all users to check their batteries from time to time.

Edward Piso

Thanks for that Edward, again it points to economies in the electronic design, in particular, the supply regulation.

A handmade resistor

Dear Elektor readers — have you ever needed an oddball resistor value like 3 k Ω and there's nothing to match in the component drawers? Cut off a slice of 'IC foam' (yes the conductive black stuff they use to prevent ESD on ICs during transport and handling), use your ohmmeter and trim the piece to the desired value. I tested it for an LED and it worked just fine!

Nivard (by email)

Seems like clever method but not sure about the stability of the resistance and of course the current rating!

Which Brain for my Robot?

Dear Jan — your fine overview of microcontrollers published in the Summer Circuits 2007 issue on robotics mentions a number of devices that are pin compatible with the BS2. Although I appreciate the difficulty in covering each and every compatible micro, I would like to mention that

1. The StAver-24M32 is a module containing an Atmel ATmega32 that's programmed over RS232. To program it you need BASCOM-AVR or WinAVR.

2. ARMexpress modules offer 16 TTL compatible digital IO lines and an equally simple to use serial interface. There exists a simple to learn Basic Compiler and a pre-configured C Compiler (see www.coridumcorp.com). As opposed to

Corrections & Updates

Coil Clinic - June 2007, p. 62-65, ref. 060195-I

The 'Low Battery' message is erroneously displayed when the battery voltage is sufficiently high. The problem is conveniently solved by replacing R2 (10 k Ω) with a 56 k Ω resistor.

Voltage Stabiliser - July/ August 2007, p. 86, ref. 070280-I

The input voltage range for this circuit is 3 V to 25 V, not 13 V to 25 V as indicated in the circuit diagram.

Tube Sound - June 2007, p. 38-44, ref. 070067-I

The circuit diagram in Figure 5 contains a few errors. The correct rating of C6 and C7 is 47 μ F / 100 V as indicated in the parts list. Also, C7 should be reversed, i.e. the negative terminal is connected to ground.

The ratings of the fuses shown in Figure 6 are higher than those stated in the parts list. The lower ratings are adequate however.

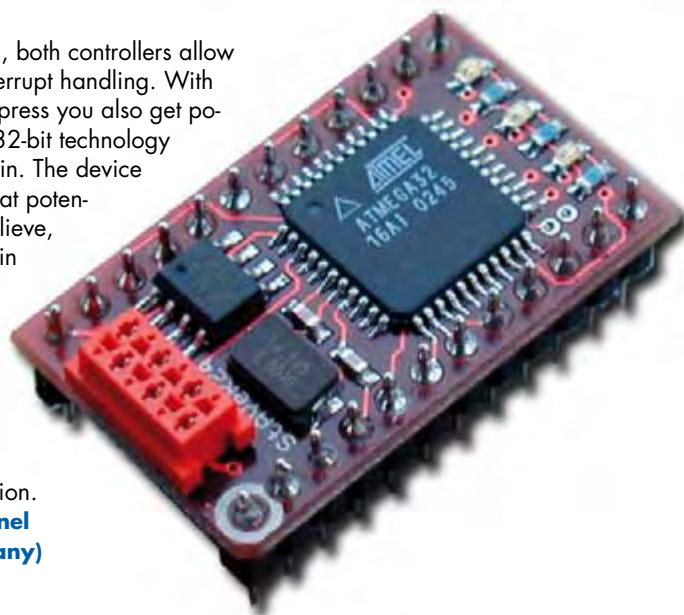
Speedmaster - May 2007, p. 50-55, ref. 070021-I

As correctly indicated by the text and the PCB design, output 15 of the sensor (XOUT) is connected to the AN0 input of the R8C via a 1-k Ω resistor. In the circuit diagram however, AN0 and AN2 are shown reversed. XOUT should go to AN0 and ZOUT, to AN2.

the BS2, both controllers allow real interrupt handling. With ARMexpress you also get powerful 32-bit technology thrown in. The device has great potential I believe, for use in came-

ras to give robots vision.

C. Kühnel (Germany)



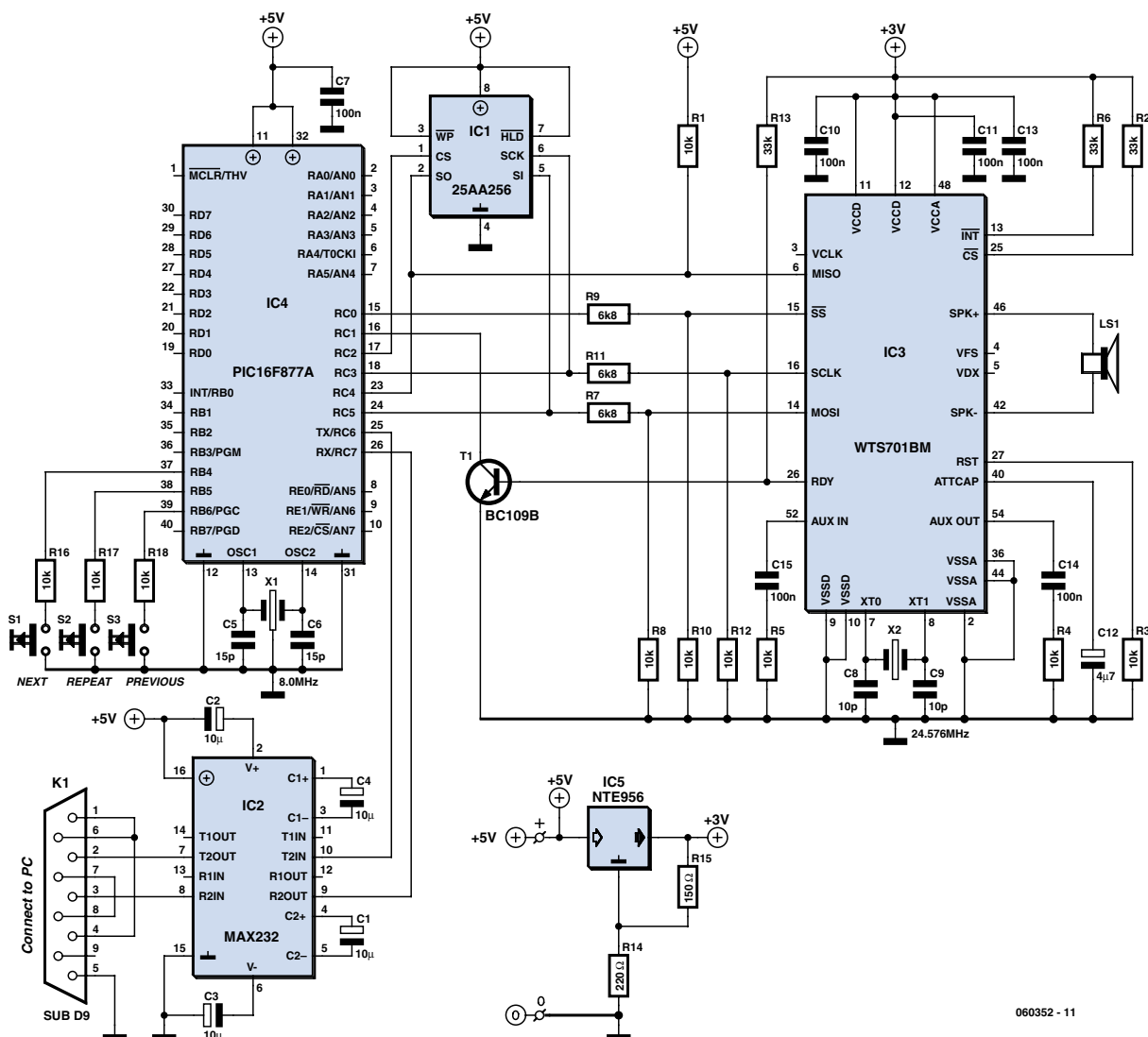
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E-Dictator



060352 - 11

Alexander Pozhitkov

Here is a microcontroller-based system that acts like a speech-enabled reminder with a very intuitive interface.

The user interface of the E-dictator is very intuitive and simple. Upon turning the system on, it is immediately able to reproduce stored messages or record new ones. All messages recorded into E-dictator are stored in non-volatile memory.

To record new messages, E-dictator must be connected to a PC via a serial port and connector K1. Any terminal program (such as HyperTerminal) set to 19200, 8, N, 1 should do. No commands whatsoever are necessary to make E-dictator start recording: just paste your text into the message window or use Send Text File from the Transfer menu (HyperTerminal). Every character received by E-dictator is echoed to the PC allowing the user to visually check the data transfer, at the end of which E-dictator automatically stops receiving.

Paragraphs of uploaded text are separated by a carriage return (CR). There is no limit to the size of the paragraphs (i.e. message). The only limit is the total volume of text that can be uploaded, which is determined by the capacity of EEPROM (IC1). Currently, 32 kbits of text can be uploaded into E-dictator.

Once the text has been uploaded, the buttons 'Next', 'Repeat' and 'Previous' will prompt E-dictator to reproduce the messages.

The speech processor and EEPROM interact with the microcontroller via an SPI interface, which is implemented via RC3, RC4 and RC5 pins of the micro. The ICs are activated one at a time via RC0 and RC2 outputs of the microcontroller. Voice output is by way of a miniature 8-Ω loudspeaker.

The speech processor (IC3) is a Winbond device produced in four versions: male or female voices for English or Chinese languages. Its processor has SPI connectivity covering data, control and status. Of the other pins that can be used to monitor the status of

the processor, E-dictator employs only one, called 'Ready' (RDY). Resistors R7-R12 act as voltage dividers to adjust 5-V logic to 3-V logic on the speech processor input lines. The open-drain output of the speech processor (MISO) is tolerant of 5-V swings, allowing a seamless connection of the speech processor to the microcontroller. RDY is an open-drain feedback pin pulling Low when the internal buffer of the speech processor is full. RDY was found to be 5-V intolerant, i.e. major faults would occur in the operation of IC3 if this pin was pulled up to 5 V. Therefore, transistor T1 is necessary to adjust voltage levels.

The software was written in assembly language using Microchip IDE. The PIC program is organized in an event-driven fashion. An event loop is constantly running upon the program start. Two conditions cause the loop to break: occurrence of a data character in the UART buffer or a press-button event.

Recording messages. When data arrive to the UART buffer, the program switches to a message recording mode. In this mode, as soon as the character arrives to the UART buffer it is echoed back to the PC and also immediately transferred into EEPROM via the SPI. The EEPROM can only continuously receive up to 64 bytes, which is determined by its paged organization. As soon as the 64-byte page is full, the EEPROM needs some time (up to 5 ms) to actually store the data. While the EEPROM is completing its internal write cycle, the PC does not stop transmitting characters. Those characters are temporarily stored in the RAM of the microcontroller until the EEPROM is ready for more data. As soon as that is the case, the stored characters are flushed into the EEPROM. After

that, the microcontroller returns to its regular procedure of direct transmission of the data from the UART to the EEPROM. Recording mode stops when a timeout occurs in the data transmission, which causes the program flow to return to the event loop.

Playing back messages. When you press a button, this event is registered and the program flow is diverted from the event loop to a speaking mode. The PIC micro maintains a pointer to the current message. If the user pressed 'Repeat', then microcontroller retrieves text from the EEPROM starting from the appropriate address. Due to the EEPROM and speech processor sharing the same SPI bus, the PIC micro stores a portion of the text message in its internal RAM and uploads text into the speech processor piece by piece: while the speech processor is interpreting and speaking the text, the microcontroller retrieves further parts of the message from the EEPROM and stores in its RAM. This procedure continues until the entire message is transferred from the EEPROM to the speech processor.

If the user presses 'Previous' or 'Next', the program scrolls through EEPROM to locate the appropriate message. When it is located, the program executes the same procedure as described in the previous paragraph.

(060352-1)

The project software is available as a free download from www.elektor.com. Follow Magazine → October 2007 → Mailbox.

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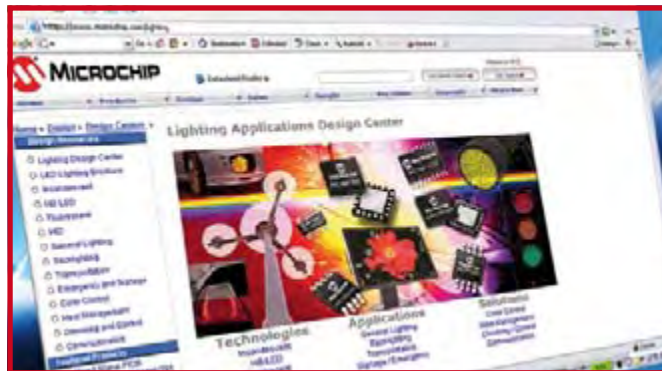
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Online lighting applications design centre

Microchip announces an online Lighting Applications Design Centre on the internet. The comprehensive website provides a wide range of technical tools and resources that designers can use to add intelligence to lighting designs — including information relating to Microchip's PIC® microcontrollers, dsPIC® Digital Signal Controllers (DSCs), analog and memory products, as well as development tools.



New lighting technologies, such as light emitting diodes (LEDs),

dimnable fluorescent ballasts and high intensity discharge (HID)

lamp ballasts, demand increased performance with greater energy

efficiency. The flexibility of Microchip's low-cost digital, analog and memory products enables designers to easily add intelligence to lighting applications.

Benefits include energy savings, prolonged product life, improved safety and light quality, reduced component counts, remote control and diagnostic capabilities, and the ability to easily adapt existing lighting designs.

www.microchip.com/lighting

(070679-5)

Test-pins dot co dot uk

Allendale Electronics are pleased to announce the launch of test-pins.co.uk, an eCommerce shop for all your test pin and receptacle requirements. The company stocks a wide range of test pin head and styles including, Convex, Concave, Spear, Serrated, Plain Radius, Crown. Our Website offers a cross reference search of other manufacturers of Test Pins, providing you with our direct equivalent.

Test-pins has a secure online shop, with a wide range of shipping options including time definite such as by 9am Next Day, Pre noon and



even a Saturday Delivery Service. The P50 Series are ideal for between centres down to 1.27mm and a current rating of 3 A. Likewise the P156 Series is suitable for 3.97mm between centres and have a current rating of 5 A. Test pins have a brass barrel with

gold plate finish construction and the plungers are heat-treated beryllium copper rhodium plated over hard nickel for reliable contentions and long life probes.

All test pins are available in two spring pressures – full technical data and drawings available on

the website.

Custom test pins can be manufactured from small to large volume to customers requirements and to suit individual applications.

(070679-1)

**Allendale Electronics Ltd.,
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Web: www.Test-pins.co.uk,
email: Sales@Test-Pins.co.uk**

PowerBench for power supply engineers

Vicor announces the launch of PowerBench™, a suite of online power supply design tools that helps ensure designers select the best power supply to meet their requirements. If an appropriate standard product does not already exist, engineers can use PowerBench to design a customer-specific product, allowing them to focus on their ideas rather than the constraints dictated by power supply availability.

By uniquely integrating design, ordering, and manufacturing processes, PowerBench minimizes costs and lead time. The tools also provide unprecedented levels of information such as immediate price and availability quotes, giving complete control to the user. PowerBench enables engineers to determine whether a standard,



existing non-standard or customer-specific specification power supply will best meet the needs of their application. Vicor is the only power supply company to manufacture

all products – whether standard or customer-specific – using the same production line and process. This reduces NRE, costs and lead times, ensuring comparable pricing for

standard and non-standard supplies as well as the same outstanding levels of quality and reliability for all products.

Engineers use PowerBench's module design system to specify online the exact power supply they need and verify in real time its performance and attributes. This eliminates the risk of specifying the wrong power supply for the application. PowerBench tools encompass the design of DC-DC converters, AC-DC and DC-DC partitioned power architecture (VIPAC and VIPAC Arrays), and a broad range of power-factor corrected AC-DC power supplies.

www.vicoreurope.com/powerbench

(070679-VII)

Robots donated to schools and colleges

The InstMC Wessex Section has donated a number of Lego Mindstorms Robot kits to Education Establishments in the Hampshire and Dorset Area and is aiming for more donations in the future due to the great feedback received so far.

Donations are being funded from Social Events run by the Section with many more such events being planned.

The Lego Mindstorm Education kits comprise a programmable processor and I/O brick with a cut-down version of industry standard software LabView NXT.

The brick takes inputs from a very wide range of sensors (movement, proximity, temperature, sound, light, touch together with being able to drive actuators and motors with positional feedback.

The command and reaction code is programmed graphically with nesting, branching and feedback loops in abundance but is suitable for young children as well as Instrumentation and Control System Engineers. The processor bricks can communicate with each other over Bluetooth as well as to a programming and monitoring PC.

The online Mindstorms community is vast with downloadable code blocks, example projects, videos of others creations and competitions.



Mr. John Lambert, Teacher at Shirley School receives the robot kit.



Cevn Vibert (centre left holding robot) and Dr Klaus-Peter Zauner (holding kit box), with Kisan Visavadia (far left) and Richard Ashley-Smith (far right), and in front, Rob Spanton and Stephen English of the Student Robotics Club, and Philip Bennett.

Southampton University Students are creating a robot competition for Hampshire schools to encourage robotics and other engineering fields to flourish. So far eight schools have confirmed they will compete to construct fully autonomous robots. The team are still seeking sponsorships! Joyce Lewis, Marketing and Communications Manager for School of Electronics and Computer Science University of Southampton, said "It was very good to welcome you to the School and we are all delighted with the robot! Thank you so much!"

Dr Klaus-Peter Zauner, ECS Tutor at Southampton University, teaches a course on Biologically-inspired Robotics and for example is working on robots controlled by slime mould!

Southampton Saints Radio broadcast an interview with Cevn Vibert, Education Officer for Wessex InstMC also MES Business Manager for

Silchester Control Systems, and caught up on the vital need for more Engineers in the UK to continue the UK's global strength in innovation.

King Edward VI School will be using the donation education kits to help promote the vital 'engineering spark' to young students up to GCSE level.

Shirley School will be working with young people during science and after school clubs to demonstrate robotics, learn construction, instrumentation and motion programming skills.

Wessex Section are doing their bit for the Institute's Royal Charter: "To promote for the public benefit, by all available means, the general advancement of the science and practice of measurement and control technology and its application." This, coupled with frequent schools and colleges visits for open days and student talks is what the section can do with only volunteers but is it enough for the UK's future? What can you do?

(070679-III)

www.instm.org

www.studentrobotics.org

<http://www.ecs.soton.ac.uk/about/news/1273>



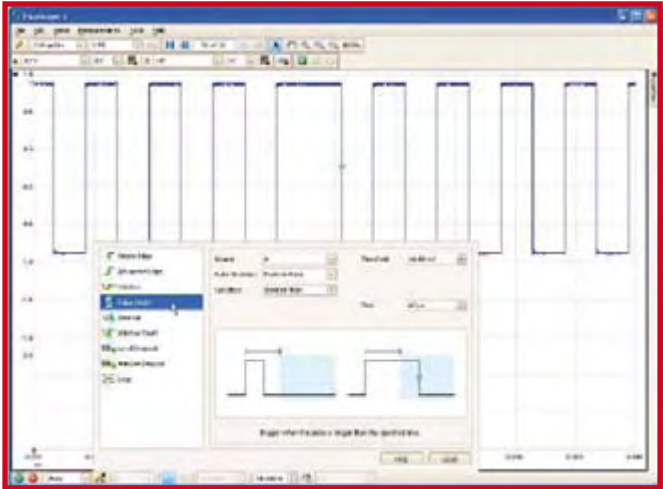
At King Edward VI School, Mr. Simon Barker, Head of Design Technology was awarded the Lego Mindstorms robot kit.

PicoScope 5000 PC oscilloscopes with new advanced trigger types

Pico Technology, have just added a set of advanced trigger types to the PicoScope 5000 series scopes to make it easier to trigger on complex waveforms.

The PicoScope 5000 series PC Oscilloscopes are Pico's top-performing scopes, with the world's fastest real-time sampling rate, for a USB PC scope, of 1 GS/s. This, together with a probe-tip bandwidth of 250 MHz, makes them ideal for use with high-speed analogue and digital signals. The scope's huge memory buffer — either 32 M or 128 M samples depending on the version — ensures that the high sampling rate can be used on a wide range of timebases without losing detail.

The new advanced trigger types are part of a continuing programme of upgrades for the PicoScope 5000 series scopes, which has recently seen the addition of



an auto-setup command and a new spectrum view. The new trigger types are dual-edge, window, pulse-width, drop-out, interval and logic triggering. Window triggering detects when signals go into or out of a given range, so is useful for finding overvoltages. Pulse-width triggering can recognise

short or long pulses, so helps you find glitches and timing violations. The drop-out trigger finds the moment when a repetitive signal, such as a clock, goes dead. Interval triggering detects when two successive clock edges fail to meet a timing condition. Finally, logic triggering lets you trigger on practically any

combination of up to four input levels or voltage windows.

If you're troubleshooting digital signals, you will be able to use these new trigger types to obtain a stable display of complex digital waveforms such as serial data streams and control signals. The PicoScope 5000 series scopes are ideal instruments for digital troubleshooting because of their high sampling rate and large buffer size, which when used together allow you to capture long-duration snapshots with high time resolution.

The latest PicoScope 6 upgrade with advanced triggering is available now for download, free of charge, from the Picotech website.

www.picotech.com

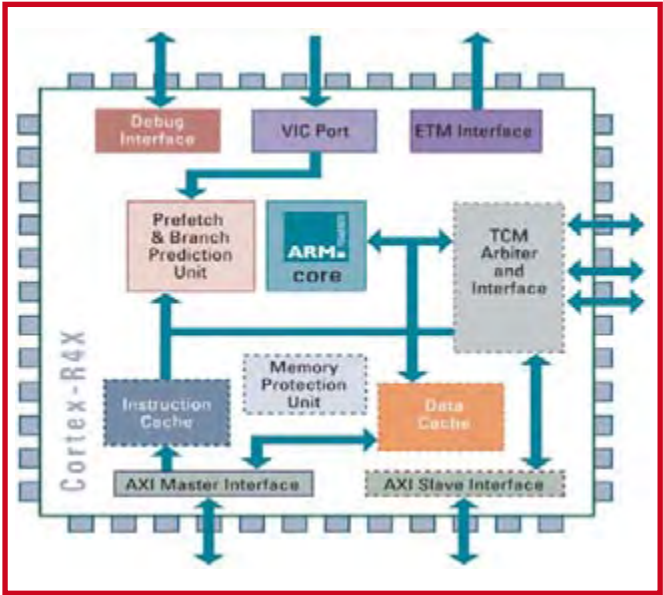
(070679-II)

Cortex-R4X processor implementations

ARM and Intrinsicity, Inc. announced their agreement to produce high-performance implementations of the ARM® Cortex™ family of processors. The first of these will be implementations of the Cortex-R4 processor operating at around twice the frequency achievable using standard synthesis techniques on the same silicon process.

The processor implementations incorporate Intrinsicity's Fast14® 1-of-N Domino Logic (NDL) technology, which enables faster circuit speeds while minimizing power consumption and area. The ARM Cortex-R4X processor implementations enable higher capacity and data rates without increasing unit costs for very high-volume, deeply embedded applications such as hard disk drives, printers and networking equipment.

The Cortex-R4X processor implementations incorporate all of the advanced features of the popular Cortex-R4 processor. These enable the execution of complex control algorithms and real-time workloads in next-generation embedded systems, while maximizing power efficiency. The extremely flexible lo-



cal memory architecture enables the tightly coupled memory (TCM) to be unified into a single logical address space while providing the same performance as cache memory. Straightforward direct memory access (DMA) support for the TCM extends the use of this memory for shared buffers and streaming data.

In addition, all versions of the Cortex-R4 processor offer embedded Error Correcting Code (ECC) technology which monitors memory accesses to detect and correct errors, providing very high reliability and availability. The advanced AMBA® 3 AXI compliant bus interfaces allow high performance memory backplanes to be implemented us-

ing the ARM PrimeCell® portfolio. Various configurations of the Cortex-R4 processor will be available as Cortex-R4X implementations, on a range of silicon processes. The first implementation will operate at 600MHz under worst-case operating conditions on the TSMC 65LP process. As a cycle-accurate implementation of the Cortex-R4 processor it executes all the same software binaries, and is fully supported by the RealView® Development Suite. Standard Cortex-R4 processor models can be used for cycle accurate modelling of the Cortex-R4X processor implementation with RealView SoC Designer, offering rapid prototyping and architectural exploration.

The Cortex-R4X processor implementation is available for licensing from ARM immediately, with delivery expected in Q1 2008. ARM Partners will be able to choose among a range of off-the-shelf fixed configurations, with the option to order custom configurations as needed.

www.intrinsicity.com
www.arm.com

(070679-IV)

BitScope USB Mixed Signal Oscilloscope

Analog + Digital

Digital Storage Oscilloscope

- ✓ Dual Channel Digital Scope with industry standard probes or POD connected analog inputs. Fully opto-isolated.

Mixed Signal Oscilloscope

- ✓ Capture and display analog and logic signals together with sophisticated cross-triggers for precise analog/logic timing.

Multi-Band Spectrum Analyzer

- ✓ Display analog waveforms and their spectra simultaneously. Base-band or RF displays with variable bandwidth control.

Multi-Channel Logic Analyzer

- ✓ Eight logic/trigger channels with event capture to 25ns.

DSP Waveform Generator

- ✓ Built-in flash programmable DSP based function generator. Operates concurrently with waveform and logic capture.

Mixed Signal Data Recorder

- ✓ Record to disk anything BitScope can capture. Supports on-screen waveform replay and export.

User Programmable Tools and Drivers

- ✓ Use supplied drivers and interfaces to build custom test and measurement and data acquisition solutions.

Inventing the future requires a lot of test gear...

...or a BitScope



BS100U Mixed Signal Storage Scope & Analyzer

Innovations in modern electronics engineering are leading the new wave of inventions that promise clean and energy efficient technologies that will change the way we live.

It's a sophisticated world mixing digital logic, complex analog signals and high speed events. To make sense of it all you need to see exactly what's going on in real-time.

BS100U combines analog and digital capture and analysis in one cost effective test and measurement package to give you the tools you need to navigate this exciting new frontier.



Standard 1M/20pF BNC inputs

Smart POD Connector



Opto-isolated USB 2.0

12VDC with low power modes

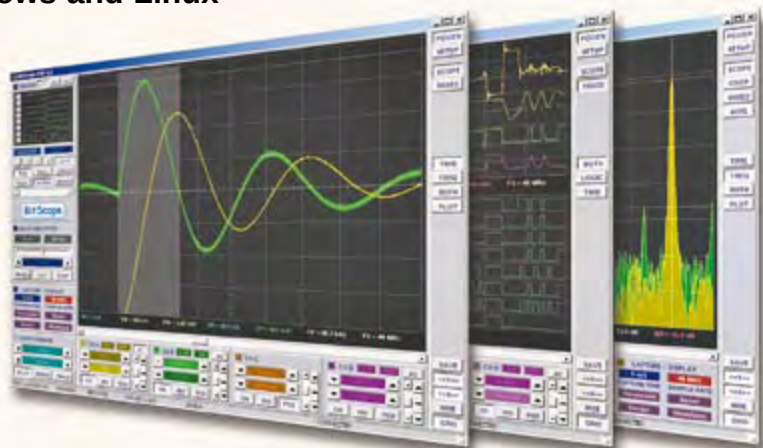
BitScope DSO Software for Windows and Linux

BS100U includes BitScope DSO the fast and intuitive multichannel test and measurement software for your PC or notebook.

Capture deep buffer one-shots, display waveforms and spectra real-time or capture mixed signal data to disk. Comprehensive integration means you can view analog and logic signals in many different ways all at the click of a button.

The software may also be used stand-alone to share data with colleagues, students or customers.

Waveforms may be exported as portable image files or live captures replayed on another PC as if a BS100U was locally connected.



www.bitscope.com

Elektor electronics



Elektor House,
it doesn't get more
historical than that!

Wisse Hettinga

For more than 40 years Elektor has taken its readers on a journey of discovery through the world of electronics. First in the Netherlands, and quickly followed by other countries and language areas. The unique formula of this magazine has withstood the test of time. The magazine, the books and events, the projects you can build yourself — all in all an enormous collection of activities and this goes around the whole world. Hence the byline electronics worldwide. What's in a name?

The answer is given by our readers themselves. Mention *Elektor* in an arbitrary group of boffins or techies and everyone will come up with a different story, anecdote or memory: the first radio or amplifier, the first computer, the first ... name whatever you like! A great many readers, now often with good jobs in process automation or electronic product development made their first steps with the help of *Elektor* magazine. Putting aside a sense of modesty: in these 43 years *Elektor* has written 'electronics' history and built an enormous reputation while half a dozen competitors fell off their perch. All this time *Elektor* has been true to its principles: unless otherwise indicated, circuits described have been tested and work; all designs are repeatable and the

magazine has always closely followed the latest technology. However, since the beginning of the 1980's the evolutionary pace of electronics has also become the greatest threat. With the arrival of ICs, surface mounted technologies and digital technology, building things yourself became less attractive and viable. At the same time, consumer electronics became considerably cheaper, which removed an important argument for making things yourself. Disappeared completely? No, building and discovering things for yourself continues to have unbelievable attraction, and worldwide many people occupy themselves doing this, either privately or professionally.

s worldwide

The secret

For the big secret behind *Elektor* as a publication and institution we have to look across **all** borders. Soon after the launch of the Dutch edition in 1964 it became clear that there was also potential in other countries. A German edition quickly followed and in a few years the circulation increased there to 100 kcopies. After that came the United Kingdom (1974) and France (1978). We recently also launched *Elektor* in Spain. With our own activities and licences, websites in five languages, a large selection of books and live events we inform an audience of 2 million people worldwide. We receive reactions and mail from the entire world about our articles and products. We are, to be honest, quite proud of this. Even better than this, we see good opportunities for further expansion of the title into more countries, regions and/or language areas. We are currently taking the first steps to develop activities in China and Eastern Europe. To give shape to all plans and ambitions we have changed the name of the publisher from Segment to **Elektor International Media** and the name of the Dutch language magazine is changed from *Elektuur* to *Elektor* to bring it in line with all other editions.

"The purpose of the publication remains unchanged however" were the words of Bob van der Horst at the launch of the Dutch *Elektuur* in 1964, when referring back to his earlier publication *Elektronica-Wereld*. "We will be primarily practically oriented and in this way supplement the theoretically oriented foreign magazines". Words to the same intent can still be said today. In as much as the first *Elektor* was about informing, inspiring and activity, discovering for yourself all the things you can do with electronics, *Elektor* these days is no different: we remain very much a projects-oriented and hands-on magazine. *Elektor* continues to explore the boundaries of electronics, and everyone is invited to come along to discover and experience. We have however entered the path of professionalism more and more. Indeed, exactly those people who say: "*Elektor*, now wasn't that the hobby mag from the seventies? Amazing to see you're still around".

Turning your interests into a job

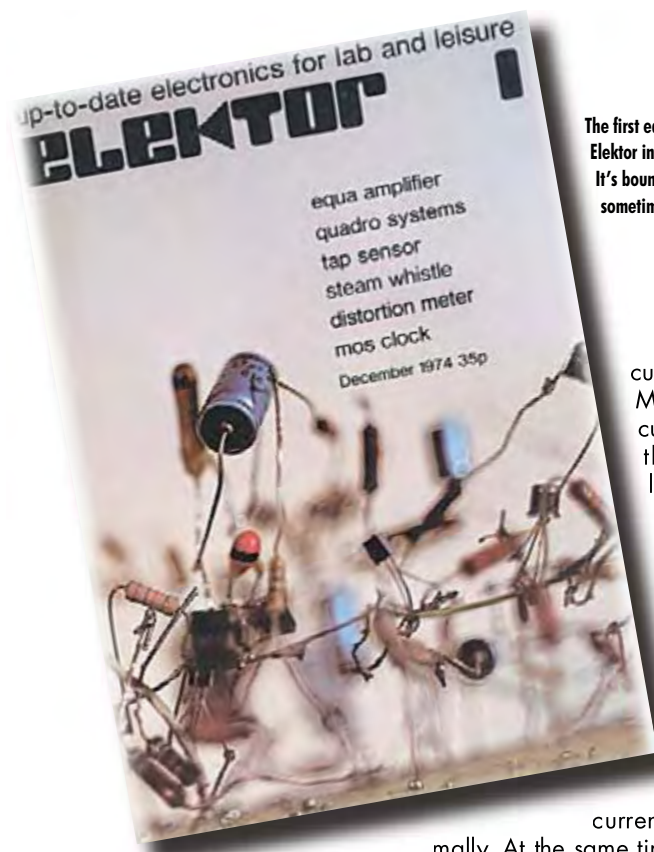
We ourselves prefer to call it a 'special interest' magazine. A whole generation of readers have literally turned their hobby into a profession and so gave proof that 'interest' does not distinguish between spending time at 'work' or 'leisure'. You just have it. We know that many professionals read the magazine as a source of ideas for new technologies or chip sets. Via the website alone you can find hundreds of cir-

Borders, what borders? An illegally translated and published version of *Elektor's* 308 Circuits book pictured in Iran. Well it's all Greek to us!



That's him! Jan Buiting, editor of this the English-language edition of *Elektor* has been with the company since 1985. Jan's cherished projects are the 1986 *Elektor* Satellite Receiver and the 1989 Filmnet Decoder. Both projects were authored by him in collaboration with two friends (who shall remain anonymous). The Filmnet decoder resulted in a sell-out of the magazine, extensive press coverage and about 20,000 units built, mainly in the UK and Scandinavia.





The first edition of
Elektor in English.
It's bound to appear
sometime on Flog It!

cuits and designs. Many of these circuits have found their way into large and small applications.

As we said before; the secret of *Elektor* is its multilingual approach.

The individual language-defined markets are

currently served opti-

mally. At the same time, we see new regions with in increasing interest in electronics and in particular what you can do with it yourself. Eastern Europe and China are prominent examples of this. Step by step, we discover the possibilities for us, and – this may sound a bit strange – for you as well. As an invariable part of the formula for the magazine, exploring new developments for the magazine is of great interest not just for the publishers but for readers as well.

With the recent addition of a Spanish *Elektor* there will certainly be a new influx of information and ideas. Just thumb through the magazine — in your issue you will see contributions from authors/designers whose native tongue is German, English, Dutch or French (but also Finnish, Danish, Portuguese, Turkish or Greek in which case manuscripts are supplied in basic English). The PR4401 LED driver board that was added free on the cover of the September 2007 issue of *Elektor* was a joint effort between German and Dutch companies. A total of 150,000 of these tiny PCBs will enter the market!

International cooperation is a daily reality for *Elektor*. We have language-specific editors directly in house and we hope to add a Spanish speaking colleague to the team soon. All language editions are written, DTP'ed and printed simultaneously, or at least in true multitasking fashion to strict deadlines. At our central production offices you will hear at least four languages spoken every day (not including dialects and accents).

The English version of *Elektor* has been on publication without fail these past 33 years. Articles originate from an original (language) version and are given a template-like layout by our in-house DTP staff. The original language is always one of four we publish in: English, Dutch, French or German. Translated versions are produced from the original material, and the language editors provide for a localised News, Products & Market section in the magazine, as well as for Mailbox and the readers forums. In addition there are language-specific websites, the largest of which is the English-language one at www.elektor.com.

The lab

Almost everything we publish in the magazine goes through the *Elektor* lab first. Here we test, develop, build prototypes and design the modules for DIY construction and sale through our SHOP (formerly 'Readers Services'). Furthermore, there is a continuous stream of responses and questions from readers and companies, which all have to be answered. In this way the lab plays an important role in the formula for the magazine and is at the same time a source of inspiration. All new technologies, development kits and equipment come to life here. It is conspicuous that visitors from companies are always keen to sit in the lab. They are apparently at ease among all the technical bric-a-brac, measuring equipment, modules, components and tools! At our new location we have also made room for the audio lab. Here we can thoroughly test amplifiers, filters, using our dependable 20k Audio Precision 2722 rig.

An important activity in the lab is the design of PCBs for circuits. In 2007 the lab team migrated from Ultiboard to Altium Designer PCB layout software. At the same time, we see that via the lab we have more and more contact with companies that are also active in the area of electronics design, manufacture and development. We are always looking for new ways of cooperation.

Elektor Live

A new addition to our product range goes by the name of *E-vents*. These include a series of masterclasses where designers, authors and experts from the industry share their knowledge on, for example, audio, PCB design and home automation. In addition we will be organising a number of company-sponsored events for our readers. It works along the line of: *Elektor* opens doors that normally remain closed. We have made agreements with a number of market leading companies for events or training/instructions day(s) for our readers. In this way, readers obtain direct access to very specific information about a certain type of product that's introduced on the market by that company or institution. It's all low-profile, but the house is always full.

To the castle

We do all this with about 40 staff from our central offices in Beek, near Maastricht in the Netherlands. Beek, of all places? It's not that surprising. The founder of *Elektor*, Bob van der Horst, happened to live there and the company grew from his attic. A (then) contemporary office building was literally built in his back garden in 1975. Because of all the activity around *Elektor* this building is now entirely worn out and we move to premises with more character; a real stronghold, the 13th century **Castle Limbricht**, about 15 km from the Beek location. The castle, now rebaptised **Elektor House**, has been there for centuries and appears to be eminently suitable for all our new activities.

The future

The secret for *Elektor* is that we refuse to see borders or barriers *anywhere*. The same is true for the future — adding new languages to the list of activities appears to be a good strategy for the magazine. Not all that surprising, really. Electronics is not, and never was, bound by country borders and users — developers work, (re)search and inspire each other worldwide, using English as the *lingua franca* but also their native tongue — hence: *electronics worldwide*.

(070661-1)



CAN-1 Board - Interface CAN via MCP2551.

CANSPI Board - Make CAN network with SPI interface.

RS485 Board - Connect devices into RS-485 network

Serial Ethernet - Make ethernet network with SPI Interface (ENC28J60).

IrDA2 Board - Irda2 serve as wireless RS232 communication between two MCU's.



CF Board - Easy way to use Compact flash in your design.

MMC/SD Board - Easy way to use MMC and SD cards in your design.

EEPROM Board - Serial EEPROM board via I2C interface.

RTC Board - PCF8583 RTC with battery backup.



ADC Board - 12-bit analog-to-digital converter (ADC) with 4 inputs.

DAC Board - 12-bit digital-to-analog converter (DAC) with SPI.

Keypad 4x4 Board - Add keypad to your application.

Accel. Board - Accel. is an electronic device that measures acceleration forces.



PICFlash programmer - an ultra fast USB 2.0 programmer for the PIC microcontrollers. Continuing its tradition as one of the fastest PIC programmer on the market, a new PICFlash with mikroCD now supports more PIC MCUs giving developer a wider choice of PIC MCU for further prototype development.

mikroCD debugger enables you to execute mikroC / mikroPascal / mikroBasic programs on the host PIC microcontroller and view variable values, Special Function Registers (SFR), memory and EEPROM while the program is running.

- All of our products are shipped in special protective boxes.

- On-line secure ordering provides fast and safe way of buying our products.

EasyPIC4 Development Board

Complete Hardware and Software solution with on-board USB 2.0 programmer and mikroCD



Following tradition of its predecessor EasyPIC3 as one of the best PIC development systems on the market, EasyPIC4 has more new features for the same price. The system supports 8-, 14, 18, 20, 28 and 40 pin PIC microcontrollers (it comes with a PIC16F877A). **USB 2.0** on-board programmer with **mikroCD** (In-Circuit Debugger) enables very efficient debugging and faster prototype development. Examples in **C**, **BASIC** and **Pascal** language are provided with the board.

LV24-33 Development Board

Complete Hardware and Software solution with on-board USB 2.0 programmer and mikroCD



System supports 64, 80 and 100 pins **PIC24FJ96GA010** - **PIC24** 16-bit microcontrollers (it comes with PIC24FJ96GA010 - PIC24 16-bit Microcontroller, 96 KB Flash Memory, 8 KB RAM in 100 Pin Package). Examples in **BASIC**, **PASCAL** and **C** are included with(in) the system. You can choose between USB and External Power supply. **LV 24-33** has many features that make your development easy. **USB 2.0** on-board programmer with **mikroCD** (In-Circuit Debugger) enables very efficient debugging and faster prototype development.

PICPLC16B Development Board

Complete Hardware and Software solution with on-board USB 2.0 programmer and mikroCD



PICPLC16B is a system designed for controlling industrial systems and machines. 16 inputs with **optocouplers** and 16 **relays** (up to 10A) can satisfy many industrial needs. The ultra fast **mikroCD** (In-circuit Debugger) enables very efficient debugging and faster prototype development. Features : **RS485**, **RS232**, **Serial Ethernet**, **USB 2.0** on-board programmer and **mikroCD** (In-Circuit Debugger) on-board.

mikroElektronika Compilers

Pascal, Basic and C Compilers for various microcontrollers



Supporting an impressive range of microcontrollers, an easy-to-use IDE, hundreds of ready-to-use functions and many integrated tools makes MikroElektronika compilers one of the best choices on the market today. Besides mikroCD, mikroElektronika compilers offer a statistical module, simulator, bitmap generator for graphic displays, 7-segment display conversion tool, ASCII table, HTML code export, communication tools for SD/MMC, UDP (Ethernet) and USB, EEPROM editor, programming mode management, etc.

Each compiler has many routines and examples such as EEPROM, FLASH and MMC, reading/writing SD and CF cards, writing character and graphics on LCDs, manipulation of push-buttons, 4x4 keyboard and PS/2 keyboard input, generation of signals and sounds, character string manipulation, mathematical calculations, I2C, SPI, RS232, CAN, USB, RS485 and OneWire communications, Manchester coding management, logical and numerical conversion, PWM signals, interrupts, etc. The CD-ROM contains many already-written and tested programs to use with our development boards.

mikroElektronika manufactures competitive development systems. We deliver our products across the globe and our satisfied customers are the best guarantee of our first-rate service. The company is an official consultant on the PIC microcontrollers and the third party partner of Microchip company. We are also an official consultant and third party partner of Cypress Semiconductors since 2002 and official consultant of Philips Electronics company as well. All our products are RoHS compliant.

Uni-DS 3 Development Board

Complete Hardware and Software solution with on-board USB 2.0 programmer



The system supports PIC, AVR, 8051, ARM and PSoC microcontrollers with a large number of peripherals. In order to continue working with different chip in the same development environment, you just need to switch a card. **UNI-DS3** has many features that make your development easy. You can choose between USB or External Power supply. Each MCU card has its own USB 2.0 programmer!

EasysPIC4 Development Board

Complete Hardware and Software solution with on-board USB 2.0 programmer and mikroCD



The system supports **18, 28** and **40** pin microcontrollers (it comes with dsPIC30F4013 general purpose microcontroller with internal 12-bit ADC). **EasysPIC4** has many features that make your development easy. Many of these already made examples in **C**, **BASIC** and **PASCAL** language guarantee successful use of the system. Ultra fast **USB 2.0** on-board programmer and **mikroCD** (In-circuit Debugger) enables very efficient debugging and faster prototype developing.

EasyARM Development Board

Complete Hardware and Software solution with on-board USB 2.0 programmer



EasyARM board comes with Philips LPC2214 microcontroller. Each jumper, element and pin is clearly marked on the board. It is possible to test most of industrial needs on the system: temperature controllers, counters, timers etc. **EasyARM** has many features making your development easy. One of them is on-board USB 2.0 programmer with automatic switch between 'run' and 'programming' mode. Examples in **C** language are provided with the board.

EasyAVR4 Development Board

with on-board USB 2.0 programmer



The system supports **8, 20, 28** and **40** pin microcontrollers (it comes with ATMEGA16). Each jumper, element and pin is clearly marked on the board. It is possible to test most of industrial needs on the system: temperature controllers, counters, timers etc. **EasyAVR4** is an easy-to-use Atmel AVR development system. Ultra fast **USB 2.0** on-board programmer enables very efficient and faster prototype developing. Examples in **BASIC** and **Pascal** language are provided with the board.

Easy8051B Development Board

with on-board USB 2.0 programmer



System is compatible with **14, 16, 20, 28** and **40** pin microcontrollers (it comes with AT89S8253). Also there are **PLCC44** and **PLCC32** sockets for 32 and 44 pin microcontrollers. **USB 2.0** programmer is supplied from the system and the programming can be done without taking the microcontroller out.

LV 18FJ Development Board

Complete Hardware and Software solution with on-board USB 2.0 programmer and mikroCD



System supports 64, 80 and 100 pin **PIC18FxxJxx** microcontrollers (it comes with PIC18F87J60 - PIC18 Microcontroller with an integrated 10Mbps Ethernet communications peripheral, 80 Pin Package). **LV 18FJ** is easy to use Microchip PIC18FxxJxx development system. **USB 2.0** on-board programmer with **mikroCD** (In-Circuit Debugger) enables very efficient debugging and faster prototype development. Examples in **C**, **BASIC** and **Pascal** language are provided with the board.

dsPICPRO 3 Development Board

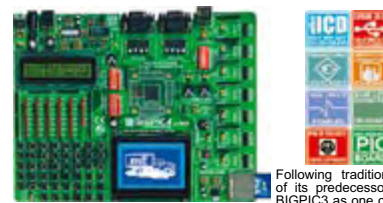
Complete Hardware and Software solution with on-board USB 2.0 programmer and mikroCD



The system supports dsPIC microcontrollers in 64 and 80 pins packages. It is delivered with dsPIC30F6014A microcontroller. **dsPICPRO3** development system is a full-featured development board for the Microchip dsPIC MCU. dsPICPRO3 board allows microcontroller to be interfaced with external circuits and a broad range of peripheral devices. This development board has an on-board USB 2.0 programmer and integrated connectors for MMC/SD memory cards, 2 x RS232 port, RS485, CAN, on-board ENC28J60 Ethernet Controller, DAC etc...

BIGPIC4 Development Board

Complete Hardware and Software solution with on-board USB 2.0 programmer and mikroCD



Following tradition of its predecessor BIGPIC3 as one of the best 80-pin PIC development systems on the market, **BIGPIC4** continues the tradition with more new features for the same price. System supports the latest (64) and 80-pin PIC microcontrollers (it is delivered with PIC18F8520). Many of these already made examples in **C**, **BASIC** and **Pascal** language guarantee successful use of the system. Ultra fast on-board programmer and **mikroCD** (In-circuit Debugger) enables very efficient debugging and faster prototype developing.

BIGAVR Development Board

with on-board USB 2.0 programmer



The system supports 64-pin and 100-pin AVR microcontrollers (it is delivered with ATMEGA128 working at 10MHz). Many already made examples guarantee successful use of the system. **BIGAVR** is easy to use Atmel AVR development system. **BIGAVR** has many features that makes your development easy. You can choose between USB or External Power supply. **BIGAVR** also supports Character LCD as well as Graphic LCD.

EasyPSoC3 Development Board

with on-board USB 2.0 programmer



The system supports **8, 20, 28** and **48** pin microcontrollers (it comes with CY8C27843). Each jumper, element and pin is clearly marked on the board. **EasyPSoC3** is an easy-to-use PSoC development system. On-board **USB 2.0** programmer provides fast and easy in-system programming.

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SOFTWARE AND HARDWARE SOLUTIONS FOR EMBEDDED WORLD

MUGEN - A Hybrid

The best of both worlds?

Wim de Haan

There are many different configurations for audio amplifiers, including types with bipolar transistors, FETs, ICs, and valves. The amplifier described here uses a mixture of transistors and valves to combine the advantages of both approaches and thus deserves the designation 'hybrid'. The result is an amplifier with audiophile performance.

Valves (or 'vacuum tubes') are experiencing a real revival in the audio world, which can readily be seen from the large number of commercial amplifiers and DIY designs that have appeared in recent years.

Unfortunately, valve amplifiers are relatively costly compared with transistor amplifiers, in part due to the need for a high voltage supply and output transformers. Output transformers in particular are a major investment.

This design attempts to remedy this situation by replacing the output valves and transformer by a solid-state circuit using modern transistors, which can drive a loudspeaker directly. Valves are used in the input stage.

Driver circuit

The amplifier (**Figure 1**) consists of a voltage stage and a current stage. The voltage stage, which is the driver portion, is built around valves V1 and V2, and it must provide adequate amplification of the input signal. Here 20 to 30 dB is a practical figure. The current stage, which is built around transistors Q4 and Q5, enables the amplifier to drive 4-ohm or 8-ohm loudspeakers. The current stage acts as buffer and does not have any gain.

The voltage stage has to supply a solid 25 V_{eff} to the current stage to drive the amplifier to its maximum output level. A key factor here is that the signal

must have sufficiently low distortion, since overall negative feedback is not used in this design. The circuit must also be able to drive a load impedance of 10 k Ω , since the driver circuit sees R11 (20 k Ω) in parallel with the combination of P3 and R16 (20 k Ω). The impedance could be increased by bootstrapping or using MOSFET drivers, but bootstrapping and MOSFET drivers do not fit with the concept of this amplifier.

In other projects implemented entirely with valves, the author has acquired experience with driver stages that must supply output signals with large amplitudes and low distortion. The 'long-tailed pair' circuit is exceptionally well suited to this task. This configuration was also chosen because it can act as a phase splitter, which allows a certain trick to be used as explained below.

The long-tailed pair can be regarded as a differential amplifier that amplifies the difference between the signals on the two control grids. The input signal is connected to the 'left' input. The 'right' input is tied to ground here, so the output signal is an amplified version of the input signal. An advantage of this arrangement is that feedback can be connected to the right input, where it will be subtracted from the original signal. This negative feedback reduces the amount of distortion.

The common cathodes of the two

halves of the ECC83 (US equivalent: 12AX7) can be regarded as a third input, which here provides 6 dB of local negative feedback.

A characteristic of the long-tailed pair is that it has two outputs with opposite phases (180 degree phase offset). The left anode is 'in phase', while the right anode is 'out of phase'.

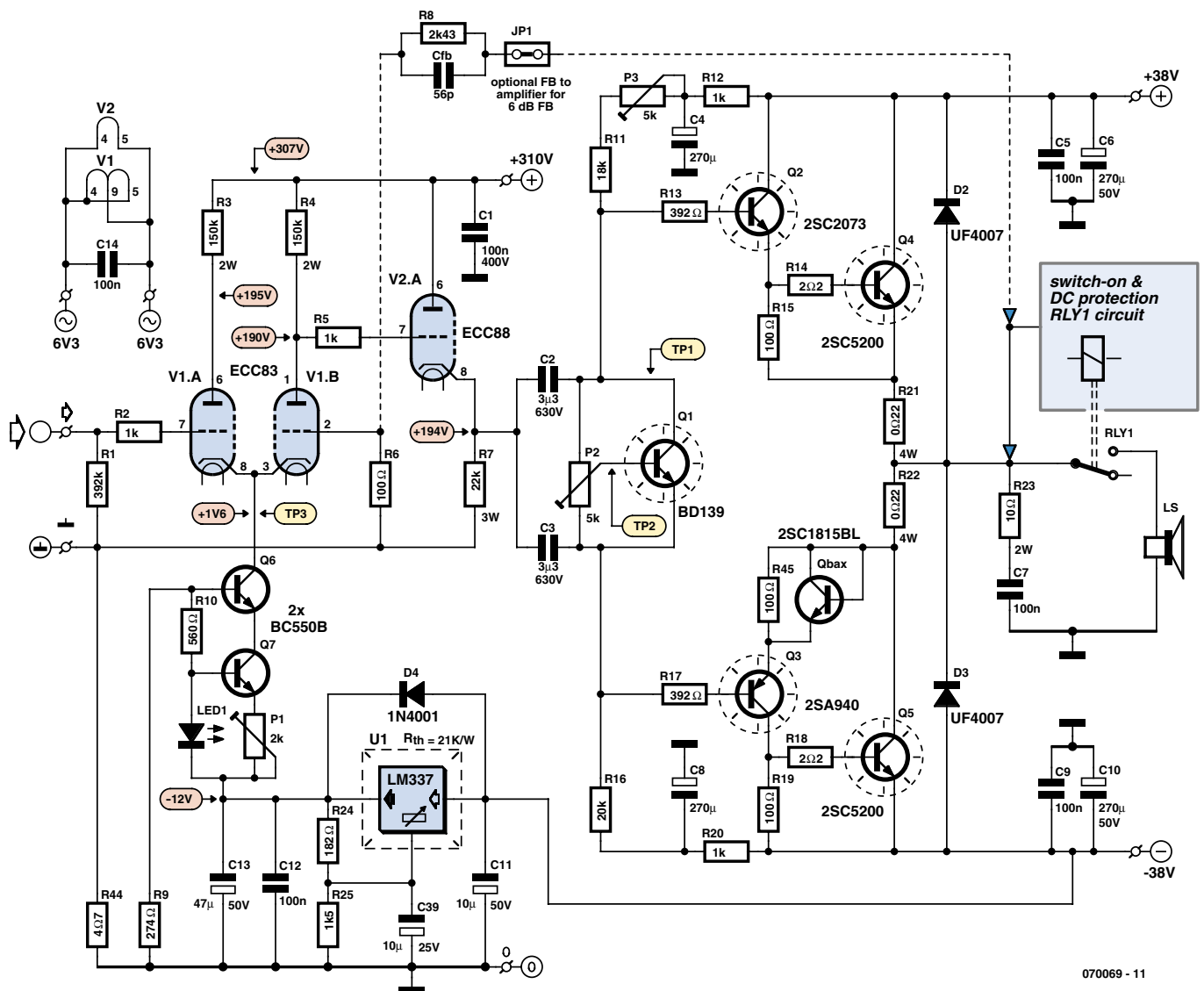
The long-tailed pair normally has a common cathode resistor, which is what gives it its name. A current source is used instead in this design. The high internal impedance of the current source improves the characteristics of the circuit, including the distortion, and the operating current of the ECC83 can be adjusted easily using a trimpot.

Due to its high amplification factor (100) and excellent availability, the ECC83 is the right choice for this application. The need for high gain can be explained as follows. The long-tailed pair has 6 dB of local negative feedback. A normal cathode-resistor or grounded-cathode amplifier built around an ECC83 can provide a gain of more than 35 dB, and the long-tailed pair circuit used here can provide more than 29 dB. The original intention with this amplifier was to avoid using overall negative feedback. However, we have included an option for adding 6 dB of overall negative feedback. A jumper/header is provided on the PCB for this purpose. This allows every-

Mugen Hybrid Amp – Mugen (mu-gen) is a Japanese word that means 'infinity' or 'endless'. 'Endless' is the name of a track on the live CD Changeless by the Keith Jarrett Trio. This piece was the source of the author's inspiration for this design.

Figure 1. The hybrid amplifier has a valve driver stage and a transistor output stage.

Audio Amplifier



Specifications (measured without overall negative feedback)

Input sensitivity:	825 mV (8 Ω) 770 mV (4 Ω)
Input impedance:	300 kΩ
Gain :	29 dB (23 dB with negative feedback)
Output power (1% THD):	70 W into 8 Ω 110 W into 4 Ω
THD + noise	at 1 W/8 Ω : < 0.1 % at 10 W/8 Ω : < 0.15%
Damping factor:	20 (with 8-Ω load)

one who builds the amplifier to decide what he or she finds best. Even with overall negative feedback, the gain is still high enough (23 dB) to provide adequate input sensitivity.

This brings us to the previously mentioned trick. With a normal cathode-resistor circuit, it would not be possible to obtain overall negative feedback by feeding the output signal back to the cathode in the usual manner, because the output signal is in phase with the input signal and this would cause positive feedback. The V1b output signal of the long-tailed pair is out of phase, and this makes overall negative feedback possible.

Overall negative feedback forms the subject of a lot of debate. The author has learned from experience that an amplifier with strong negative feedback has a less open and 'pleasant' sound than a design without negative feedback. A value of 6 dB represents a good compromise.

A disadvantage of the ECC83 is that it has a relatively high output impedance. Consequently, a cathode follower is included after the ECC83 to provide sufficient drive for the transistor stage. The cathode follower has a low output impedance (less than 500 Ω), compared with around 50 k Ω for the long-tailed pair. After much experimenting, the best results were obtained with an ECC88 in this position. The bias is set to satisfy the maximum anode voltage rating of the ECC88 (130 V_{DC}). However, the JJ version of the ECC88 has a maximum anode voltage rating of 220 V, the same as the Philips ECC88. The high value of the cathode resistor of the ECC88 allows the ECC83 to be coupled directly to the ECC88. The ECC88 is self-biasing thanks to the large amount of negative DC feedback provided by cathode resistor R7.

A supplementary advantage of the cathode follower design used here is that the cathode voltage is 0 V when the circuit is cold and gradually rises to

its operating bias level of approximately +194 V as the ECC88 warms up. The coupling capacitors are charged gradually during this process, with the result that the transistor stage does not have to handle any spikes.

Exceptionally good results can be obtained by using a current source in place of cathode resistor R7. When an Ixys IXCP10M45 was used as the current source, a distortion of less than 0.1% (without negative feedback!) was measured at an output power of 45 W. However, this IC is difficult to obtain, so this option was not pursued any further.

For practical reasons, the amplifier described here uses JJ Electronics valves. They are readily available, nicely priced, good-quality valves, and they come from current production.

Many people regard the 6N1P as a replacement for the ECC88, but with this design the distortion was not acceptable when a 6N1P was used. A simple and interesting alternative is to use a 5751 in place of the ECC83. These are directly interchangeable types. The amplification factor is slightly lower, but this is not a problem. From an acoustic perspective, the author prefers a 5751 (from ECG/Philips or NOS) in combination with a JJ ECC88. If you have adjusted the amplifier for operation with an ECC83, the voltage at TP3 will increase automatically by about 2.2 V if you replace it with a 5751.

Coupling capacitors

The valve and transistor stages are linked by two high-quality coupling capacitors. They cannot be omitted in this design, since the DC voltage on the cathode of the ECC88 is about 194 V. Unfortunately, these capacitors affect the ultimate sound of the amplifier. The sound characteristics of capacitors are the subject of heated debate among audiophiles. Listening tests have shown clearly that these capacitors have an important effect. We finally settled on a type from the Clarity-Cap SA series, which has an extremely good price/quality ratio. Thanks to its high working voltage (600 V), the SA series is very well suited for use in designs with high voltages, such as valve circuits. The PCB layout can also accommodate types from other manufacturers, including Wima and Solen. The value of 3.3 μ F was chosen to position the low-frequency roll-off well below 10 Hz. Note that the coupling capacitance combines with the input imped-



ance of the transistor stage to form an RC filter with a corner frequency of

$$1 / (2\pi \times 3.3 \mu\text{F} \times 10 \text{ k}\Omega)$$

the coupling capacitors must have a working voltage of at least 400 V_{DC}.

Current stage

The current stage (power stage) is based on bipolar transistors. Although MOSFETs such as the BUZ900P or 2SK1058 families would also be an option, they were intentionally not chosen for this design.

The selected driver transistors are often used in audio amplifiers. They have outstanding characteristics for audio use, and besides that they are inexpensive. The output transistors (2SC5200) have excellent characteristics, and they are specifically designed for audio applications, readily available (but beware of imitations!), and very robust thanks to their large SOA (safe operating area) range. The 2SC5200 is available in two versions, with an 'O' or 'Y' suffix. This code designates the h_{FE} range. Both types work well, but all of the transistors should be the same type. The O type was used in the prototypes and the final version of the amplifier.

The current stage is a standard quasi-complementary output configuration, which means a configuration with two identical NPN output transistors. This contrasts with the currently common practice of using a complementary design with an NPN type and a PNP type. Quasi-complementary output stages were often used in the 1970s and early 1980s because complementary PNP transistors were not available, or were too expensive. This configuration has acquired a bad reputation among many people, but this is not justified. Very good results can be obtained with a quasi-complementary design. The main advantage is that the output transistors are identical. NPN and PNP transistors can never be more than approximately equivalent. This is why manufacturers such as Naim still use only the NPN/NPN configuration. The ultra-modern Denon PMA1500AE amp also uses a quasi-complimentary NPN output stage, in this case using two UHC n-type FETs.

The selected supply voltage of $\pm 38 \text{ V}_{DC}$ is optimal for this output stage and allows a 4-ohm or 8-ohm load to be driven without any problems.

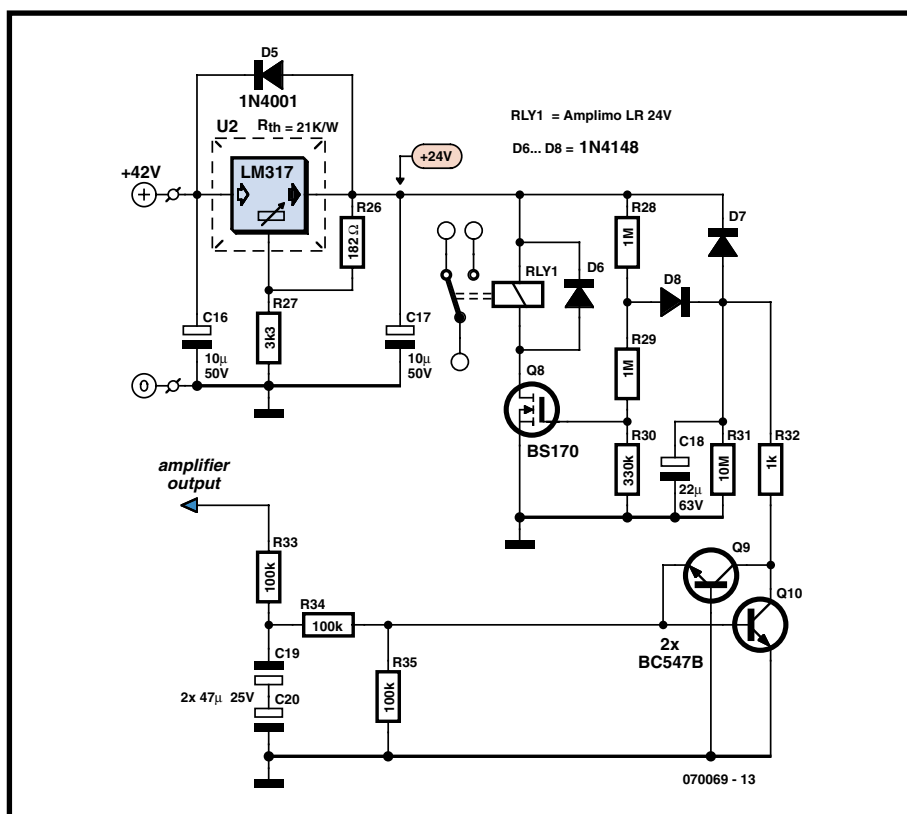


Figure 2. This circuit provides a switch-on delay and DC protection for the output.

Circuit details

Resistor R1 is a grid-leak bias resistor for V1a. Its value is not critical, but the resistor is essential because the valve would otherwise not be able to generate the negative bias that sets its DC operating point. R2 forms a low-pass filter in combination with the input capacitance of the ECC83. This prevents any tendency to oscillation. The same thing applies to R5 in combination with the ECC88. Anode resistors R3 and R4 are dimensioned to yield a voltage of slightly more than 190 V on the anodes of V1. V1 thus has the right bias with an anode current of 0.8 mA. The power dissipation is well within the permitted value.

The long-tailed pair with V1 uses a current source built around Q6 and Q7. The LED provides a reference voltage, and the current can be set easily with P1. The total current is approximately equal to $1/P1$. A separate power supply using an LM377 provides a voltage of -12 V for the current source.

The overall negative feedback is applied to the control grid of V1b. As already mentioned, a value of 6 dB was chosen here. This is determined by the ratio of R8 and R6. A small capacitor

(56 pF) can be connected across the feedback resistor to increase stability. The bias of the ECC88 is chosen to generate an anode current of approximately 9 mA with an effective anode voltage of around 115 V_{DC}. The power dissipation is 1 W, which is beneficial for the service life of the valve. The total distortion would be slightly less at a higher current, but the life of the valve would be reduced significantly by the higher dissipation.

Q1 sets the quiescent current of the output transistors, and it must be fitted close to the output transistors to achieve good temperature stability. Minimum quiescent current is obtained when the wiper of P2 is turned fully toward the collector of Q1. P2 must be a ten-turn potentiometer of very good quality. The R11/P3 pair and R16 ensure the DC stability of the amplifier output, and the values of these components also determine the input impedance of the circuit, which is approximately 10 k Ω (20 k Ω || 20 k Ω). These values could be increased if MOSFETs were used, but here this is not possible due to the amount of base current required by Q2 and Q3. R12/C4 and R20/C8 are additional decoupling networks, and they are indispensable. C4

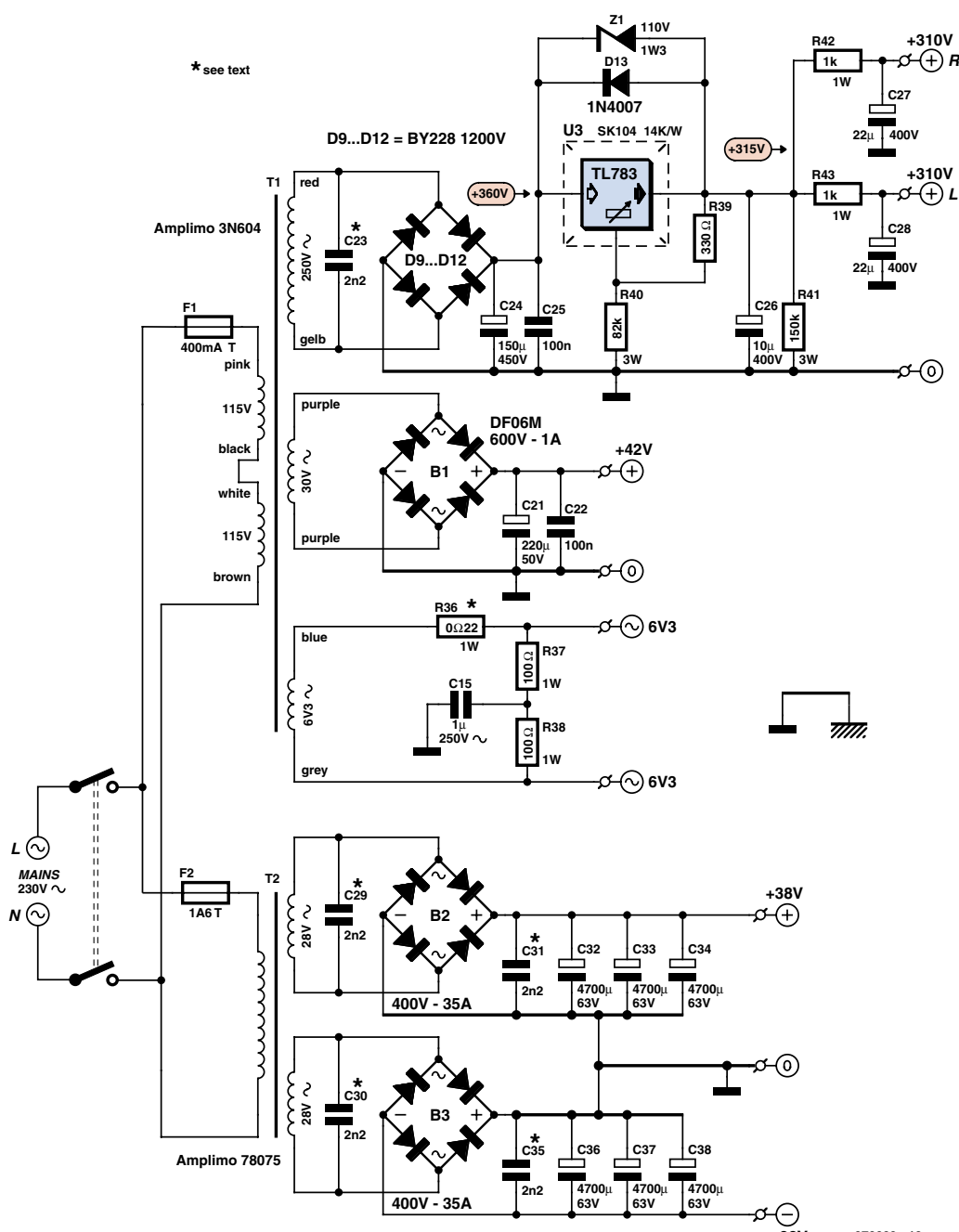


Figure 3. The power supply provides four different voltages.

and C8 can also be 220 μF or 330 μF if desired. P3 allows the DC offset of the output stage to be set to zero. Active DC offset control in the form of an opamp integrator is intentionally not used here because the author believes that this affects the sound quality of the amplifier.

Q2 and Q4 form a Darlington pair that provides adequate current gain, as do Q3 and Q5. Q3 and Q5 form what is called a 'Sziklai pair', which is used

here to mimic a PNP transistor. Quasi-complementary circuits normally use a 'Baxandall diode' to improve symmetry and linearise the response. This approach was used in the Ekwa amplifier published in *Elektor* in 1972. In the present design, a transistor configured as a diode (Q_{bax}) is used instead of a normal diode. The measured distortion at 1 W was 0.22% with a diode in the circuit, while the value with a 2SC1815 configured as a diode was 0.08%. Note

that the BL version of the 2SC1815 should be used here. Although the -O, -Y and -GR versions can also be used, they yield results that are practically the same as with a normal diode. The difference decreases gradually at levels greater than 5 W. The PCB is designed to allow a 2SC2073 or a 1N4007 to be used instead. This is also the order of preference. Obviously, only one of these three types of components can be fitted on the board.

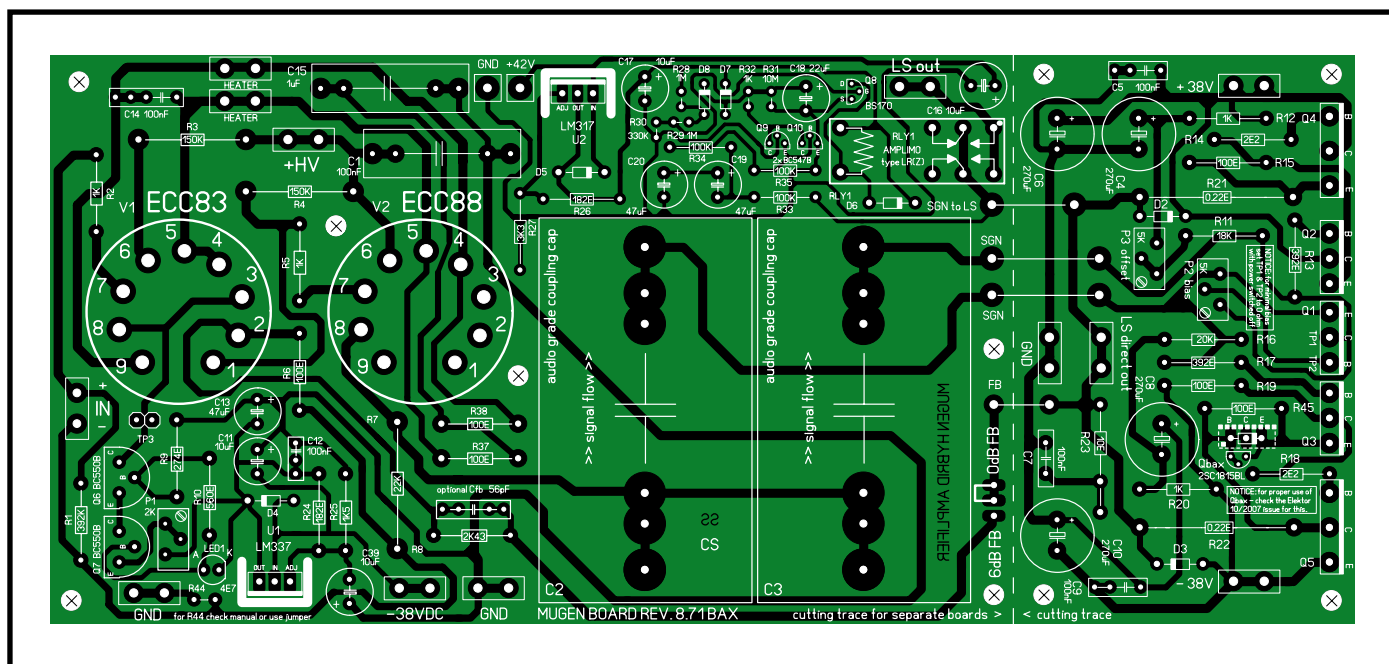


Figure 4. The amplifier board can be split in two, depending on how it is arranged in the enclosure. Component overlay reproduced at 80% of actual size.

Thanks to the inherent local negative feedback, the output stage is very stable with regard to temperature drift and quiescent current. The emitter resistors should preferably be Interteknik MOX types. They are non-inductive and have relatively small dimensions. The amplifier output has a Zobel network built around R23 and C7, which ensures stability above 100 kHz.

Base resistors (R13, R17, R14, and R18) are used for all transistors in the output stage to prevent oscillation. The resistors for the driver transistors (R13 and R17) are essential.

The heatsink extrusion for each output stage must be rated at 0.7 K/W or less to ensure reliable operation.

The switch-on delay and DC protection circuit (**Figure 2**) is built around relay RLY1 and MOSFET Q8. This circuit was previously used in the Valve Final Amp design published in the April/May 2003 issues of *Elektor Electronics*. The switch-on delay is approximately 30 seconds. If a hazardous DC voltage is present at the output, the relay will disconnect the amplifier output from the loudspeaker. The relay used here is an Amplimo type with special contacts that make it especially suitable for use as an output relay in audio amplifiers.

A coil can optionally be fitted in series with the output to make the amplifier more general-purpose with respect to possible capacitive behaviour

of the speaker. This coil is omitted in the version of the amplifier described here. A DIY coil with an inductance of 4 μH , consisting of 16 turns of 0.75-mm enamelled copper wire wound on a 6.3-mm drill bit, can be used here if desired. A 15 $\Omega/2\text{ W}$ resistor must be fitted inside the coil and soldered across the coil.

Power supply

The high-voltage supply (**Figure 3**) uses a type TL783 voltage regulator IC. The input voltage of the TL783 must be approximately 360 V_{DC} for proper operation. The Amplimo toroidal high-voltage transformer used here provides this voltage in a manner that is perhaps somewhat unorthodox. The 250-V winding is so generously dimensioned that it is hardly loaded by the ECC83s and ECC88s, so the secondary voltage is a good deal higher than the rated 250 V. You should bear this in mind if you use a different transformer. The TL783 is fitted with a small heat sink and must be mounted insulated. Voltage divider R39/R40 sets the output voltage to around 315 V. Resistor R41 is included to discharge the electrolytic capacitors when the amplifier is switched off. R40 and R41 must be 3-watt types. R42/C27 and R43/C28 are additional RC filters for the left and right channel, respectively. The high voltage for V1 and V2 is approxi-

mately 310 V_{DC} .

If you cannot find a Wima FKP1 type for C23 as specified in the components list, you should omit it.

The 30-V winding of transformer T1 is used for the switch-on delay and protection circuit.

The AC filament voltage is tied to ground via a capacitor. In this case it cannot be connected directly to ground. This is because the cathode of the ECC88 is not close to ground potential here, but instead at +195 V. The capacitor arrangement allows the maximum cathode-filament voltage rating to be respected. This floating filament supply works well in practice. A value of 0.47 μF can be used instead of 1 μF with equally good results.

The value of R36 must be determined experimentally. This resistor determines the value of the filament voltage, which must be close to 6.3 V.

The power supply shown here is suitable for stereo use, but it can also be used for a mono final amplifier. If it is used for a stereo version with a single transformer and a single supply PCB, then R37, R38 and C15 only have to be fitted on one of the two amplifier boards, although fitting them on both boards will not do any harm.

The $\pm 38\text{-V}$ supply is simple but effective. A toroidal transformer with a secondary voltage of $2 \times 28 V_{\text{AC}}$ gives the best results in terms of output power. If you use a different type of transform-

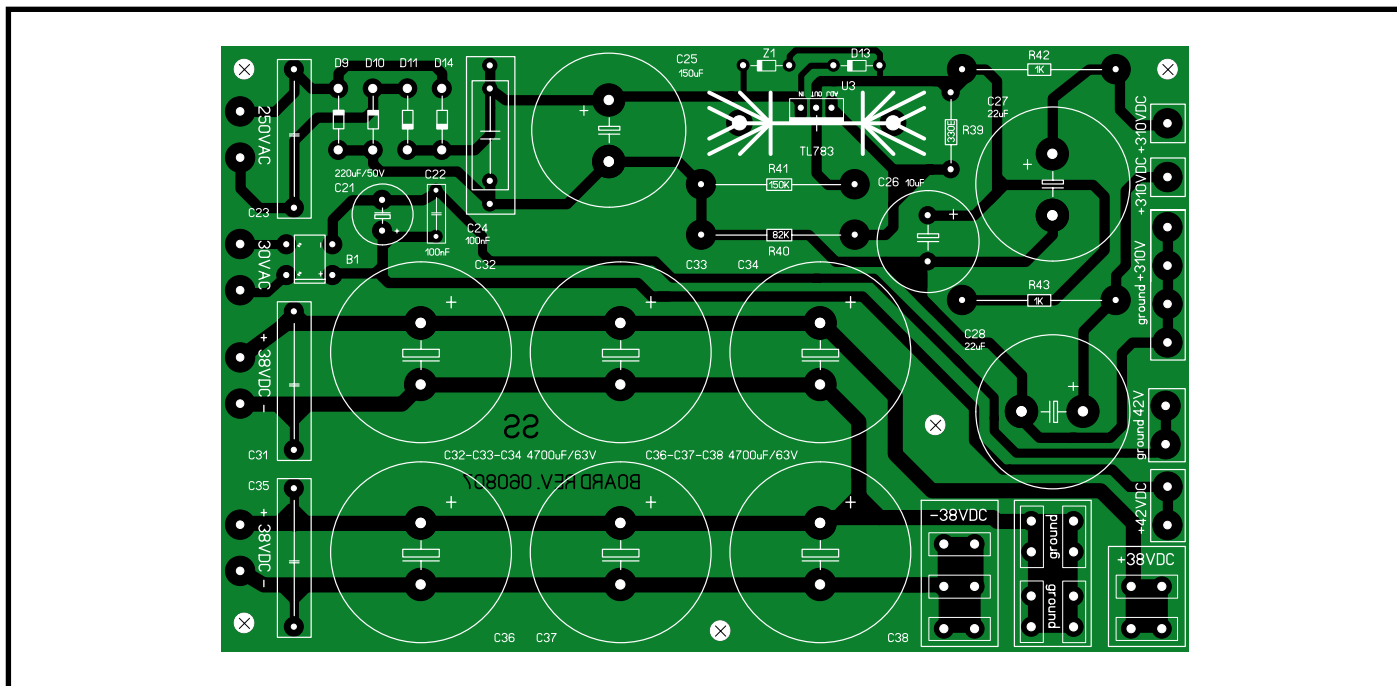


Figure 5. The power supply board is dimensioned for a complete stereo amplifier. Component overlay reproduced at 80% of actual size.

COMPONENTS LIST

amplifier & power supply

(for a stereo version, all components must be purchased double)

Resistors

(1% metal film, 600mW unless other rating indicated)

- R1 = 392k Ω
- R2, R5, R12, R20, R32 = 1k Ω
- R3, R4 = 150k Ω 2W (BC PR02 series)
- R6, R15, R19, R45 = 100 Ω
- R7 = 22k Ω 3W (BCPR03 series)
- R8 = 2k Ω 43
- R9 = 274 Ω
- R10 = 560 Ω
- R11 = 18 Ω
- R13, R17 = 392 Ω
- R14, R18 = 2 Ω
- R16 = 20k Ω
- R21, R22 = 0.22 4W (Intertechnik MOX)
- R23 = 10 Ω 2W
- R24, R26 = 182 Ω
- R25 = 1k Ω 5
- R27 = 3k Ω 3
- R28, R29 = 1M Ω
- R30 = 330k Ω
- R31 = 10M Ω
- R33, R34, R35 = 100k Ω
- R36 = to be determined (0.22 Ω using 3N604)
- R37, R38 = 100 Ω 1W (see text)
- R39 = 330 Ω
- R40 = 82k Ω 3W
- R41 = 150k Ω 3W
- R42, R43 = 1k Ω 1W
- R44 = 4 Ω 7
- P1 = 2k Ω , 15-turn preset, T93YB (Vishay) or 3296Y (Bourns)
- P2, P3 = 5k Ω , 15-turn preset, T93YB (Vishay) or 3296Y (Bourns)

Capacitors

- C1 = 100nF 400V_{DC}

- C2, C3 = 3 μ F 3 400V_{DC} (ClarityCap SA 630 V audiograde capacitor)
- C4, C6, C8, C10 = 270 μ F 50V (Panasonic FC, Farnell # 9692436)
- C5, C9, C12, C14, C22 = 100nF 50V
- C7 = 100nF (Vishay MKP-1834, Farnell # 1166887)
- C11, C16, C17 = 10 μ F 50V
- C13 = 47 μ F 50V
- C15 = 1 μ F 250V (e.g. Wima foil capacitor, see text)
- C18 = 22 μ F 63V
- C19, C20 = 47 μ F 25V
- C21 = 220 μ F 50V
- C23 = 2nF2 (Wima FKP-1/700 V_{AC}, see text)
- C29, C30, C31, C35 = 2nF2 (Wima FKP-1/700 V_{AC})
- C24 = 150 μ F 450V
- C25 = 100nF 450 V_{DC}
- C26 = 10 μ F 400V
- C27, C28 = 22 μ F 400V
- C32, C33, C34, C36, C37, C38 = 4700 μ F 63V (BC056, 30x40 mm, Conrad Electronics # 446286-89)
- C39 = 10 μ F 25V
- Cfb = 56pF (optional)

Semiconductors

- D1 = not used
- D2, D3 = UF4007 (if necc. 1N4007)
- D4, D5 = 1N4001
- D6, D7, D8 = 1N4148
- D9, D10, D11, D12 = BY228
- D13 = 1N4007
- LED1 = LED, 5mm, red
- Z1 = zener diode 110V 1.3W
- Q1 = BD139
- Q2 = 2SC2073
- Q3 = 2SA940
- Q4, Q5 = 2SC5200
- Q6, Q7 = BC550B
- Q8 = BS170
- Q9, Q10 = BC547B

Qbx = 2SC1815BL

U1 = LM337

U2 = LM317

U3 = TL783 (Conrad Electronics # 175012-62)

Valves

V1 = ECC83 (pref. JJ Electronics)

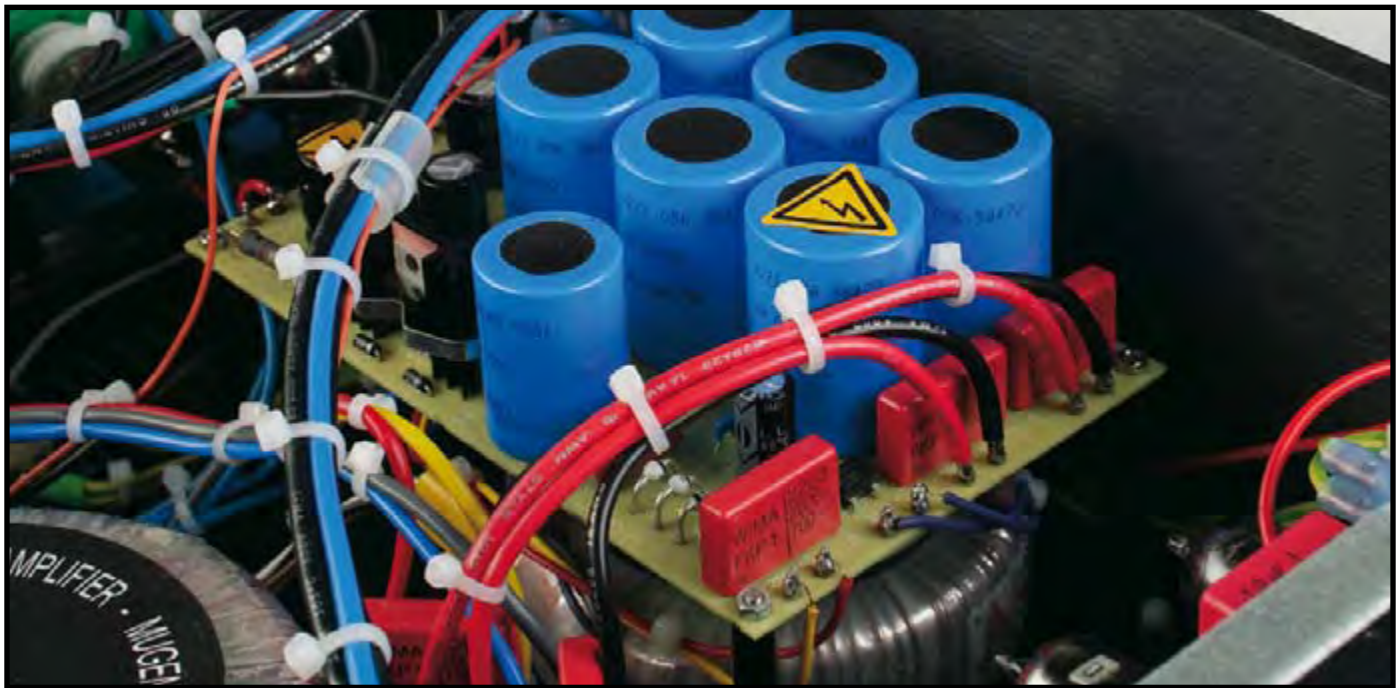
V2 = ECC88 (pref. JJ Electronics)

Miscellaneous

- B1 = bridge rectifier 600 V piv @1A (DF06M)
- B2, B3 = bridge rectifier 400V piv @ 35A
- T1 = mains transformer, sec. 30V + 250V + 6.3V (Amplimo type 3N604)
- T2 = mains transformer, sec. 2x28 V_{AC}, 300VA (Amplimo type 78057)
- RLY1 = output relay 24V (e.g. Amplimo type LR)
- Heatsink profile for U3 (Fischer SK104 25,4 STC-220 14K/W (e.g. Conrad Electronics # 186140-62)
- Heatsink profile for U1 and U2, Fischer FK137 SA 220, 21K/W (e.g. Conrad Electronics # 188565-62)
- Heatsink profile for Q4 and Q5, 0.7K/W or better
- 9-way valve socket (Novall), PCB mount, for V1 and V2
- Amplifier board, no. 070069-1 (mono), www.thepcbshop.com
- Supply board, no. 070069-2, www.thepcbshop.com

Suggested suppliers

- Toroidal transformers and output relay: www.amplimo.nl
- ClarityCap SA capacitors: www.claritycap.co.uk
- www.capsandcoils.com
- http://wduk.worlddomain.net (OEM like Soniqs SAX)



er here, a type with a more conventional value of $2 \times 25 \text{ V}_{\text{AC}}$ can be used, but the maximum output power will be somewhat less. The 2.2-nF Wima FKP-1 capacitors provide additional decoupling.

Construction

The PCBs for the amplifier and the power supply are shown in **Figures 4** and **5**. The actual size layouts can be downloaded from the *Elektor* website, or you can order ready-made boards from PCBShop. The board shown in Figure 4 is for a mono amplifier, so you need two amplifier boards and a power supply board for a stereo version.

The components list has several components with quite specific descriptions or type numbers. Based on the author's experience, you will obtain the best results from the amplifier if you use these components. However, you are naturally free to experiment with comparable components.

Assembling the power supply board is straightforward. Use good-quality blade connectors for the various supply and ground terminals. This makes wiring the amplifier much easier. After the power supply board is done, you can assemble the amplifier boards.

The amplifier board is designed so that it can be split in two in order to mount the power stage on the heat sink and the driver stage somewhere else, such as on the base of the enclosure. However, the wiring between the two parts

must be kept as short as possible.

Figure 6 shows clearly how the transistors of the power stage are fitted (all insulated!). For best results, first fit the transistors to the heat sink, bend their leads at right angles, and then secure the board to the heat sink with screws. Do not solder the transistors in place until everything is properly positioned.

An enclosure with two large heat sinks on the sides was used for the prototype (see the photo of the fully assembled amplifier in **Figure 7**). It is

big enough to hold a complete amplifier board.

The two supply transformers and the bridge rectifiers for the $\pm 38\text{-V}$ supply are fitted in the middle of the base of the enclosure. The supply board is located above transformer T1.

The amplifier board and supply board have several ground connections. They must all be connected separately to a single star point as indicated in **Figure 8**. In order to avoid ground loops, the grounds of the $\pm 38\text{-V}$ supply, the $+42\text{-V}$ supply and the $+310\text{-V}$ supply

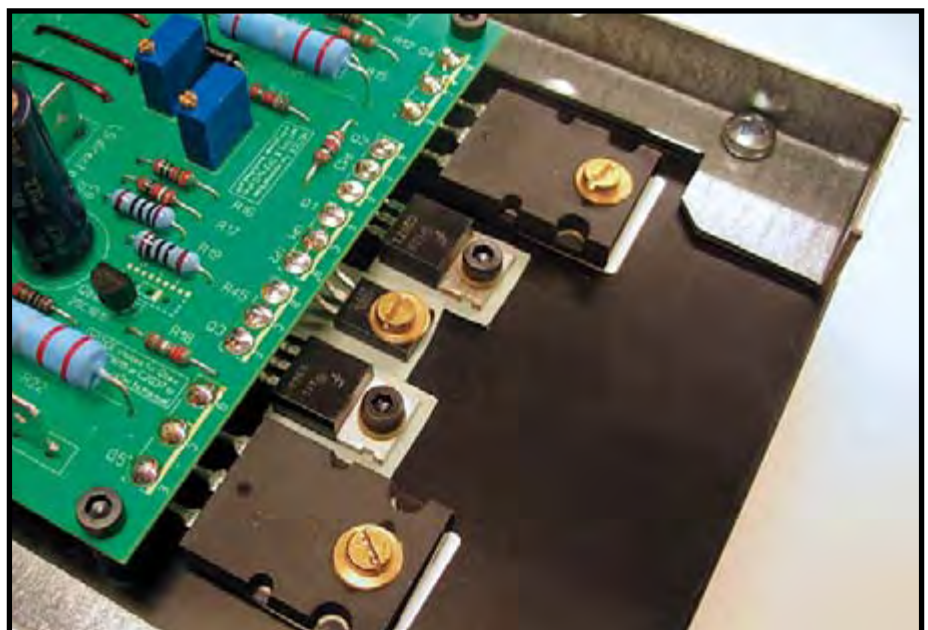


Figure 6. Fitting the power stage transistors.

are not joined on the supply board. The 4.7- Ω resistor (R44) between the input neutral terminal and circuit ground is optional and can be replaced by a wire link, but in the prototype this resistor proved to be necessary to keep the overall arrangement free of hum.

Be sure to use plastic standoffs for mounting the circuit boards. Metal types can cause shorts between PCB tracks and the heat sink or chassis.

A mains entry unit, a double-pole mains switch, a pilot light and a pair of fuse holders for the transformers can be fitted on the primary side. In this regard, consult the instructions on the *Electrical Safety* page that's published regularly in the magazine, or accessible permanently on the Elektor website.

Alignment

Inspect all components and connections before switching on the amplifier. Check that the transistors are insulated from the heat sink and from each other, check the polarity of the electrolytic capacitors, and check that the right valves are fitted in the sockets. The ECC83 and ECC88 are absolutely not electronically interchangeable.

The amplifier has three adjustment points:

- P1 sets the operating current of the ECC83.
- P2 controls the quiescent current of the output transformers.
- P3 adjusts the DC level of the output.

Before switching on the amplifier, ensure that the wiper of P2 is at the end connected to the collector of Q1.

This results in minimum quiescent current. Test points TP1 and TP2 are provided for this purpose on the PCB. Adjust potentiometer P1 to a value of approximately 800 Ω before soldering it to the board.

After switching on the amplifier, adjust P1 so the DC voltage at TP3 is +1.6 V. The exact value is not critical, but the DC voltage measured across R7 must be close to +195 V ($\pm 5\%$). If necessary, readjust P1 to obtain this value. The anode voltage of V1b should be about +190 V. These three voltages are interrelated.

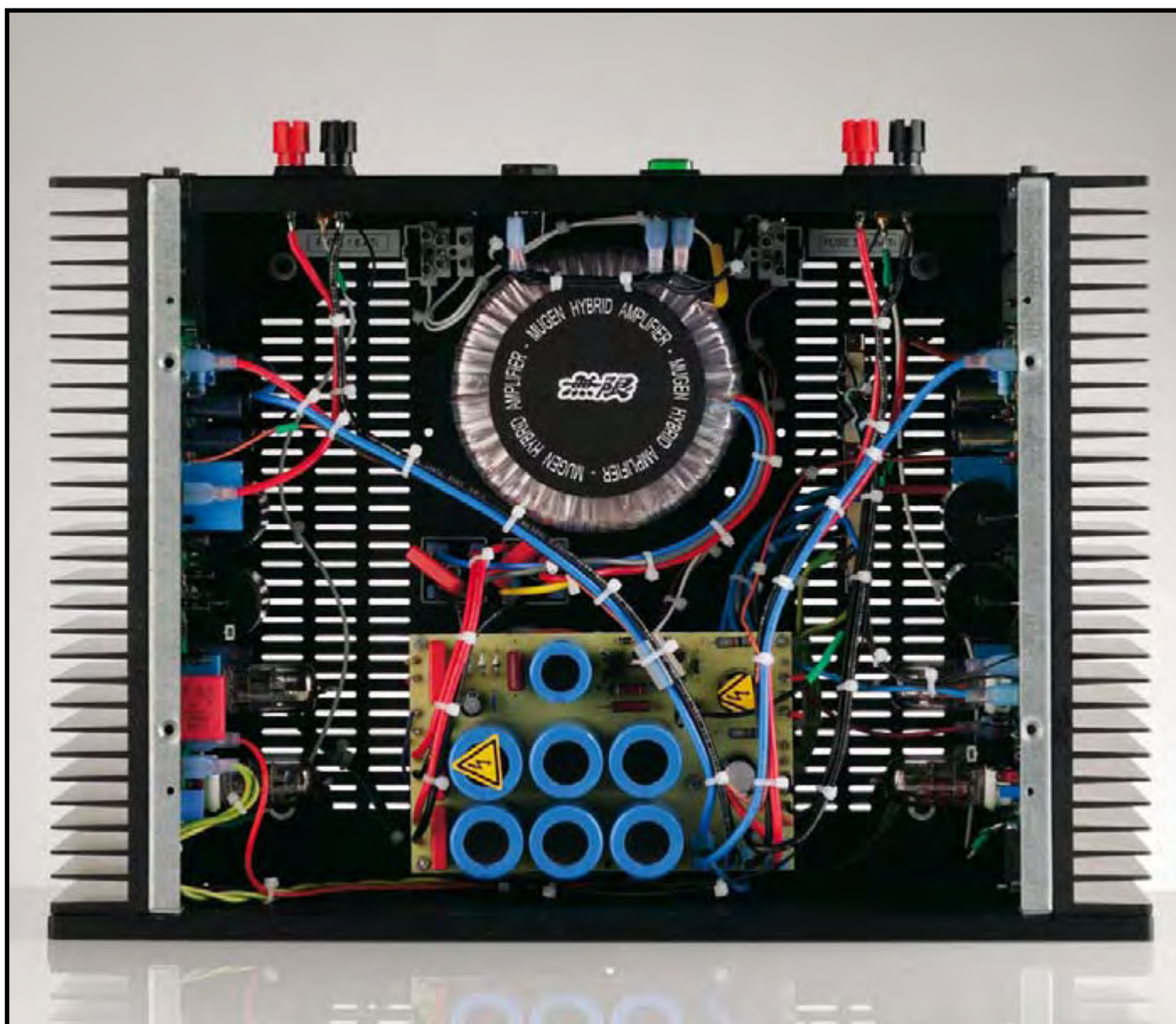


Figure 7. The fully assembled amplifier.

After this, adjust P2 and P3 with no input signal and no load. P3 controls the output offset. The DC voltage measured at the output must lie between +50 mV and -50 mV. It varies slightly, which is normal. Then adjust P2 to set the quiescent current. The DC voltage across emitter resistor R21 or R22 must lie between 22 mV and 33 mV (for a quiescent current of 100 to 150 mA). After the amplifier has warmed up for approximately 15 minutes, check all the values again and adjust the settings as necessary.

You can repeat this procedure several times during the first hour. In between these adjustment cycles, you can test run the amplifier with an inexpensive loudspeaker (such as a PC speaker) and a bit of music.

Key points

- Be careful! High voltages are present at various places on the circuit boards. Remember that residual voltages can be present for a while after the amplifier is switched off.
- Be kind to your loudspeakers: never connect or disconnect inputs or interlinks unless the amplifier is switched off.

Results

Despite the fact that overall negative feedback is not used in this amplifier, it has relatively low distortion. The distortion is less than 0.1% at low power levels. This respectable value is the result of careful component selection and dimensioning. The damping factor is also suitable for practical use. This

is often a problem with final amplifiers that do not use negative feedback.

The sound characteristics of an amplifier are often difficult to express in words, but here we'll try to give you an impression in a few sentences. The amplifier can create a splendid sound stage, the lows are controlled, and the dynamic behaviour is convincing. The listening pleasure is thus also very good. The Mugen amplifier has an honest character without any signs of an exaggerated 'valve sound' (i.e. colouration).

By combining a valve driver stage with a transistor power stage, the Mugen amplifier offers the best of both worlds at an attractive price.

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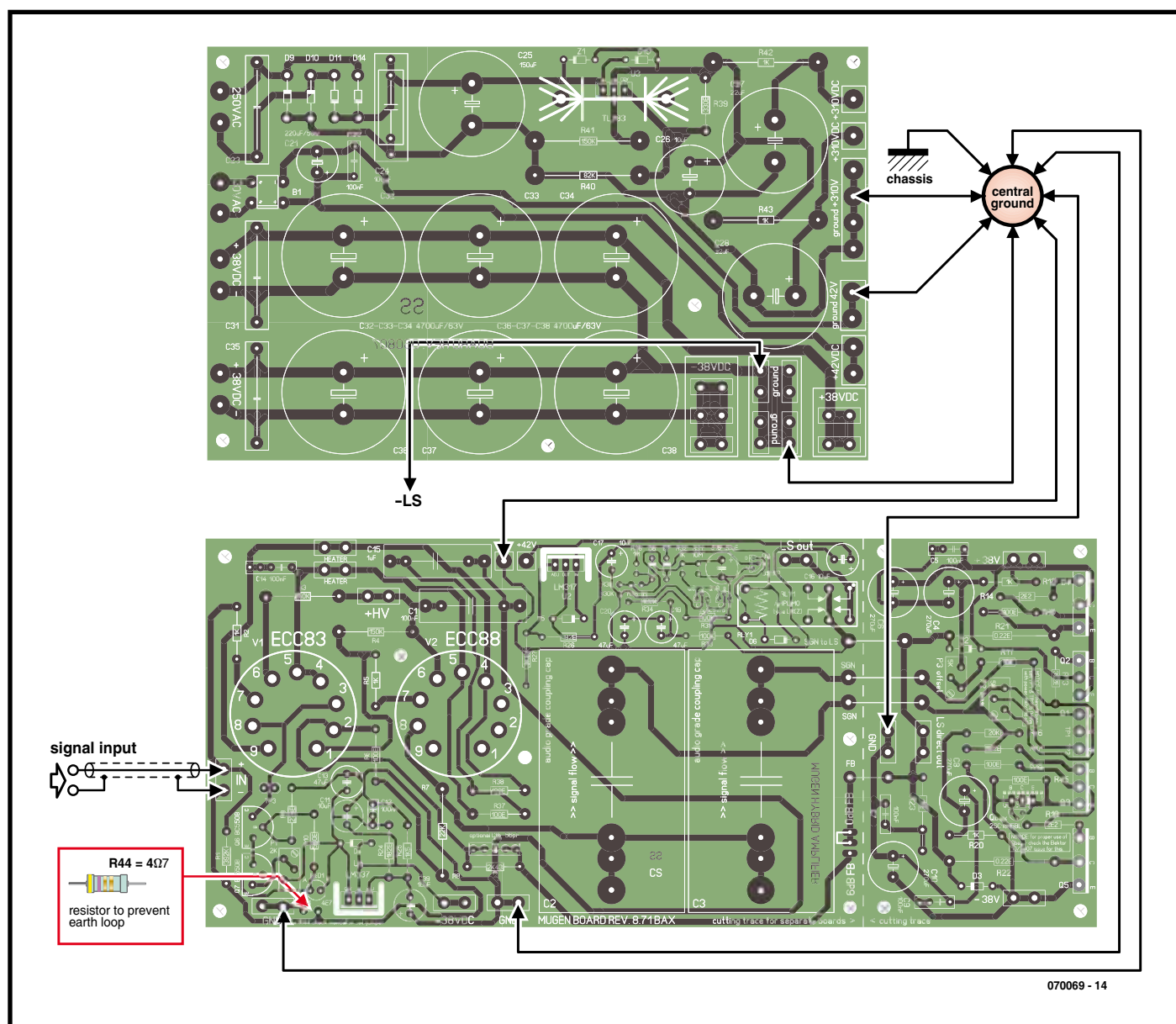


Figure 8. The ground connections must be arranged this way in the enclosure. They are all tied to a single ground point connected to the enclosure.

Interference-free Sound

Mains filter for clean audio power

Joost Waagebaert

When listening to your favourite CD, any audiophile will at some occasion realise that the CD concerned used to sound better during the previous listening session. Or perhaps just the other way around. The cause for this difference in quality cannot be directly traced to one of the carefully assembled chain of audio components and saddles the listener with a feeling of uneasiness. To exclude all technical causes we need a decent mains filter, which at the least ensures that nothing can be blamed on the very beginning of the audio chain, the power supply.

The nice thing of audio as a hobby is the freedom to take as long as you like to choose or build audio components until the whole installation sounds just 'perfect'. The achievement of this goal cannot be established scientifically, of course. It is a subjective matter that is the cause of many discussions and just as many opinions. This is, however, not the subject of this article. Instead, we concentrate on the phenomenon cited in the introduction, namely: why does identical source material sound better on one day than another?

Clocked in noise...

State of mind can play a role here, but is it also possible to find a technical basis for these differences in listening experience? An electrical cause which is often forgotten, is the quality of the energy required to power our audio equipment, the energy from the mains.

The number of devices that are connected to the mains increases every day. Many modern appliances use energy-saving switching power supplies.

These, by their very nature, generate quite a bit of noise on their mains connection. Examples are computers, TVs, battery chargers, etcetera. The assumption can be made that each of these appliances conforms to the European EMC requirements and therefore sends only a limited amount of noise back to the mains. For a number of appliances it is, of course, the sum of all the individual interference levels that determines the total noise level of the mains, and this can add up to quite a bit.

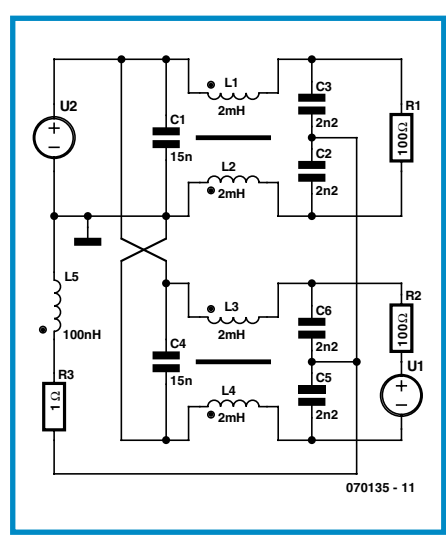


Figure 1. The equivalent circuit of two appliances, each with a mains filter, that are connected in parallel.

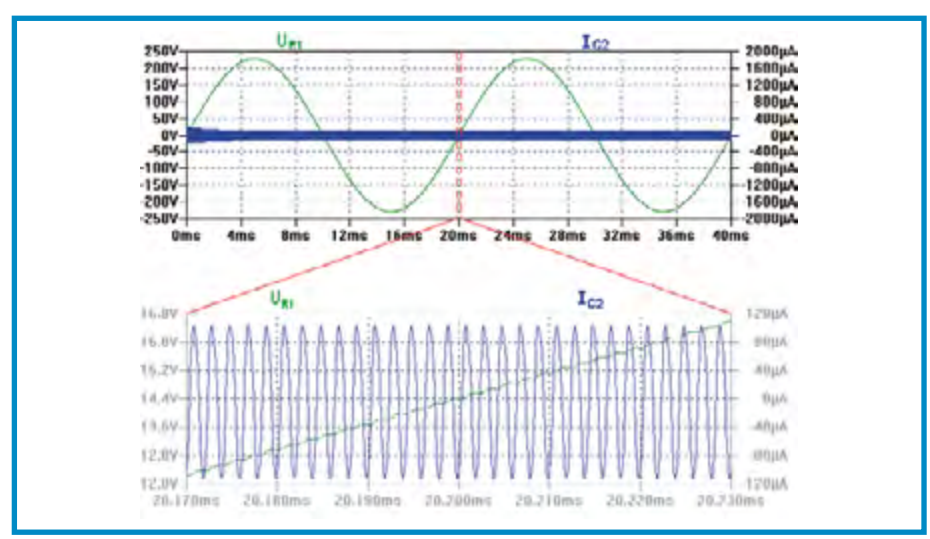


Figure 2. The current that will flow through C2 as a result of interference source U2.



The author connected two transformers in parallel for the prototype, so that they are smaller and the whole filter could fit in a lower enclosure.

Another source of noise is the use of power-line communication equipment (alarm systems, remote controls, energy meters and such). These use the mains network, in addition to being their power source, also as communication network. The frequencies that are permitted for this use cover a range from 3 to 148.5 kHz.

Furthermore, there are the traditional polluters: incandescent lamp dimmers, electric motors, fluorescent lights, etc. All in all, the power source that is available to power our expensive audio equipment can be significantly polluted. To power the equipment from such a source is disrespectful of the audio engineers who moved heaven and earth to realise a dynamic range of 100 dB for audio signals (that is a fraction of $1/10^5$ of a typical $2 V_{\text{RMS}}$ -audio signal, that is, 20 μV). It is therefore not inconceivable that a polluted mains can penetrate into the signal path of an audio component and prevent the device from performing at its optimal level.

A solution

An obvious approach to filtering the undesired interference from the mains is to use a traditional, ready-made mains filter (see **Figure 1**). This consists of a coil (L1, L2) and a few Class

X and Class Y capacitors (C1, C2, C3). This is a method that works well and proves its use every day, but is less suited for audio applications. In audio equipment, the X capacitor does its job as expected and removes the differential mode interference. The problem is with the Y capacitors. Normally speaking, these conduct common-mode interference nicely to earth. However, the current through the earth conductor has no limitations with respect to direction of flow. There is therefore no reason to suppose that signals which are already present on the earth conductor could not penetrate the audio equipment via the Y-capacitor!

This situation is drawn in Figure 1 with a PC as the other device. The PC has the same mains filter as the audio component (L3, L4, C4 to C6). U1 represents the interference which is generated by the switching power supply in the PC. **Figure 2** shows the result of the simulation. This clearly shows that the interference source U1 generates a current through capacitor C2 and as a result also generates interference across R1 (which represents the load of the connected audio equipment). So the interference from the PC enters the audio equipment via the very filter that was supposed to clean the mains voltage!

In a traditional mains filter such as this one, the coil is connected in series with the load. This seems to be no problem at first glance since the impedance of the coil at 50 Hz is negligible. This is obviously true for loads that draw a constant power, but not for a power amplifier which is reproducing a dynamic piece of music. The power requirements of an amplifier naturally follow the dynamics of the reproduced music. And that includes frequencies up to 20 kHz. The filter certainly has an effect at these frequencies: it limits the rate at which the current for the power supply in the amplifier can increase, with audible differences as a possible consequence.

A better solution

The filter shown in **Figure 3** is purely connected in parallel with the mains. It is really a 'frequency selective short-circuit' for disturbance signals that we want to eliminate. Translated into impedance, this filter therefore needs to have as low as possible a value for the frequencies of the disturbance. The series network L1/C1 has an impedance of nearly zero at the resonance frequency ($1/2\pi\sqrt{L1C1}$). R1 has been added so suppress the tendency of the LC network to oscillate. This reduces the impedance at higher frequencies. With the addition of C2,

higher frequencies experience an even larger short circuit. The choice of the resonant frequency of L1/C1 is such that it falls in an 'important' frequency range of the audio signal, so that the interference suppression is the most effective. This resonant frequency has to be sufficiently far away from 50 Hz, of course. Since the impedance peak of an LC filter is quite narrow, it would be ideal to use multiple LC networks with different resonant frequencies, spaced at one octave apart, for example. In this way a wide frequency range with low impedance can be realised. This will however quickly become expensive, heavy and quite large. This design limits itself to one single LC combination. This would appear to have only limited effect on the transfer characteristic, but is very useful for restricting the consequences of mains voltage drop-outs.

Further improvements

The filter up to this point only works for differential-mode interference. Common-mode interference is not affected and as has just been shown, Y capacitors are very undesirable. Why don't we use an isolating transformer? 230 V in, 230 V out, the mains is nicely separated and you're done... Unfortunately this does not work. The common-mode interference happily appears on the secondary side of the transformer because of the parasitic capacitance between the primary and secondary windings. There are good (and expensive) trans-

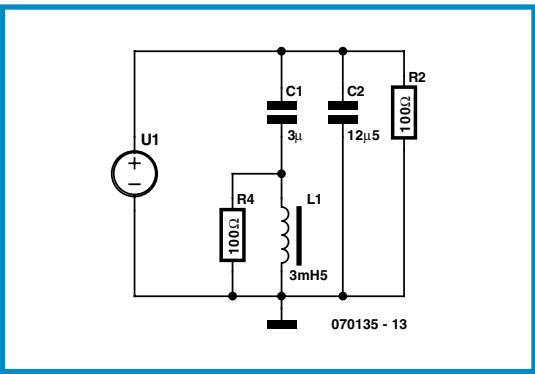


Figure 3. A parallel filter works better in an audio system.

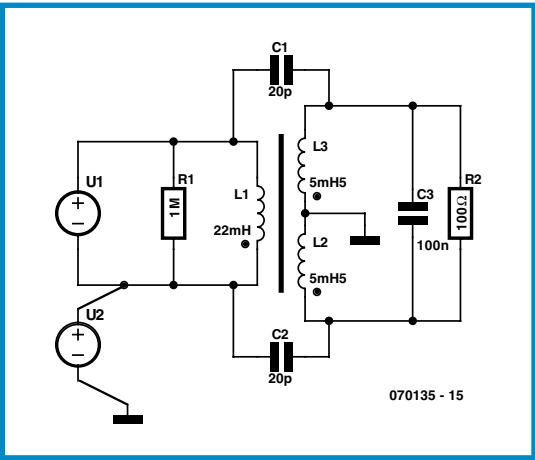


Figure 4. We can use this circuit to suppress common-mode interference.

formers with multiple screens between the windings that can suppress interference by impressive amounts. In order to realise this, the screen has to be connected to earth however. This again results in undesirable capacitive

coupling between earth and the secondary side of the filter. Another approach of dealing with common-mode pollution is the use of a winding with a centre tap on the secondary side of the transformer. This centre Tap is connected to the earth conductor. The result of this is that the common-mode voltages at the ends of the transformer winding are in anti-phase and therefore cancel each other out (Figure 4). U2 is the common-mode interference source. Owing to the parasitic capacitance in the transformer (C1 and C2), this signal is also at the outputs and therefore also across load R2. Because of the way the transformer is made, these signals are displaced in phase by 180°. They therefore disappear for the attached load. The ideal transformer for this type of filter needs to have a very small capacitance between the windings in combination with a limited bandwidth (around 50 Hz) – a filter in its own right and unaffordable. You can come a long way however using standard transformers if you connect two back-to-back. Figure 5 shows the complete schematic. This schematic immediately offers another possibility for additional filtering, using C3. In Addition, varistor R2 gives protection for incoming spikes. It is **not** a good idea to connect varistors from phase and neutral to earth, because these parts have a parasitic capacitance of about 350 pF and therefore would look like a type of Y capacitor. If after all the foregoing the temptation exists not to connect the 'pollut-

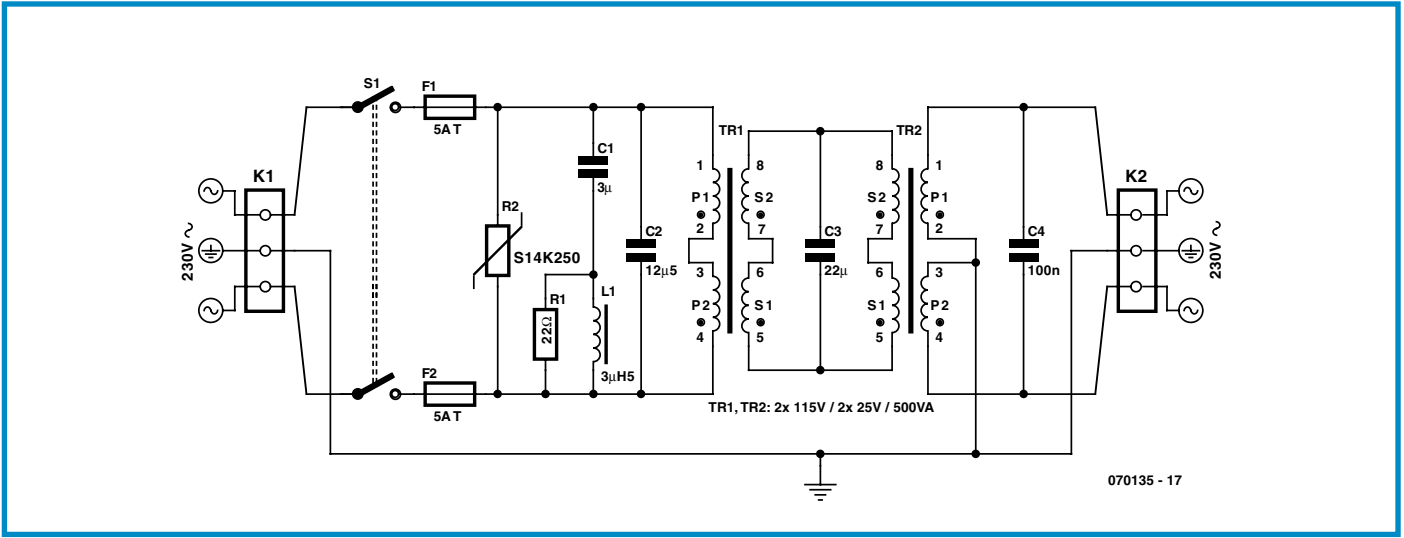


Figure 5. The complete schematic for the mains filter.

ed' earth connection to the audio equipment then we have to strongly advise against that. The earth connection has to be present always, to ensure safety in the event of an isolation fault!

Components

It is perhaps unnecessary to mention that the complete filter of **Figure 5** is connected to the mains. That means that there are lethal voltages present on the components and these must never be touched when the filter is plugged in! The components for the filter are quite different from the minuscule SMD bits that have to be bought for a 'normal' electronic project. You have to look for them at suppliers of, among other things, motor controls. The capacitors are, for example, available from Epcos in their series 'Power electronic capacitors for General purpose applications' (refer [1]). The coil is available from Siemens, among others, with the name 'Single Phase Reactor' (ref. [2]).

For the transformers, any type of 300 VA to 500 VA with a secondary voltage from 36 V to 50 V can be used. On the primary side two 115V windings have to be available. The prototype was built with toroidal transformers to limit the size and weight. This minimises the stray magnetic field at the same time.

Results

The first listening tests did not result in cries of joy and the language that is typical for various audio forums (along the line of "the music is much more open and deeper and broader and ..."). The conviction that the filter did indeed do its job came after the filter was removed from the system again. The sound was clearly different. The higher frequencies in particular benefit considerably from this filter.

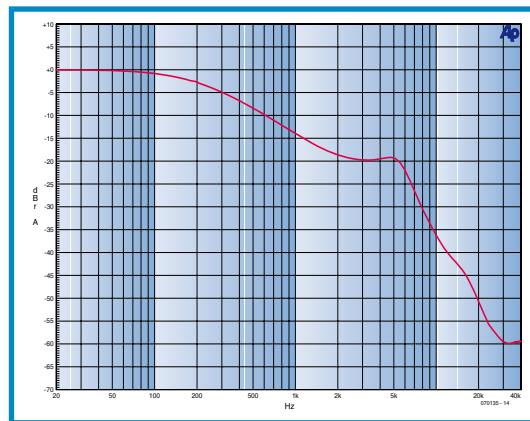


Figure 6. Transfer function of the complete filter. This clearly shows that higher frequencies are strongly attenuated.

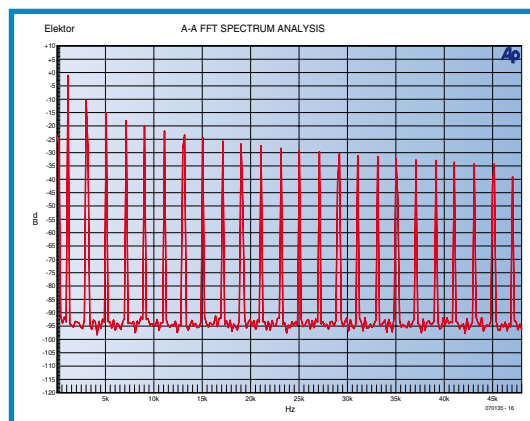


Figure 7. An FFT of a square wave with a frequency of 1 kHz. The characteristic odd harmonics slowly reduce as the frequency increases.

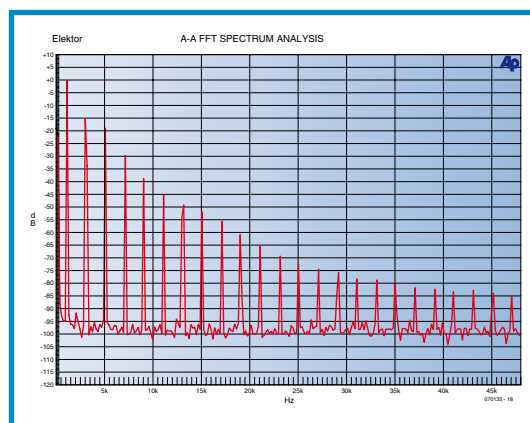


Figure 8. The same square wave, but measured after the filter. It is obvious that the higher harmonics reduce much quicker in amplitude. Here the 1-kHz signal is attenuated by 15 dB relative to Figure 7.

For the technical justification we obviously made a few performance measurements on the filter. The transfer function is drawn in **Figure 6**. The graph shows that the filter starts to filter at quite a low frequency. Above 5 kHz the curve drops rapidly. High noise frequencies on the mains voltage are filtered very effectively.

Figures 7 and 8 show how effective a square wave signal of 1 kHz (**Figure 7**) is filtered by the filter (**Figure 8**) and in this way provides a much cleaner mains voltage. So this prevents undesirable signals from entering via the power supply and influencing the audio signal.

Conclusion

The use of a ready-made filter does not generally have the desired effect in combination with a component in an audio signal chain. It usually goes wrong because of the Y-capacitors which pass noise on the earth wire unfiltered through to the mains voltage. Fortunately through a different filter design a better solution can be found.

By judging the results of the filter proposed here for yourself, you can make up your own mind whether it is worth the effort to filter the mains voltage that the audio installation requires. We are not going to say that there is a world of difference. But a difference there certainly is with this circuit.

(070135-1)

Web Links

- [1] www.epcos.com/inf/20/50/ds/B3236X.pdf
- [2] www.automation.siemens.com/cd-static/material/catalogs/e86060-k2803-a101-a4-7600.pdf
- [3] www.epcos.com/inf/70/db/var_01/01590173.pdf
- [4] www.epcos.com/inf/20/25/ds/b32320_22.pdf

COMPONENTS LIST

Resistors

- R1 = 22Ω 1W
- R2 = varistor 250 V, e.g. Epcos S14K250, see [3]

Capacitors

- C1 = 303.3 μF 250 VAC, e.g. type B32360A4305J080 from Epcos, see [1]
- C2 = 10-15 μF 250 VAC, e.g. B32360A2106J050 or B32360A2156J050 from Epcos, see [1]
- C3 = 20-25 μF 100 VAC, see [4]
- C4 = 100nF 250 VAC X class capacitor

Miscellaneous

- L1 = 3-4 mH 50Hz choke, e.g. 4EM4700-OCB00 from Siemens, see [2], p. 24.
- F1, F2 = fuse, 5AT (slow)
- TR1, TR2 = mains transformer, primary 2 x 115 V, secondary 36-50 V; 300-500 VA

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ElekTrack

Tracking & tracing with GPS

Chris Vossen

Position determination is all the rage. The manufacturer of the well-known TomTom navigation system has become a publicly traded company, and the alarm systems of expensive cars and other vehicles often comprise positioning systems so they can report where the vehicle is located. However, such systems are rather expensive, so we decided to take the DIY approach and develop our own version, dubbed ElekTrack.

Nowadays we want to know the current position of everything. Where's that package I ordered? Is the book I want already back in the library? Has my nephew's train arrived already? Technology has advanced so much in recent years that there's almost no situation we can imagine that doesn't already have a solution. And otherwise we provide a solution!

Big Brother

People are often a bit nervous about organisations that keep track of everything, but in some cases this is exactly what we want. For example, consider car security and alarm systems. Those of us who can afford the latest Maybach or Mercedes SLR will doubtless encounter stringent security requirements when they take out insurance for their vehicles. Quite often these cars must be fitted with security systems that include vehicle tracking and tracing capability in addition to standard anti-start and alarm functions. This means that they have a built-in GPS-based positioning system that reports

the vehicle location to a message centre. Stolen vehicles are indicated by red spots on a map in the control room.

Passenger cars are not the only vehicles being fitted with tracking systems. Lorries and boats can also benefit from such systems. More and more excavating machines are also being fitted with security systems, because they are stolen by the truckload. With a built-in track & trace module, these pricy machines can be tracked down and recovered.

Of course, not everybody has an excavating machine or a Bentley in the garage, but it's still possible to find other interesting uses for a GPS tracker. For example, on a scooter or motorcycle. And if you're a private detective, such a system is bound to make your eyes light up.

We developed the ElekTrack to give our readers an opportunity to experiment with GPS tracking. Due to the large number of SMD components and the difficulty of soldering such

components, we decided to supply this module fully assembled only.

Objective of the design

What must a tracking aid be able to do in its simplest form? Naturally, you want to be able to track the unit's location. We chose the most obvious solution for the position determination part: GPS. With this, the system can identify its position nearly everywhere in the world. In addition, GPS is presently very accurate, and as long as the European Galileo system [1] is not yet operational, it is the best 'alternative'. We decided on SMS for data transmission. Although data transmission is not actually live with this approach, it is possible almost everywhere and at all times. The GPRS network would have been another good option for data transmission. GPRS works with a direct link via the Internet, so data can

Figure 1. As you can readily see from the schematic, everything revolves around the GSM modem.

be displayed live on a computer with Internet access. The location could thus be queried without any time delay, and the data could be stored 'live' in a database. However, we gave the preference to the simpler SMS system.

The design

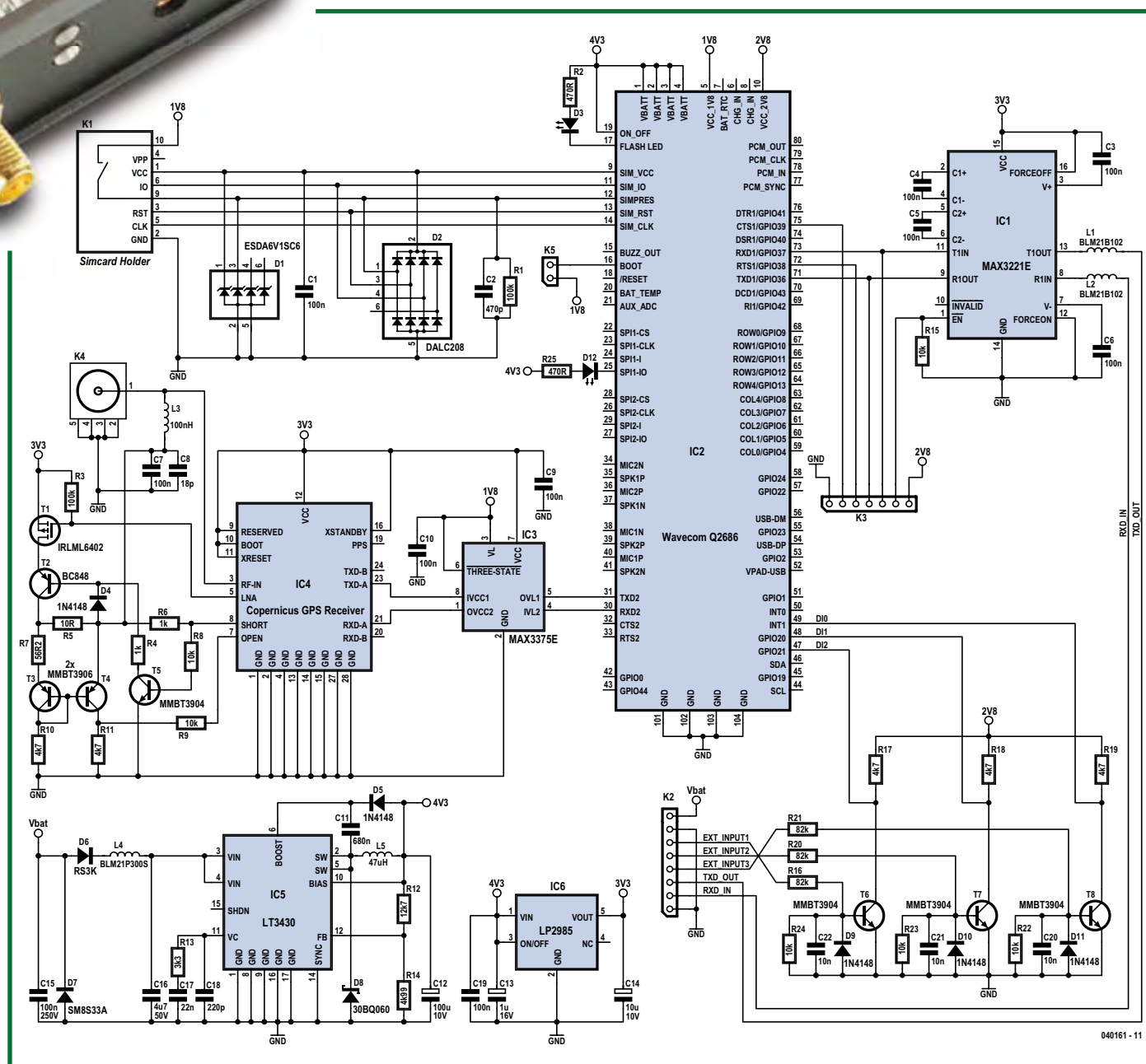
thus consists of two main modules: a GPS module and a GSM module. The GSM module is a type Q2686 from Wavecom. This module can be controlled using Wavecom OpenAT commands, and it has a built-in microcontroller. The main advantage of this is shorter development time compared with using a separate modem, since it is not necessary to implement a microcontroller or any peripheral logic. Everything is located in a single module. This also keeps the overall design nicely compact.

For the GPS module, we decided on the Copernicus from Trimble. This is a successor to the Lassen iQ, which already showed what it could do in the USB

GPS receiver design published in the May 2005 issue of *Elektor Electronics*.

Schematic diagram

A glance at the schematic diagram in **Figure 1** quickly shows that everything is built around the GSM modem. The GPS module is connected to UART2 of the modem via a logic-level converter (IC3). The circuitry around T3, T4 and T5 detects whether the antenna circuit is shorted, open, or connected normally. The GPS module supplies power to the active antenna via T1 and T2. Two supply voltages are necessary for proper operation of the circuit: 4.5 V and 3.3 V. They are provided by IC5 and IC6. IC5 (a LT3430) is a buck convert-





er operating a frequency of 200 kHz. Resistors R12 and R14 determine the output voltage, which is set to approximately 4.5 V.

IC6 provides the supply voltage for the GPS module. It generates a fixed 3.3-V output voltage from a 4.5-V input voltage. Three identical level converters are formed using T6, T7 and T8. They convert the relatively high input voltages to logic levels that comply with the specifications of the GSM modem.

IC1 is a standard RS232 converter, which among other things can be used for connecting the unit to a PC in order to program the modem. You can also use IC1 as a port for your own applications. D1 and D2 protect the input of the GSM module against static discharges that can occur when the SIM card is inserted in the socket.

LED D3 shows the status of the GSM link. If it is continuously on, the modem is not logged in to the network. It starts blinking as soon as the modem logs in successfully. LED D12 shows the status of the GPS module.

External connections

The power supply can work with an external 12-V or 24-V system. Based on tests, the ElektorTrack requires an external supply voltage of at least 8 V for proper operation. The external power source must also be able to supply sufficient current. Relatively high peak currents occur when the GSM modem is transmitting data. The average power consumption of the unit is around 500 mW, so a 9-V battery would only last for approximately 2 hours. A scooter or motorcycle battery will hold out for a lot longer. Naturally, it would always be possible to modify the soft-



ware in order to reduce the current consumption. For instance, you could implement a function to place the GPS module in sleep mode with an SMS command and awaken it with another command.

Naturally, the unit also has antenna connectors: one for the GPS module and one for the GSM module. The modem also has several logic inputs. They can be used for purposes such as connecting an alarm to the ElektorTrack. A voltage above approximately 8 V will cause the digital input of the GSM modem to be triggered. When this happens, a text message can be sent to one of two previously programmed telephone numbers. You will have to implement this in the software yourself, since this function is not yet included as standard. Perhaps it will be implemented in a firmware update.

The GPS module can be configured using various commands. For this purpose, the module must be linked to a PC by a cable. A program such as HyperTerminal for Windows must be used to configure the ElektorTrack unit. The serial port of the PC must be configured as shown in Figure 2.

Startup

The first thing you have to do is to check whether the SIM card is protected by a PIN code. Use the following command for this:



`at+cpin?`

If the modem responds with '+CPIN: READY', the SIM card does not need a PIN code. If you receive the response '+CPIN:SIM PIN' instead, the SIM card needs a PIN code, and this will first have to be eliminated. The current firmware does not yet support automatic PIN code use. This may be implemented in a future version of the firmware. Check our website for the latest version.

If you enter the command

`at+cpin=xxxx`

(where 'xxxx' is the pin code of the SIM card), you will receive 'OK' in response.

Next you have to request disabling of PIN checking by entering the following command:

`at+clk="SC",0,xxxx` (where 'xxxx' is again the PIN code of the SIM card). The modem will again respond with 'OK'.

In order to check whether the modem can now log into the network automatically, you have to reset it with


```
at+cfun=1
```

If everything goes well, the upper LED (D12) will start blinking after a bit less than a minute. This means that the mo-

dem has successfully logged in to the network. If you wish, you can check this by entering the command

```
at+cops?
```

The modem will respond with
+COPS: 0,2,20408
OK

(here '20408' is the operator number,

Better than GPS

The Global Positioning System (GPS) was originally developed for military use. In response to steadily increasing demand for accurate position determination, the GPS system was released for civilian use a bit at time. At first, the accuracy of the satellite signals was intentionally degraded by the US authorities who originally established the system. This restriction was removed a few years ago, so consumers can now use the full resolution of the system. This allows GPS to be used to determine positions with a potential error of up to three metres. The positioning accuracy depends on the number of 'visible' satellites and whether a WAAS or EGNOS signal is received.

The terms WAAS and EGNOS relate to systems that can be used in combination with GPS to increase positioning accuracy. WAAS stands for 'Wide Area Augmentation System', while EGNOS stands for 'European Geostationary Navigation Overlay Service'. The EGNOS and WAAS systems do the same thing, but the former is for Europe and the latter for North America. Each system consists of a network of satellites and ground stations that generate a GPS correction signal that can be used to increase positioning accuracy by a factor of up to 5 on average. A receiver that supports WAAS or EGNOS generates positions that differ from true positions by less



than 3 metres in more than 95% of all cases.

EGNOS currently consists of three geostationary satellites and several ground stations distributed over Europe. The ground stations collect information from each other and generate a correction signal. The ground stations know their own locations with high accuracy, and they compare their positions with the signals received from the satellites, since the paths of the satellite signals can be distorted by atmospheric conditions and other causes. The correction signal is then transmitted to the geostationary satellites. This data has the same format as the standard GPS signal, so it can be read by any GPS receiver that supports WAAS.

EGNOS is a joint project of ESA, Eurocontrol and the European Commission, and it works with the American GPS navigation system and the Russian Glonass navigation system. The EGNOS satellite number for Europe is 33. Many GPS systems indicate whether they are receiving a correction signal. The term 'differential' is also used for this.

The MSAS system, which operates the same way, is used in Asia.



Figure 2. The settings shown here must be used for serial communication.

which depends on the provider.)
Now the modem will log into the network automatically as soon as power is applied to the module.

Security

The first thing you have to do is to change the password. The default password is 'elektor'. To change the password, first enter the following command to request the password:
`at+password?`
The modem will respond with '+PASSWORD:: elektor'. To change the password, use the command:
`at+password="gpsmodule"`
Note: you must enter the quotation marks as shown; otherwise you will receive an error message. The maximum password length is 20 characters.

GPS status

The GPS module is connected to the serial port of the modem. Two commands for requesting data from the GPS module are implemented in the first version of the firmware. The first command is

`at+gpshealth?`

The following is an example of a possible response from the modem:

```
Rcvr status code = 0x01
(Don't have GPS time yet)
Receiver health byte = 0x11
Battery backup: BBRAM not
available at start-up
Antenna feedline fault: An-
```

tenna line open/short
Type of fault: Open detected
OK

From this, you can deduce that the GPS module does not have any valid coordinates at present. The antenna status indicates a fault situation. The fault type indicates that the antenna connection is open-circuited. The antenna is probably not connected.

If the command is issued again after the antenna has been connected, you might receive the following response:

```
Rcvr status code = 0x00 (Do-
ing position fixes)
Receiver health byte = 0x01
Battery backup: BBRAM not
available at start-up
Antenna feedline fault: OK
OK
```

Here you can see that the antenna status is 'OK'. If the antenna input is short-circuited, a 'Short circuit' status message will appear. The receiver status code reports that the receiver

was able to determine a valid position. When the module is first enabled, the receiver status code indicates the number of satellites being received. When the receiver has managed to determine a valid position, the lower LED (D3) starts blinking. If this LED is on continuously, something is wrong. It could mean that the module is not receiving enough satellites, but it could also mean that the antenna is connected incorrectly.

Normal use

Now that you have determined that a link has been established, you would like to know the latitude and longitude coordinates. Enter the following command for this:

`at+gpsposition?`

The modem will return a set of coordinates in response, such as

```
Long: 5.803043 E;
Lat: 50.941492 N;
OK
```



Figure 3. ElekTrack knows exactly where to find Elektor's new head office!

Practical problems

Anyone who writes software knows that little bugs always find a way to creep into the code. When we first developing the software, we had problems with sending SMS messages. It seemed like the SMS service of the modem somehow didn't want to work. After spending several hours looking for the source of the problem and reading through documentation, we came up with the simple but brilliant idea of trying a different SIM card. That meant a quick trip to the shop to pick up a new SIM card. And just imagine our surprise when we discovered that there were no problems at all with the new card!

Of course, we found it rather remarkable that everything worked OK with the new SIM card, so we contacted the supplier. It turned out that there was indeed a bug in the modem firmware. Logging in to the SMS service evidently did not work properly with some types of SIM cards. This problem has been corrected in the latest version of the firmware.

Another problem that is probably familiar to most software developers is the difference between little-endian and big-endian memory organisation. The GPS module outputs latitude and longitude coordinates as doubles in radians. The GPS module operates in little-endian mode, while the GSM module operates in big-endian mode. When you import the data (as ASCII values), the order of the bytes must therefore be reversed. If you convert little-endian radian data in a big-endian processor, the results are naturally all over the map. We overlooked this detail at first. Your first impulse is to think that you made a mistake in the code that performs the conversion. In retrospect it's all pretty obvious, but in the midst of the fray it's a hard nut to crack.



Of course, you want to be able to request the coordinates via SMS so you can request the position of the module remotely. To prevent unauthorised persons from receiving a reply from the module if they send a text message to it, the module must have a password. Send the following message to the module via SMS to assign it a password:

```
info:<password>:<phonenum>
or
INFO:<password>:<phonenum>
```

Note: 'info' must be written either entirely in upper case or entirely in lower case. The password you configured using the `at+password` command must be entered here in place of `<password>`.

The `<phonenum>` parameter is option-

al. The reply is returned to the sender by default. If you want to have the reply be sent to a different number, you can use this parameter to specify the desired number.

After a few seconds, the ElektorTrack will send a text message via SMS with the longitude, latitude and altitude data, which can be used to determine the location of the ElektorTrack unit. For example, you can do this online at [2] (**Figure 3**) or [3].

The ElektorTrack is supplied as fully assembled unit, and you can order it via our webshop at www.elektor.com. The latest version of the software is also available on our website. And of course, we always appreciate hearing from our readers about interesting ideas and applications.

(040161-1)

Web Links

- [1] en.wikipedia.org/wiki/Galileo_positioning_system
- [2] www.gpscoordinates.eu
- [3] <http://boulter.com/gps>

Flash of Inspiration

'Cheap as chips' phone flash makes versatile lights source

Michael Gaus and Bernhard Kaiser

Barely believable: inside a low-cost flash gun the authors discovered hidden treasure — a Freescale 8-bit controller equipped with 4 kB of Flash memory suitable for in-circuit programming. Add a homebrew programming adapter and a couple of free programs off the Internet and you've got a multifunction LED lamp!

The boom in camera phones means you can now pick up tiny snap-on flash guns for a couple of pounds if you know where to look. And if you look inside them you'll find some extremely bright LEDs and some sophisticated electronics that make these bargain units ideal for conversion into pocket torches, signalling lamps and more. Some descriptions of the control logic found on the Internet [1] were the authors' inspiration for this project. That's not all. Since even a simple flash

gun requires some logic and needs to tell the mobile phone what it's doing, there's normally a small microcontroller among the components. If you're thinking this controller is going to be some anodyne mask-programmed no-name product, prepare for a pleasant surprise, at least with the MPF-10 KRY from Sony Ericsson. Inside this little beauty we find an industry-standard 8-bit controller by Freescale, equipped with 4 kB of Flash memory with the bonus of in-circuit programming capabili-

ty. And doesn't this just beg you to create your own mini programs? That way you can get rid of the existing external control logic, which in turn leaves empty space in the casing for your own purposes. A whole raft of features can then be realised quite simply: constant illumination, dimming, flashing on and off or a stroboscope effect. The sample software our authors have written provides all these functions, enabling this LED lamp project to be used as a multifunctional torch, for low energy light-



Figure 1. The phone flash employed can be bought for a couple of pounds on the Internet.

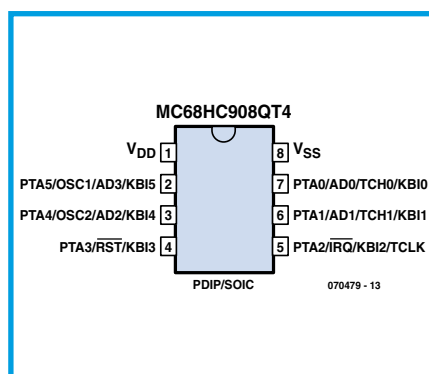


Figure 2. Pin assignments for the miniature 8-bit Controller.



Figure 3. The step-up transformer can be seen among the passive SMD components.



Figure 6. Programming is carried out via this connector on the phone flash. The matching connector illustrated can be bought online.

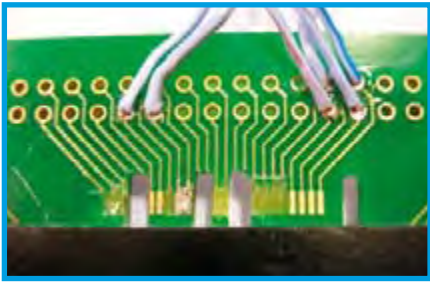


Figure 7. You can also make the matching connector yourself using a PCB designed for SMD components.



Figure 9. When the 'Power Cycle Dialog' window appears the supply voltage must be switched off and on again briefly.

ate cheerfully down to a level of 1.0 V.

Programming adapter

Reprogramming the tiny microcontroller requires a relatively simple programming adapter. Basically this is just an RS-232 level changer (see Figure 5). If you intend to program several phone flash units it would make sense to use the existing multiway connector as this has links to all the connections necessary for programming.

You will need a counterpart for the multiway connector to plug into it and can buy this online [3] (see Figure 6). It is sold by speciality mobile phone spares dealers under the name 'connector strip for Sony Ericsson T68' or something similar to that. If you cannot track it down you can also make up your own from a PCB intended for SMD components with 0.9 mm distance between tracks (Figure 7).

When you put the project into practical use you will also need a power connector to the DC voltage and for this you can either employ another matching connector or else solder the power leads direct to the microcontroller. The second approach will naturally require opening up the case of the unit (see inset Opening up the case).

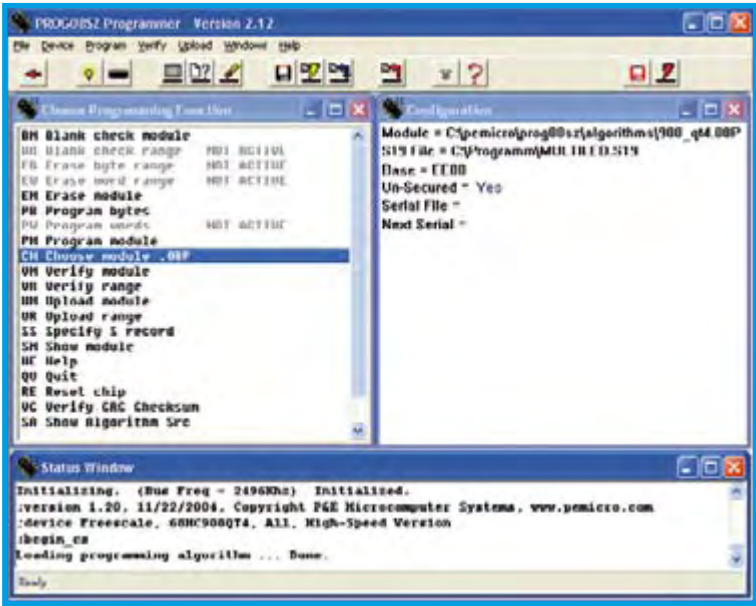


Figure 8. A series of settings needs to be made when using the serial interface.

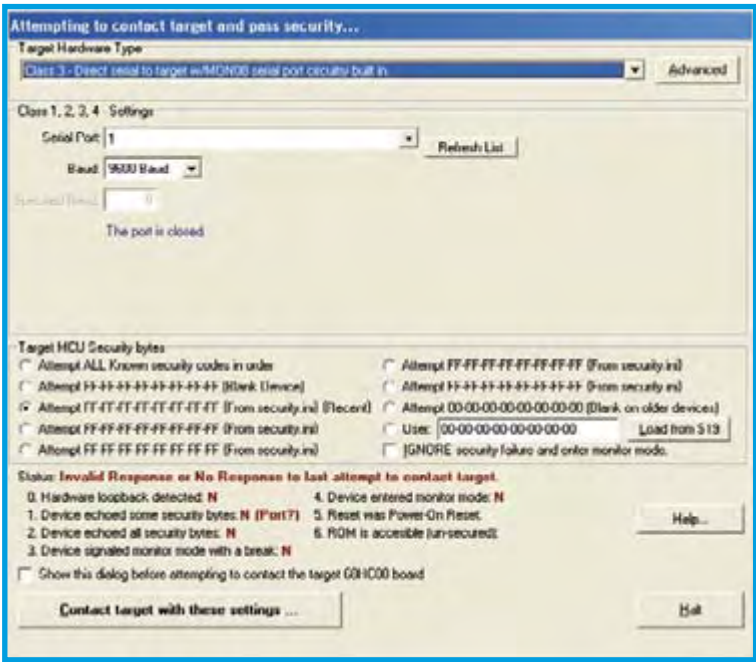


Figure 10. The programming file is selected with 'SS'. The module is erased with 'EM' and programmed with 'PM'.

Compiler

Software requirements are just a compiler and suitable programming software. To generate a new program (or modify our sample program MULTILED.C) the freeware compiler SDCC-2.6.0 [4a] is ideal, although you can also use Freescale's CodeWarrior development environment that was described in the March and April 2007 issues of *Elektor Electronics* [4b]. For Windows systems select 'sdcc-win32' in [4a] as your download.

The source code of the C file can be created and manipulated in a simple text editor such as Notepad. When writing your own programs remember that Variables containing 'near' must be declared to make sure they end up in the internal RAM, for example:

```
unsigned char near cTest;
```

At the outset of our programming activity we need to turn off the Watchdog function with:

```
CONFIG1 = 0x01; // disable Watchdog
```

The compiler is called up with a small batch file (for convenience we have included the file in the software Zip file 070479-11 that you can download

from the *Elektor Electronics* website [5]):

```
sdcc -mhc08 --out-fmt-s19 --  
code-loc 0xEE00 --stack-loc  
0xFF MULTILED.C  
pause
```

0xEE00 is the start address of the internal Flash memory bank. The stack begins at Address 0xFF in the internal RAM and runs downwards.

Programming

The compiler produces several files from the source code, including an .S19 file. This is used for programming the microcontroller.

You will need to install the tool 'PROG08SZ Programmer' from PEMICRO [6]. This freeware program requires no-cost registration before you can download it so go first to the

and Hex file) that you can download gratis from the *Elektor* website [5]. The program MULTILED.C operates in two different modes.

The 'constant/dimmed light' mode allows you to operate the LEDs at maximum brightness with power enabled without needing to press the built-in switch. Pressing the button puts the dimmer into operation, with the step-up transformer cycled on and off by the Enable input. Keeping the button pressed further dims the brightness by reducing the On/Off phase. Once the minimum brightness level programmed has been reached the lamp regains maximum brightness.

You can enter 'flash/strobe' mode by applying power and simultaneously pressing down the flash button. Repeated operation of this button switches the frequency between 60 different values.

Caution

Please take great care when using this device, as the ultra-bright LEDs can all too easily damage your sight. Never look at the light source at close quarters or for any extended period of time.

Login page ('New Account'). Following this, download the installation file 'prog08sz_interactive_install.exe'.

A number of settings need to be specified in the process of using the serial interface, which can be seen in the screenshot (**Figure 8**). When you have connected up the phone flash to the power supply and the programming adapter you have to activate the button 'Contact target with these settings'.

A new window opens, in which you need to select the microcontroller type ('908_qt4.08P').

When the window 'Power Cycle Dialog' opens (see **Figure 9**), the power must be switched off and on briefly. The actual programming comes next. First we select the correct programming file (in this example 'MULTILED.S19') using the program function 'SS' (see **Figure 10**). The module is erased with the command 'EM' and programmed with 'PM'. Using 'VM' (verify module) you can check whether the whole operation is functioning error-free.

Sample program

The authors have written a small but practical sample program (source code

(070479-1)

Web Links

[1] Phone flash info, additional photos and the inspiration for this project:

http://avr.auctionant.de/mpf-10_handyblitz

[2] Data sheet for the microcontroller:

www.freescale.com/files/microcontrollers/doc/data_sheet/MC68HC908QY4.pdf

[3] Connector for flash programming the phone flash:

<http://stores.ebay.de/MOBIL-PLANET-GMBH> (keyword: 'Anschlußleiste t68')

Or try a Google UK or eBay UK search to find a more local supplier (let us know if you do!).

[4a] C Compiler SDCC 2.6.0 (Freeware):

http://sourceforge.net/project/showfiles.php?group_id=599

[4b] Freescale SpYder project in Elektor Electronics March and April 2007:

www.elektor.com

[5] MULTILED.C, free download from the Elektor website.

Follow:

Magazine→2007→[Month]→[article title]

[6] Programming software (registration required):

https://www.pemicro.com/login.cfm?from_url=http://www.pemicro.com/downloads/download_file.cfm?download_id=83

Opening up the case

During programming (using a DIY adapter or even a fly-lead) it is important to secure the power supply, by mechanical means, from disconnection. This means opening up the case and soldering the wires to the microcontroller. This is a convenient opportunity to replace the white LEDs with coloured ones if you wish.

There are two steps to this disassembly operation.

The clear window and reflector assembly clip onto the remainder of the case. Pressing a knife or screwdriver blade into the slot releases the window/reflector assembly and allows you to separate the phone flash into two parts.



To get at the electronics you need to remove the rear cover by undoing the four cross-head screws holding the reflector assembly.



The power leads are soldered direct onto the supply pins of the microcontroller. Closing the case afterwards assures a good strain relief



USBprog

Open source Swiss Army knife

✓ AVR prog

✓ USB-RS232 inter

Benedikt Sauter and Thomas Scherer

A new microcontroller, and yet another new programmer? Anyone involved with microcontrollers today will have a drawerful of printed circuit boards and adaptors for programming various devices. Enter USBprog, which can replace all those with a single unit. As a bonus, it can even be used as a general-purpose USB I/O port and RS-232 adaptor.

Features and functions

- USB interface
- Software for both Windows and Linux
- Programmer and debugger for AVR processors
- Programmer and debugger for ARM processors
- USB-to-RS-232 converter without driver
- JTAG interface
- USB-to-digital-I/O interface (ten signals)

Benedikt Sauter was prompted to develop this design by his frustration at the fact that each new microcontroller seemed to demand its own programmer. Not only is this a waste of space

and money, it is hardly an environmentally-friendly way to proceed. Furthermore, many of the simple programmer designs available on the Internet, as well as older commercial units, require

the use of a PC with a 'legacy' interface such as a parallel printer port or an RS-232 port: these are becoming a rare feature on modern machines. These days, a USB interface is essential on any peripheral. Sometimes a serial peripheral can be given a new lease of life using a USB-to-serial converter. However, these converters are often slow, especially when it comes to software control of the handshake signals. Even transferring just a couple of kilobytes of data into the microcontroller's memory can leave you twiddling your thumbs for a minute or so, and these delays are particularly irritating when developing and debugging software. Good (i.e., fast) USB to serial converters exist but are somewhat more expensive than the more general purpose unit we describe here.

Jack of all trades?

Having set out the problems, we now try to solve them, preferably all at once! Since we want to achieve relatively fast data transfer between the USB port and the target system, it makes sense to use a USB interface chip along with a dedicated microcontroller which is responsible for high-speed communication with the processor in the target system. If we choose a reasonably powerful microcontroller for this task we will also be able to add some intelligence to the unit. We can download data into a buffer in the microcontrol-

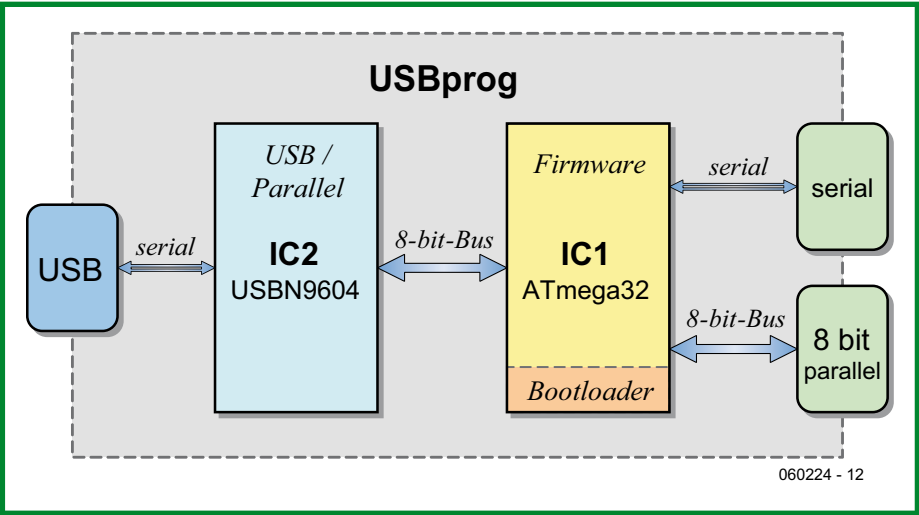


Figure 1. The block diagram of USBprog shows the combination of a USB bridge and a microcontroller.

rammer

erface

Windows & Linux



USBprog



ARM programmer



USB-I/O interface



JTAG interface

Table 1. Firmware available from the project website (status: August 2007). The range available is continuously being extended.

N°	Name	Description	Status
1	AVRISP mkII clone	Clone of the original AVRISP mkII	stable
2	OpenOCD adapter	Adapter for ARM7 and ARM9	beta
3	AT89 programmer	Developed for the Elektor Electronics AT89S8252 board	beta
4	SimplePort	Ten I/O signals that can be controlled using C, Python or Java	stable
5	JTAG adapter	Universal USB-to-JTAG adapter with C library	beta
6	USB-to-serial converter	USB-to-RS-232 converter (no extra driver needed)	pre-alpha
7	JTAGICE mkII clone	Clone of original JTAGICE mkII	in development (basic functions)
8	XSVF-USB player	Universal XSVF player	structure and source code framework in place
9	Blink demo	Simple LED flashing demonstration	stable
10	PIC programmer	Based on 'Odyssey' for Linux and Windows	structure and source code framework in place
11	USB BDM interface	Interface and debugging for 68-series processors	structure and source code framework in place
12	MSP430 JTAG	Interface for this low-power microcontroller from Texas Instruments	structure and source code framework in place

ler in one rapid operation, and then it can carry out the rest of the programming task autonomously, simulating the programming interface and transferring data to the target system (see **Figure 1**).

In fact, we can go one better: if our microcontroller is programmed with a generic bootloader, then it is possible to download into its memory whatever software is required for the particular task at hand from the PC, using the USB interface rather than using its own programming interface. Of course, this facility allows for straightforward firmware updates, but it also turns the

device into a general-purpose tool. By using firmware with different functions in USBprog's microcontroller, we can turn the unit into an AVR programmer, or an ARM7/ARM9 programmer, or a USB digital I/O port. And, since the microcontroller we use has a built-in UART, we also get a free USB-to-serial converter!

Open source

The most elegant hardware design in the world is nothing without its accompanying software, and this is especially true of USBprog. Without a

suitable bootloader and firmware to provide all the anticipated functions we would just have a useless piece of electronics. It is hardly reasonable to tell users to write their own firmware, and so, in addition to the required USB interface driver for IC2 and bootloader for IC1, the author has made a range of additional programs available on his own project website [1]; the firmware is also available for download from www.elektor.com.

Table 1 shows at a glance what firmware is available and currently in development. An interesting item al-

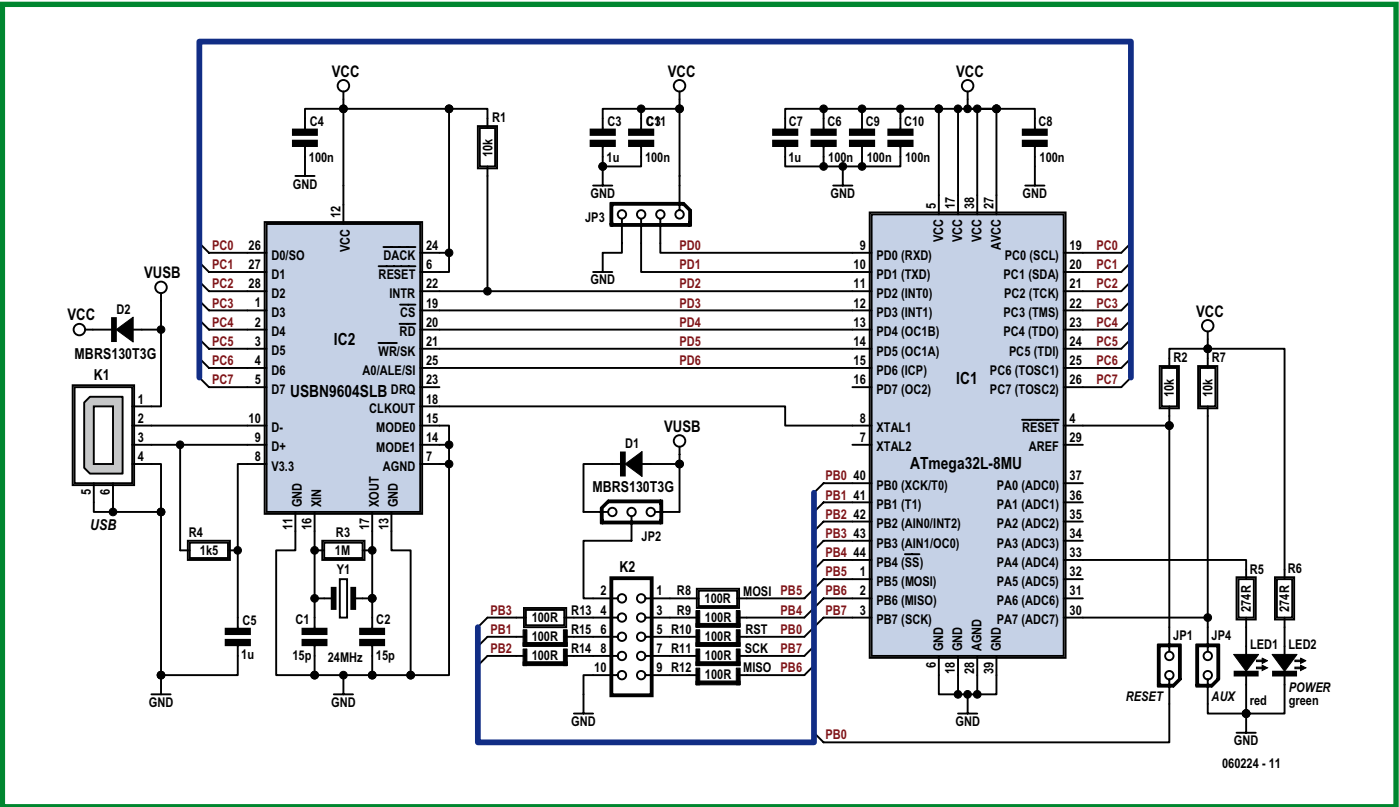


Figure 2. The circuit diagram of USBprog is hardly more complicated than the block diagram.

lows USBprog to be turned into a clone of the Atmel mkII in-system programmer. It can then be used directly with Atmel's free AVR Studio development environment [2] and other software that supports the AVRISP mkII. Another firmware option allows ARM7 and ARM9 microcontrollers to be programmed and debugged using the OpenOCD software development environment [3]. Other options allow the

unit to act as a USB-to-serial converter or simple USB interface with ten digital I/O lines. In the works are a JTAG-based programmer and firmware for programming other microcontroller families.

In the true spirit of open source software, the source code for the firmware is freely available. You are warmly encouraged to add to the project for the

benefit of all users; there is already a small community of USBprog users and developers.

In the interests of making it easier to get started with this open source project, the project site also contains software that can not only reflash the ATmega32, but also (at the press of a button) check the project site to see if any new firmware has become avail-

Table 2. Pinout of K2 under various firmware configurations.							
Pin number	AVRISP mkII clone	OpenOCD adapter	AT89 programmer	SimplePort	JTAG adapter	USB-to-serial converter	JTAGICE mkII clone
SV2 pin 1	MOSI	TDO	MOSI	Port 1	TDO	–	TDI
SV2 pin 2	VCC	VREF	VCC	VCC	VREF	VCC	VREF
SV2 pin 3	–	SRST	–	Port 2	SRST	–	–
SV2 pin 4	–	TRST	–	Port 3	TRST	–	–
SV2 pin 5	Reset	TMS	Reset	Port 4	TMS	–	TCK
SV2 pin 6	–	–	–	Port 5	–	–	–
SV2 pin 7	SCK	TCK	SCK	Port 6	TCK	–	TMS
SV2 pin 8	–	–	–	Port 7	–	–	–
SV2 pin 9	MISO	TDI	MISO	Port 8	TDI	–	TDO
SV2 pin 10	GND	GND	GND	GND	GND	GND	GND
JP3 RX	–	SRST	–	Port 9	–	RX	–
JP3 TX	–	TRST	–	Port 10	–	TX	–

able, and, if so, download it. The package is available for Linux as well as Windows, and an OS X version is planned.

Hardware

Figure 2 shows the circuit diagram of USBprog, which is hardly more complicated than the block diagram. The whole circuit draws less than 100 mA and is comfortably powered directly from the PC via the USB connector. D2 protects the PC from excessive voltages originating in hardware connected to the unit. IC2 is a dedicated USB bridge

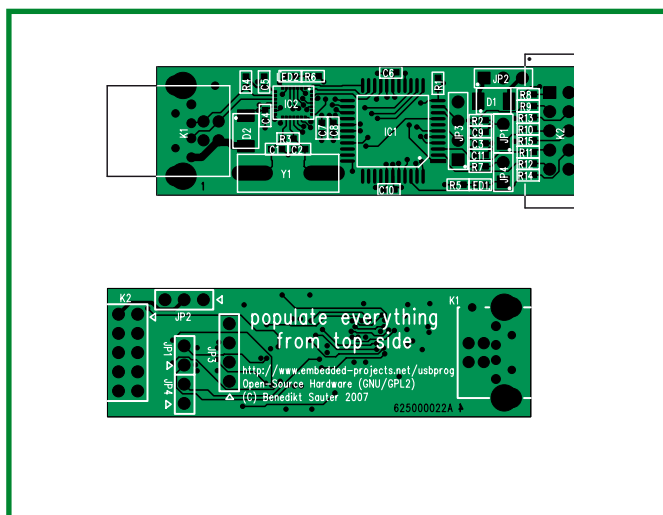


Figure 3. Most of the components on the double-sided printed circuit board are surface-mount types.

Construction and bootloader

USBprog is built on a double-sided printed circuit board and employs a number of surface-mount components, and so many readers might prefer to buy the kit available from the Elektor Shop where most of the components have already been mounted on the circuit board. Just the connectors and headers remain to be soldered. More ambitious constructors can make their own printed circuit board (**Figure 3**) using the layout available for download from <http://www.elektor.com> or order the board from <http://>

COMPONENTS LIST

Resistors

R1, R2, R7 = 10k Ω , SMD 0603
R3 = 1M Ω , SMD 0603
R4 = 1k Ω , SMD 0603
R5, R6 = 274 Ω , SMD 0603
R8...R15 = 100 Ω , SMD 0603

Capacitors

C1, C2 = 15pF, SMD 0603
C3, C5, C7 = 1 μ F, SMD 0603
C4, C6, C8-C11 = 100nF, SMD 0603

Semiconductors

IC1 = ATmega32L-AU, QFP 12x12 (Atmel)
IC2 = USBN9604SLB (National Semiconductor)
D1, D2 = MBR5130T3G, SMB DO214AA
LED1 = LED, red, SMD 0603
LED2 = LED green, SMD 0603

Miscellaneous

Y1 = 24 MHz, quartz crystal, HC49/4 case
K1 = USB socket, Type B, PCB mount
K2 = 10-way DIL boxheader, angled, PCB mount
JP1, JP4 = 2-way SIL pinheader
JP2 = 3-way SIL pinheader
JP3 = 4-way SIL pinheader
PCB, bare, ref. 060224-1, see www.elektor.com
PCB, SMD pre-fitted, all other parts supplied, order code 060224-71, see [SHOP](http://www.elektor.com) pages or www.elektor.com

which is compatible with 'full speed' USB 1.1. It transfers data using DMA, which is more than fast enough for our purposes. Its clock is derived from a 24 MHz crystal: this frequency is doubled internally and then a programmable derived frequency can be made available at the CLKOUT output. We use this to clock IC1, thereby avoiding the need for a second crystal. Most firmware will configure the clock so that IC1 runs at its maximum frequency of 16 MHz. IC1 and IC2 are connected by a number of control signals and an eight-bit bus. The function of the pins of parallel port K2 and of JP3 is determined by the firmware in use (see **Table 2**).

If JP1 is fitted the reset signal of IC1 can be driven externally via pin 5 of K2, which is needed when programming the bootloader into IC1. JP2 determines whether the hardware connected to K2 is powered directly from the 5 V

supply on the USB connector or whether the PC's supply should be protected by diode D1. D1 and D2 are Schottky types as these have a lower forward voltage drop than ordinary diodes. JP4 is available for any purpose: for example, an external push button could be connected to it.

www.thePCBShop.com, and populate it by hand.

When construction is complete (**Figure 5**) we find ourselves in a chicken-and-egg situation: before we can download the desired firmware over the USB interface, the bootloader, which performs this programming function, needs to be programmed into IC1. As a secondary function, port B of IC1 can be used for programming, and all the necessary connections are brought out to K2. If you do not already have an AVR programmer (and cannot beg, borrow or steal one from a friend) it is possible to use a PC with a parallel port and a simple programming circuit [4] that you can assemble on a breadboard.

The file 'usbprog_base.hex' can be transferred to the ATmega32 using AVR Studio, AVRDUDE or other AVR programming tool. The fuses

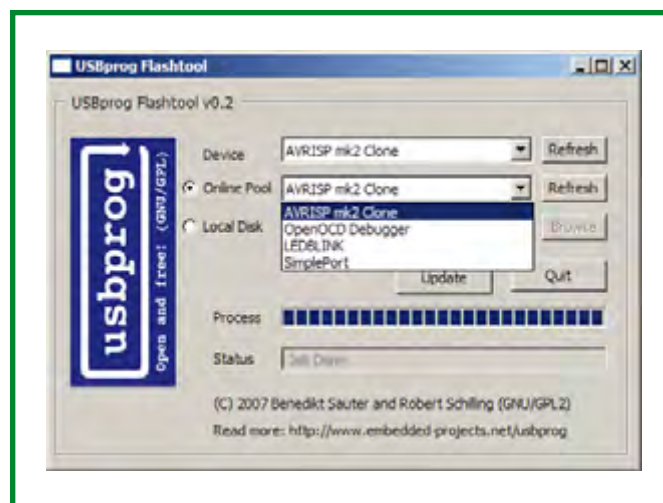


Figure 4. A screenshot of 'usbprog-gui.exe', running under Windows.

About the author

Benedikt Sauter is a passionate open source hardware and software developer and looks after USBprog applications for the project website.

Table 3. Fuse settings for the ATmega32.

N°	Fuse	Value	Description
1	BODLEVEL	1	no brown-out detection
2	BODEN	0	no brown-out detection
3	SUT0	0	start-up time = 6 CLK + 64 ms
4	SUT1	1	start-up time = 6 CLK + 64 ms
5	CKSEL3..0	0000	external clock
6	CKOPT	1	external clock
7	OCDEN	1	on-chip-debug disabled (required because Port C is used)
8	JTAGEN	1	JTAG off
9	SPIEN	0	serial program download enabled
10	EESAVE	1	chip erase also erases EEPROM
11	BOOTSZ1..0	00	boot start address = \$3800
12	BOOTRST	1	only for 'usbprog_base.hex'; otherwise BOOTRST = 0

must also be programmed according to **Table 3**. Once the bootloader and fuses are programmed, the device is ready for use.

Software

As we noted above there are both command-line and fully-fledged application versions of the program for download-

ing firmware into USBprog, available for both Linux and Windows. For Windows there is an installation program (called 'Installer.exe') on the project web site [1]. When this file is executed under Windows the command-line program ('usbprog.exe'), the version with graphical user interface ('usbprog-gui.exe'), and the appropriate driver are all installed.

When USBprog is now connected to a USB port the Windows driver wizard will recognise it and load the driver automatically.

Because of the range of architectures on which Linux runs, this version of the program does not come ready-compiled. The software archive file should be downloaded from [1] and the following procedure followed.

1. Unpack the archive: 'tar xvzf usbprog.tar.gz'.
2. Change to the 'usbprog' directory.
3. Prepare for compilation using the command './configure'.
4. Start compilation with the command 'make'.
5. Install using the command 'make install' (as root).

The USBprog software is not currently available for the Mac. However, it is possible to use USBprog as an AVRISP mkII clone with the help of the AVRDUDE free software [5], which is a command-line programming tool for AVR microcontrollers.

News and updates relating to USBprog will be posted to the project website [1].

(060224-1)

Web Links

- [1] **Project site:**
www.embedded-projects.net/usbprog and <http://www.elektor.com>
- [2] **AVR Studio:**
www.atmel.com/avrstudio
- [3] **OpenOCD:**
<http://openocd.berlios.de/web>
- [4] **Parallel port programmer:**
www.ixbot.de/index.php?page_id=188
- [5] **AVRDUDE:**
www.nongnu.org/avrdude
- [6] **WinAVR:**
<http://winavr.sourceforge.net>
- [7] **Yagarto (ARM development environment):**
<http://www.yagarto.de>
- [8] **ATmega32 data sheet:**
www.atmel.com/dyn/resources/prod_documents/doc2503.ppdf

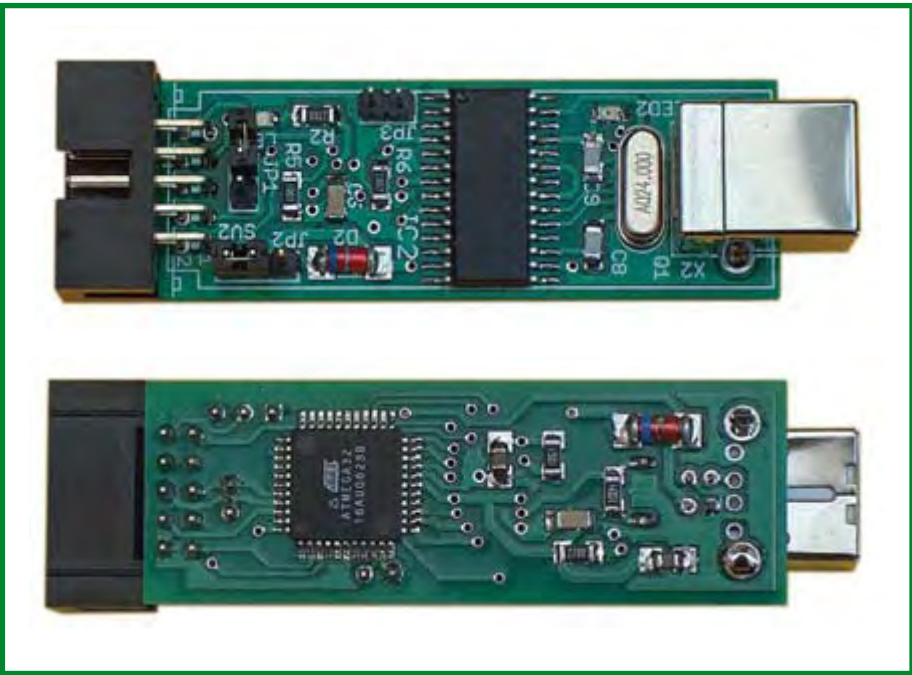


Figure 5. This prototype made in the Elektor Electronics laboratory is almost identical to the final version.

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USB/UART Interfaces

A survival guide

Antoine Authier

The first chips to interface between the USB bus and asynchronous serial busses (UARTs) appeared in the early 2000s.

Now here we are with third, fourth, and even fifth generation circuits: faster, more reliable, and more stable (especially their drivers), and offering improved features.

These ICs make it possible to connect any device that requires a full duplex asynchronous serial link (whether RS-232 compatible or not) to a USB host bus.

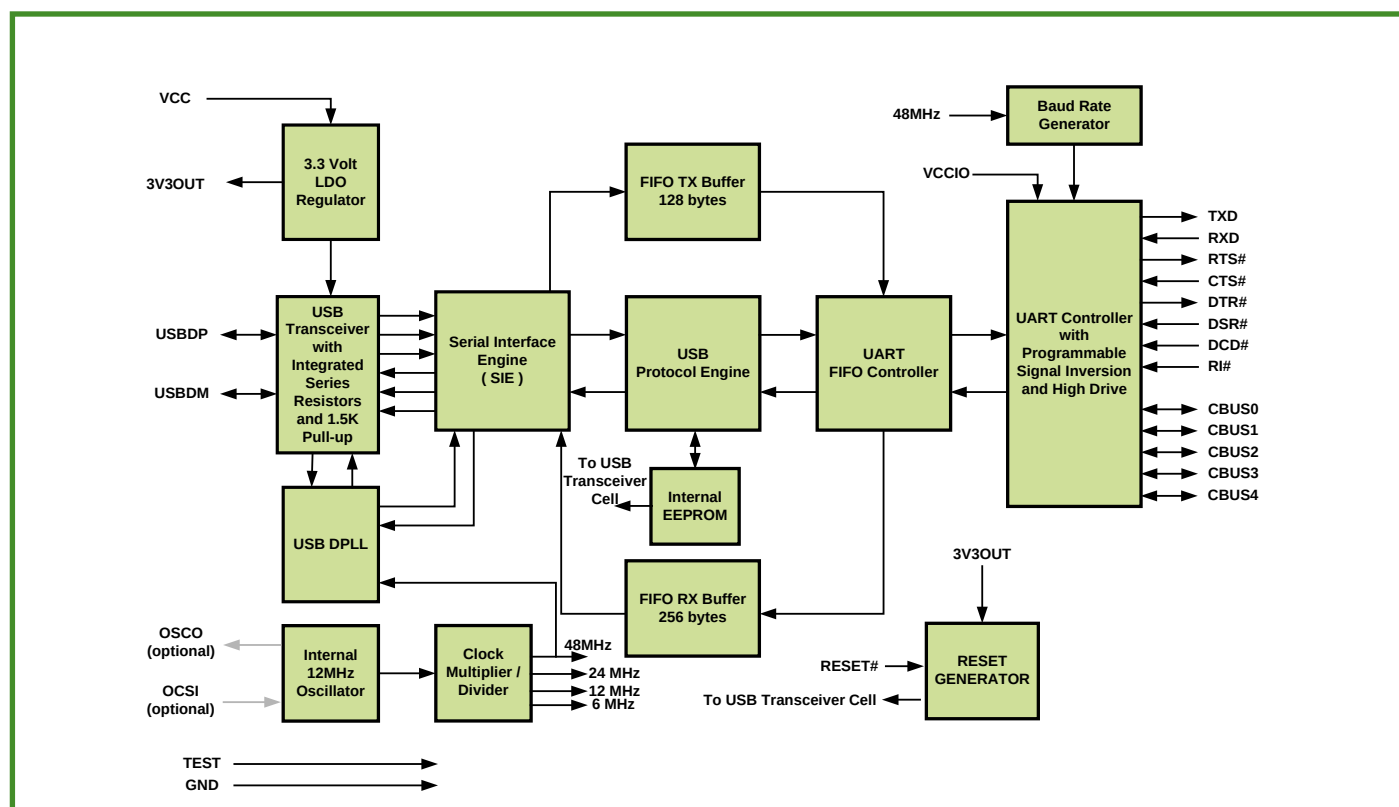
Their drivers usually offer two modes of use. The first makes it possible to simulate a traditional COM port under

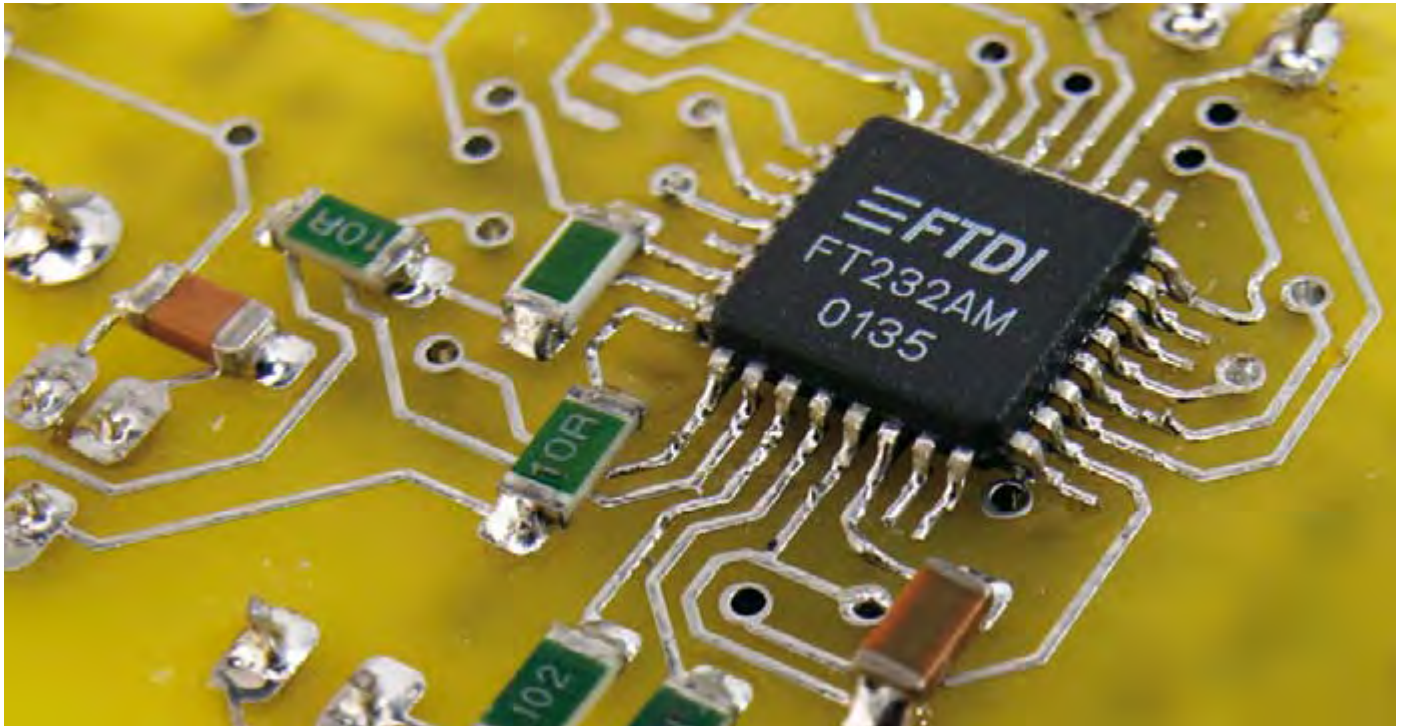
the majority of operating systems (Windows, Linux). In so doing, it increases the flexibility of the technology transition by making it easier to use older equipment designed for serial ports transparently on the USB bus.

The second mode concerns high-speed data transfer (i.e. direct block transfer,

bulk mode), in particular through the user of a larger buffer memory — so long as the conventional RS-232 signalling can be abandoned. Certain ICs make it possible to comfortably exceed the 115,200 bps limit.

The three principal players in this marketplace are the Scottish **Future Tech-**





nology Device International Ltd (in case you've ever wondered what was behind the abbreviation FTDI), American **Silicon Laboratories Inc.** ('Silabs' to their friends), and Taiwanese **Pro-lific Technology Inc.**

FTDI

The two most recent products from FTDI are the FT232R and the FT232D.

The FT232R offers a USB/serial UART (Universal Asynchronous Receiver/Transmitter) interface, and also works in synchronous 'bit bang' mode; this mode, specific to the FTDI chips, allows them to control eight high-speed input/outputs (I/O). The configuration EEPROM and USB bus connection resistors have been integrated onto the chip, along with the clock circuit, to simplify implementation and save space.

The internal clock (configurable to 6, 12, 24 or 48 MHz) is available on one of the IC pins; it can be used additionally to clock a microcontroller or external logic.

During production, each IC is given a unique identification number (FTDI-Chip-ID). FTDI are very proud of this technical innovation, which makes it possible, for example, to protect an application against copying.

The FT232D offers two independent-ly-configurable USB-UART/FIFO (First In-First Out) interfaces. It supports the

following modes in particular: UART interface, FIFO, bit bang, JTAG-compatible synchronous serial interface, I²C, and SPI bus. These last three interfaces make this IC very popular for direct connections to a wider range of chips. The JTAG compatibility makes debugging and impeccable program-

2.4.20 and it's responsible for creating the peripheral `/dev/ttyUSBx` when an FTDI IC is connected under Linux.

Various other contributors have written other implementations and supplements. Intra2net, for example, provides a special library for access in bit bang mode (<http://www.intra2net.com/de/>

A user report

"The hardware flow control wasn't working properly. Fortunately for us, the US technical support corrected the problem very quickly.

On the other hand, no source code is provided with the Linux driver. So it took us quite a lot of messing around and a bit of reverse engineering to adapt it.

In terms of the serial port synchronisation, the USB forces the transmission of frames per packet, which causes a slight delay – a few milliseconds, if my memory serves me correctly – on both transmit and receive.

But one thing's for sure – this doesn't stop you achieving transfer rates much higher than a conventional serial port."

Frederic, R&D Inventel, Paris.

ming easier.

The drivers for these circuits are supplied by FTDI free and without fees, for both Microsoft operating systems and Linux (kernel 2.4.x only, which seems pretty antique at the time of writing). Bill Ryder is the initiator of the virtual COM for Linux (<http://ftdi-usb-sio.sourceforge.net>) and is co-ordinating long-term development. Bill's driver is built into the kernel since version

`produkte/opensource/ftdi/`). Based on the 'libusb' standard, this library works very well, at least insofar as we have been able to test it.

The Windows drivers are available from the website and are well-documented.

FTDI seem to be the front-runners in the ICs most used in home-construction electronics projects.

There's a great deal of know-how out

Characteristics – Features	FTDI		Silicon Laboratories
	FT232R	FT2232D	CP2101
USB standard	2.0 Full Speed	2.0 Full Speed	2.0 Full Speed
Size of USB descriptor EEPROM (bytes)	1024	external	512
Transmit buffer size (bytes)	128	128	512
Receive buffer size (bytes)	256	384	512
Number of data bits supported	7 and 8	7 and 8	8
Number of stop bits supported	1, 2	1, 2	1
Parity supported	even, odd, none mark, space	even, odd, none mark, space	even, odd, none
Handshaking	hardware or software X-On X-Off	hardware or software X-On X-Off	hardware and software
Baud rate	RS232: 300 bps – 1 Mbps RS485: 300 bps – 3 Mbps	RS232: 300 bps – 1 Mbps RS485: 300 bps – 3 Mbps	300 bps 921.6 kbps
Suspend & Resume	yes	yes	no
Configured data rates (non-standard)	yes	yes	no
Receive time-out configurable	yes	yes	no
Generic in/out ports	5 configurable	configurable	no
In/out port Voltage configurable Via Vio pin	1.8, 2.8, 3.3, 5 V	3.3, 5 V	no
Dynamic standby Via USB port		yes	no
Supports RS-232 protocol	yes	yes	yes
Supports RS-422 protocol	yes	yes	no
Supports RS-485 protocol	yes	yes	no
Other serial bus	-	JTAG, I ² C, SPI	-
Block transfer mode	yes, bit bang	yes, bit bang	yes
Internal clock	6, 12, 24, 48 MHz	no	-
Built-in USB bus impedance matching	yes	no	yes
Supply Voltage	3.3, 5.25 V	4.35, 5.25 V	3.0, 3.6 V
Supply Via USB bus	yes	yes	yes
Serial number	FTDIChip-ID	no	no
Package	QFN-32 SSOP-28	LQFN-48	QFN-28
Software drivers	Virtual COM Port (W/L) D2XX (W/L)	Virtual COM Port (W/L) D2XX (W/L)	Virtual COM Port (W/L) USBXpress (W)

there on the Web, which is to everyone's benefit. Although it's true the supply situation was a bit tricky a few years back, the distribution network has been improved and FTDI chips are now widely available at reasonable prices. We'll shortly be giving you an introduction to their latest innovation, the Vinculum USB host controller.

Silicon Laboratories

Silicon Laboratories offers three ICs in its USB/serial interface range: the CP2101, CP2102, and CP2103. The CP2101 is the base, and the refer-

ence. It offers all the basic functions of the USB/UART interface from the *Silabs* stable. Its 5 mm package houses a USB 2.0 full speed controller, a clock, the impedance matching circuitry for resistor-less connection to the USB bus, a 512-byte EEPROM, and an RS-232-compatible UART controller. Hence no external components are needed on the USB bus side of things. The CP2102 and CP2103 are successive improvements on this, with an increasing number of functions. The internal EEPROM, extended to 1,024 bytes, can be write-protected. The CP2103 has been expanded with four independent I/O ports, their out-

put voltage adjustable (by means of an external supply). It also supports the RS-485 protocol and dynamic stand-by operation via the USB bus. Silabs also provide two types of driver. COM port emulation is available under both Windows and Linux. In this configuration, the UART interface supports all the functions of the RS-232 protocol, as well as handshaking. The CP2103 also recognizes the RS-485 protocol, and it controls four GPIOs (**G**eneral **P**urpose **I**nput/**O**utput). A driver named 'USBXpress', available for Windows only, accesses the chip directly. It's worth noting that the source code is unfortunately not supplied with the

		Prolific		Moschip	
2.0 Full Speed	2.0 Full Speed	2.0 Full Speed	1,1	2.0 Full Speed	2.0 Full Speed
1024	1024	OTP + external	OTP + external	external I ² C	external I ² C
640	640	256 / 128	-	512	512
576	576	256 / 328	-	512	512
5, 6, 7 and 8	5, 6, 7 and 8	5, 6, 7 and 8	-	5, 6, 7 and 8	5, 6, 7 and 8
1, 1.5 and 2	1, 1.5 and 2	1, 1.5 and 2	-	-	-
even, odd, none mark, space	even, odd, none mark, space	even, odd, none mark, space	-	-	-
hardware and software	hardware and software	hardware or software X-On X-Off	hardware and software	hardware and software	hardware and software
300 bps 1 Mbps	300 bps 1 Mbps	75 bps – 6 Mbps	up to 1 Mbps	50 bps – 6 Mbps	50 bps – 6 Mbps
yes	yes	yes	-	yes	yes
yes	yes	-	-	yes	yes
yes	yes	-	-	-	-
no	4	2	12	1	1
no	1.8 V – Vdd	-	-	-	-
no	yes	yes	-	yes	yes
yes	yes	yes	yes	yes	yes
no	no	no	-	yes	yes
no	yes	no	-	yes	yes
-	-	-	yes (Japanese)	-	-
yes	yes	yes	-	-	-
-	yes	no	no	no	no
yes	yes	yes	yes	-	-
3.0, 3.6 V	3.0, 3.6 V	3.6, 5.5 V	3.3, 5.5 V	4.5, 5.5 V	4.5, 5.5 V
yes	yes	-	-	-	-
no	no	yes	-	-	-
QFN-28	QFN-28	QFN-32 SSOP-28	LQFP-48 SSOP-28	LQFP-48	LQFP-64
Virtual COM Port (W/L) USBXpress (W)	Virtual COM Port (W/L) USBXpress (W)	Virtual COM Port (W/L) Direct access (to be tested)	-	Windows/Linux/Mac	Windows/Linux/Mac
Port COM Virtuel (W/L) USBXpress (W)	Port COM Virtuel (W/L) USBXpress (W)	Port COM Virtuel (W/L) Accès direct (à tester)	-	Windows/Linux/Mac	Windows/Linux/Mac

Linux driver.

Craig Shelley has re-written this driver, which is available with the source files of the current kernel. It is still at the advanced development stage.

However, the Silabs website does offer a rich and detailed knowledge base. The high-quality application circuits are provided complete with the source code for their firmware.

Prolific

Prolific offers us two recent ICs: the PL2303X-Edition and the PL2313, providing one or two USB serial interfaces respectively.

The PL2303X complies with the specifications for the USB 2.0 full-speed bus. This IC offers an internal 12 MHz clock and two generic in/out ports. The UART recognizes the RS-232 protocol. An OTP memory allows you to configure the parameters of the serial link and your manufacturer data, VendorID and ProductID. A serial number can also be written into this memory. This information can be modified in external EEPROM when this is used. The PL2313 seems to be based on an older core – it complies with the USB 1.1 standard. It offers two USB/UART interfaces complying with the RS-232 protocol. It contains an inter-

nal clock, the bus resistors, an OTP memory for customization, and 12 in/out ports.

As a bonus, it is compatible with several Japanese mobile phone interfaces iMode, CDMA-1, etc.

You are recommended to prepare the ground by obtaining the drivers for Windows and pre-installing them. Without this, the automatic installation won't work.

The data sheets for the Prolific components, the source codes, and the application notes are available under [*support > download center*] on their website. They also provide there the drivers for Windows, virtual COM, and direct



access, as well as some examples of source code describing direct access under Linux. The COM port driver under Linux is developed independently

Linux. We haven't come across this type of product before in Europe.

K-micro, an American manufacturer, also offers this type of product, but

driver and the D2XX direct access together won't work, you will be asked to uninstall the current driver.

– If your IC offers two interfaces, you

Customize your products

- ✓ Modifying the ICs' EEPROM in order to change the VendorID and/or ProductID of your device can prove risky. The reference drivers will no longer recognize the device.
- ✓ If you want to customize your projects and have your own official VendorID, it will cost you \$2,000 from the regulatory authority: www.usb.org/.
- ✓ However, you can get a batch of ten unique, official VendorID/ProductIDs from <http://www.mecanique.co.uk/> for the modest sum of £ 29.95.
- ✓ What's more, FTDI offers companies the opportunity of having a group of eight ProductIDs, provided these are used in conjunction with FTDI's VendorID (0x0403).



by Greg Kroah-Hartman; the code is built into the kernel.

Others

The last manufacturer we'll tackle here is Indian and presents a very extensive range of products.

The two recent USB/serial interfaces from **Moschip Semiconductor Technology Ltd** are the MCS7820 and MCS7840. They provide two and four interfaces respectively, complying with the USB 2.0 standard and the RS-232, RS-422, and RS-485 protocols. These components need an I²C-compatible EEPROM and can be powered directly from the USB bus. Drivers are available for both Windows and

we're not yet convincing, so we'll content ourselves with just mentioning them – you can always read more about them on their website.

So at the end of this brief introduction, it seems as if each manufacturer offers a complete range of products that are to a greater or lesser extent identical. The prices, the support offered, and the information available from the manufacturers, along with the summary table we've prepared for you, ought to help you choose.

Remarks and advice

– (tested for FTDI only)
Warning! installing the virtual COM

will have to install the same driver twice. Each interface in effect has its own group of USB endpoints, managed separately by the host device.

(070478-1)

Web Links

www.ftdichip.com/
www.silabs.com/
www.prolific.com.tw/
www.k-micro.us/
www.compuapps.com/
www.moschip.com/
www.usb.org/

“Elektor? Prescribed reading for our R&D staff because that’s where we need professional guidance for microcontroller technology.”

– Frank Hawkes, 39, development engineer –

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Home Automation

Using a broadband router to control home automation devices

Arthur Vogels

A wireless router can be used for a variety of unusual purposes, such as controlling home automation devices. This article describes a relatively simple conversion of an Asus router for use as a home automation control unit.

As already described in an article in the February 2006 issue on modifying routers, standard broadband routers can be used for many purposes that

their designers never had in mind. That article described how to add a USB port to an inexpensive Sweex router and convert it into a web server. In this

article, we show you how to modify a standard wireless router for use as the central control unit of a home automation system.

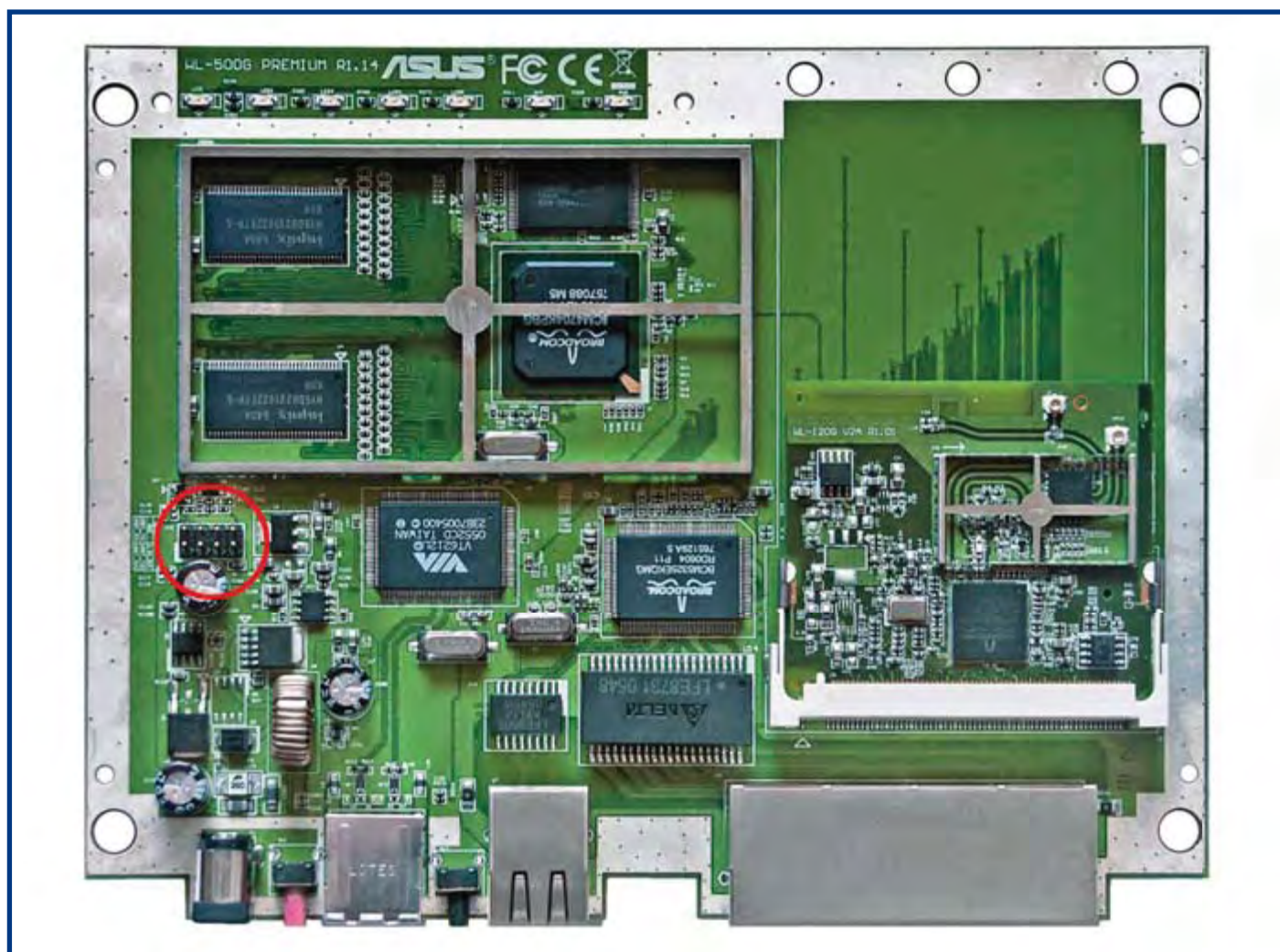


Figure 1. The PCB inside the case has an expansion connector for two serial ports.

Controller



The home automation system in question is a DIY system that was originally designed to work with a PC as the central control unit. If you use a different home automation system, you will probably have to make some adjustments to the project described here, but the basic idea is the same.

The advantage of using a router is that it consumes much less energy than a PC. You probably have a wireless router somewhere in your house for your broadband Internet connection, and it can assume an additional function.

In order to implement the system, you have to select a suitable router that can run user-generated software, fit it with a USB or RS232 port, write the home automation software, and then connect and configure everything. All of these steps are described in this article.

Router selection

There are several things you have to pay attention to when selecting a suitable router.

First, it is advisable to choose a router that uses a standard operating system. A router is actually a computer without a keyboard, mouse or monitor. But just like a PC, it has an operating system. If you want to run your own software on a router, it's handy to use one with an open operating system. Some routers use operating systems written by the manufacturer specifically for the router. As these operating systems are usually not made public, there's not much you can do with them. Fortunately, more and more routers nowadays use a variant of Linux, and this means that the source code is publicly available.

This opens the door to interesting possibilities, such as this home automation project.

It is also important to select a router that supports connection of USB or RS232 devices. This is possible with most routers. In some cases you will have to open the case for a bit of solder work, but this shouldn't pose a problem for the average *Elektor* reader.

Finally, the router must have enough memory and (preferably) a high-performance processor. After all, who knows what else you'll want to do with it after you've seen what's possible? The potential applications are nearly endless – a web server, an FTP server, an MP3 server – you name it.

The following website provides an overview of routers and their features:

<http://wiki.openwrt.org/TableOfHardware>

In this case, we chose an Asus WL500g Premium router. It costs around £ 65 (€ 80), which means it's not the cheapest model, but it has a 266-MHz processor, 32 megabytes of working memory, and two USB 2.0 ports on the rear panel. There is also a large community of hobbyists who experiment with this router (see <http://www.wl500g.info>), and you can consult them for advice if you get stuck.

Modifying the router

As delivered, the router does not support user access except via its web interface, which you can use to configure

network settings and the like. Naturally, you can't do much with the router in this condition. It's thus necessary to modify the router so it acts like a console and you can use a prompt (like a DOS prompt, but for Linux) to enter and execute commands. An obvious way to do this is to use a telnet program, but the standard firmware does not support telnet access. In order to add this capability, you can download the firmware source code from the Asus website. Then you can add a telnet module to the source code and recompile it using a compiler that can also be downloaded from the Asus website. Fortunately for those of us who are not Linux wizards, there's an easier way to do this. A modified version of the firmware is available in the form of 'Oleg's Firmware', which can be downloaded from <http://oleg.wl500g.info/#latest>. That saves you the trouble of making the changes yourself. Be sure to download the firmware version for the WL500g Premium. There are various versions of Oleg's Firmware for different Asus models, and they are not necessarily interchangeable.

The next step is to flash the new firmware. We recommend that you test the router for correct operation in its original condition before doing this. As usual, the guarantee is void if you make any modifications, so it's a good idea to make sure that you won't need it. Flashing is a simple process. First, open the router's web interface in a browser window. At the right-hand end of the navigation bar, select 'Firmware Upgrade', and then select the file with Oleg's Firmware. Flash-

ing takes a minute. If anything goes wrong, there is a recovery tool that restores the router to its original condition. This tool is on the installation CD for the router.

After flashing the firmware, you can use telnet to establish a link to the router. A program such as PuTTY can be used for this, but the standard Windows telnet utility also works. Launch telnet by entering the command 'telnet', and then enter the following string after the telnet prompt:

```
o 192.168.1.1 <enter>
```

Here 'o' stands for 'open' and 192.168.1.1 is the IP address of the router. This is the standard setting, but you might want to check it to be sure. If everything is OK, you will be asked to enter a user name and a password. The default values are 'admin' and 'admin'. Now you're logged in to the operating system of the router.

There is other alternative firmware available beside Oleg's Firmware, such as OpenWRT (<http://openwrt.org/>). It works in a similar way, although OpenWRT has the advantage that it is not specific to Asus routers. You could thus use the Sweex router described in the previous article or the Linksys WRT-54G, which is also popular.

RS232 link

Now that you can work with the router via telnet, it's time to let the router communicate with the outside world. This is necessary for the home automation application. In the home automation system used by the author, RS232 is used for connection to the control unit, but the standard version of the router only has two USB ports. Here you have two choices. The WL500g has a UART, so you can create a 'real' RS232 port with a minimum of additional hardware. The other option is to use a USB-to-RS232 converter cable. Both methods are described here.

DIY method

The circuit board is visible after you

open the case. As you can see from the photo, there is a connector on the board, or alternatively several holes for a connector. Two RS232 ports can be attached to this connector. The pin layout is printed nicely next to the connector. There are two ports (Port 0 and Port 1), each with a Tx line, an Rx line, a 3.3-V line, and a GND line. We recommend using Port 1, since Port 0 is used as a console and is thus in constant use. Incidentally, Port 1 cannot not

Be sure to use the right IC here. The 'standard' MAX232 needs a 5-V supply voltage, but the router only provides 3.3 V. The circuit can be built on a small piece of prototyping board and fitted in the router case. Use solder pins or a plug to connect the converter to the router. You can use a 3.5-mm jack socket to route the serial port to the outside world, along with an adapter cable to convert it to a 9-way or 25-way connector. There's not enough room on the rear panel of the router for a connector of this size.

You can test the port by connecting it to a PC COM port via a null modem cable and using a terminal emulator program to 'listen' to the serial port (settings: 115,200 baud / 8N1). Now you have a Linux port for your home automation application available on your router. This port answers to the name '/dev/tts/1'.

Converter cable method

As the router has two USB ports, you can use a converter cable to avoid solder work and any need to open the case. The only thing you have to check is that a driver is available for the converter you plan to use. We chose an AT-EN UC-232A, which costs about £ 10 (€ 15) and uses a Prolific PL2303 IC. A driver for this IC is included in Oleg's Firmware. However, you won't see much happen after you plug in the cable. First you have to launch the driver by typing the following commands in the Linux command line interface:

```
insmod usbserial
insmod pl2303
```

The *insmod* command adds a new module to the running operating system. *Usbserial* is a generic driver, and *pl2303* is a driver for this particular IC. After these two drivers start running, the port will be visible with the name '/dev/usb/tts/0'. However, these drivers will disappear if the router is restarted. Consequently, the commands must be included in a boot file, which is similar to the Autoexec.bat file you may recall from the DOS era. This can also be done with Oleg's Firmware, with a file named /usr/local/sbin/post-boot providing this function. However,

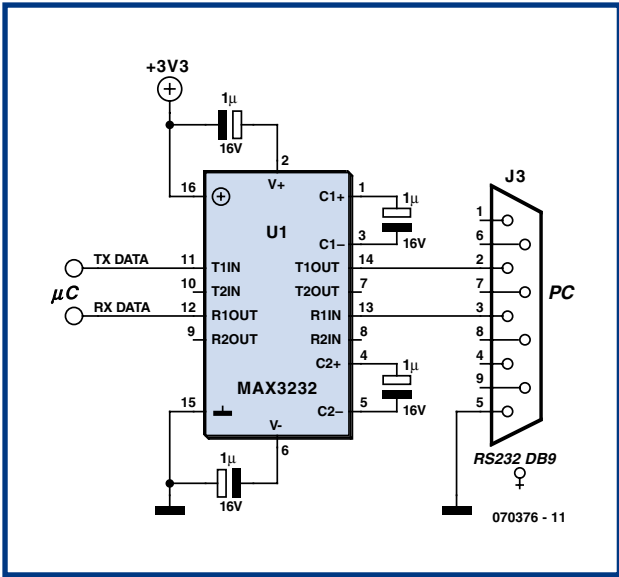


Figure 2. This circuit built around a MAX3232 must be added to create a full-fledged RS232 port.

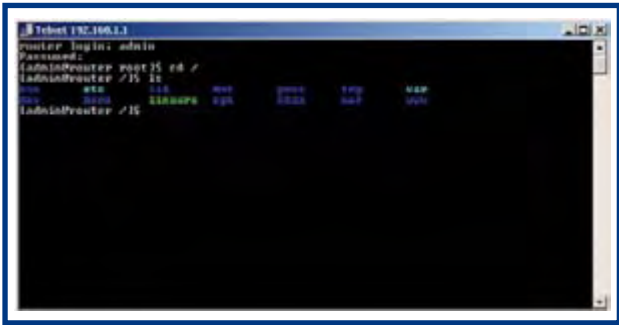


Figure 3. Access via telnet.

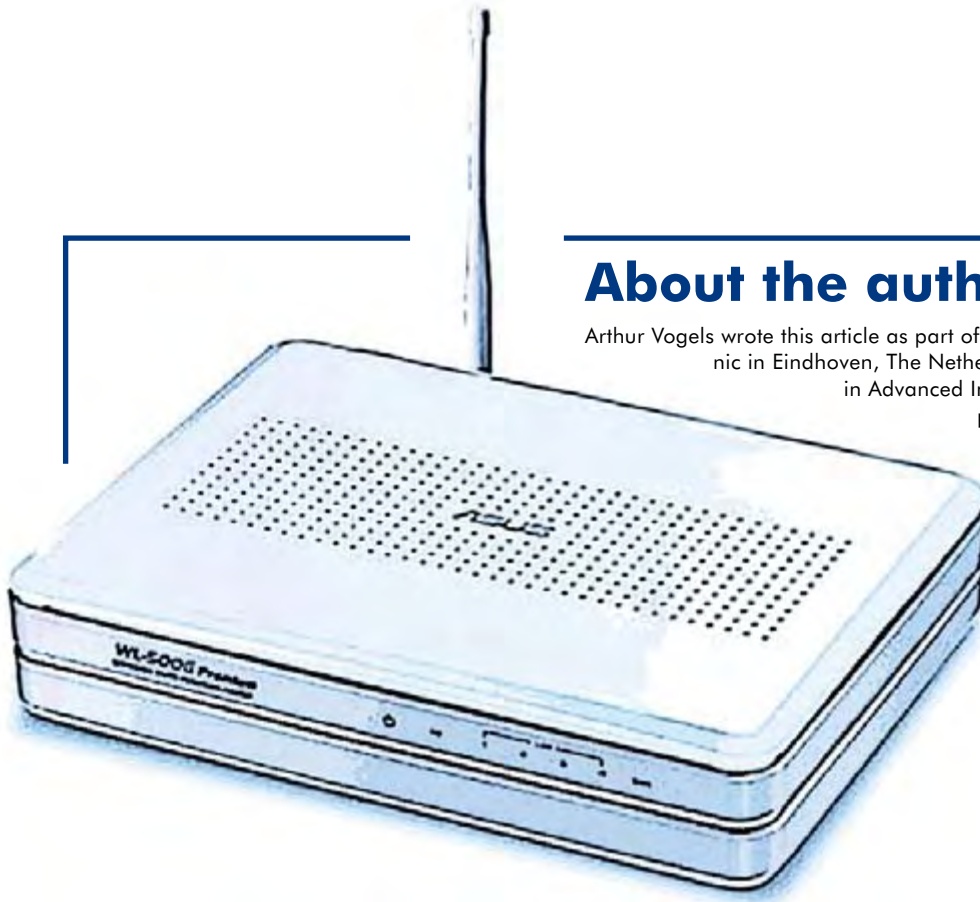
be used with early versions of Oleg's Firmware due to an IRQ conflict, but this problem is corrected in version 7b and later.

These ports use a signal level of only 3.3 V. In order to turn them into normal RS232 signals, you have to use a converter circuit with a MAX3232 such as the one shown in Figure 2.

About the author

Arthur Vogels wrote this article as part of his graduation project at Fontys Polytechnic in Eindhoven, The Netherlands. This rounded off his course of study in Advanced Informatics. He completed his graduation project in the Technical Software Engineering group of LogicaCMG in Eindhoven, which carries out innovative projects in collaboration with students of colleges and universities at various locations in the Netherlands.

See www.workingtomorrow.nl for more information.



you first have to create this file and enter the commands in it:

```
mkdir -p /usr/local/sbin/  
echo "insmod usbserial" >>  
/usr/local/sbin/post-boot  
echo "insmod pl2303" >>  
/usr/local/sbin/post-boot  
chmod +x /usr/local/sbin/post-boot
```

After this, you have to store the file in flash memory. The command for this is:

```
flashfs save && flashfs commit &&  
flashfs enable
```

Now you're done with the RS232 part, and you can start building and connecting the home automation hardware.

Home automation hardware

The hardware of the home automation system is based on an interface module that communicates with the control unit via RS232 on one side and a network of I/O modules on the other side. The control unit can be a PC or a router modified for this purpose. Sensors, actuators and motors can be connected to the I/O modules.

You can use a second-hand PC power supply to power all of this. The router needs a 5-V supply, and the home automation hardware usually needs 5 V and 12 V, so a PC supply is an ideal so-

lution. This also makes a separate AC adapter for the router unnecessary. It's best to use an 'old' AT supply instead of a newer-model ATX supply, since an AT supply is fitted with a real on/off switch.

This completes the hardware.

Software

The router runs on a platform (MIPSEL) that is not based on a standard PC processor, so it cannot run PC software directly. This means that the source code of the software first has to be cross-compiled to the router platform. You can download a tool chain for this (for use on a Linux PC) from the Asus website (http://dlsvr01.asus.com/pub/ASUS/wireless/WL-300g/toolschain323_tar.rar). Naturally, this presumes that you have a Linux system available, such as Ubuntu (<http://www.ubuntu.com/>), which is a very user-friendly Linux distribution. The software is written in C++ using KDevelop as the development environment. The nice thing about this is that it is all freeware and available as open-source software.

As the software is designed to work with the DIY hardware components, it is not described in detail here. One of the interesting elements in this connection is the web interface used to control the system. The router is already connected to a home network

for its usual job as a router, so a web page on the router is the most convenient way to give the user access to the home automation software.

One way to implement this is to write a PHP page that reads and writes text files from and to the database layer. The only other thing you need is a PHP-capable web server that can run on the router. Such a web server can be installed by following the procedures in an excellent guide available on the Internet at <http://www.macsat.com/macsat/content/category/3/13/29/>. First follow the procedure for installing the IPKG package, and then follow the procedure for installing the THT-TPD web server.

It's convenient to first configure the router for a fixed DNS before performing these procedures so it can find the server with the package lists. This can avoid a lot of problems with downloading IPKG package information.

Once the web interface is installed and running, you're all set. Now you have a router running control software for an attached home automation system, with a user interface. It's by no means the only alternative use for a broadband router, but it is one of the nicest ones.

(070376-1)

Astounding Eng

More ingenuity in solar car

Elkin Coppoolse

It all started in September last year. Since then over 40,000 man-hours have been invested on the solar car by Solar Team Twente. They have picked a daring design, based on the positively phototropic behaviour of sunflowers. Some very creative brainstorming took place to find the best possible performance for the World Solar Challenge 2007 in Australia. Tilting solar panels with Fresnel lenses aim to maximise the yield of the sun's energy in this solar car.

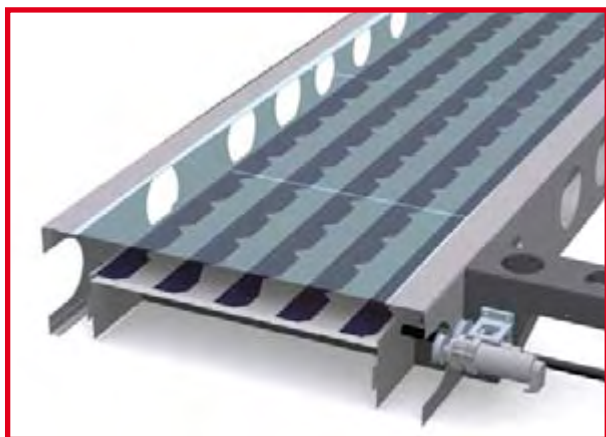


The Twente One with tilting solar panels

The changed regulations for the World Solar Challenge 2007 [1] have made it more exciting to design a potentially winning car. Many of the participating teams will focus on a car that is as light as possible and which has a low air resistance in combination with a high efficiency. Solar Team Twente [2], however, has chosen a concept that is significantly different from any of the other designs. It's a car that will stand out in the race, and has an innovative design that will improve its chances for a podium finish. The application of two innovative techniques has made the incoming energy a focal point for a potentially winning design! The solar car made by Solar Team Twente, the Twente One, has a tilting solar panel and a special lens system. We'll now take a look at the most important features of each of these parts.

Tilting wing

The 2000 or so Gallium Arsenide triple-junction solar cells are on the top of the car, which we've termed the wing. What is noticeable about this wing is that it can tilt along its longest axis. The frame of the wing is made out of aluminium and was designed to perfection using the computer program Ansys [3]. During the race the team drives from North to South Australia. During the day the sun will therefore move from the left to the right of the car. When the solar cells are perpendicular to the sun they will absorb the most energy. The refractive index will have less of an effect and the reflection of light from the coating will also be less. The solar cell will then take in more of the energy from the sun's rays. Having the wing tilt towards the sun keeps the sun at right angles to the panel for longer and hence increases the time during which the maximum power can be extracted from the cells. The tilting is a simple principle as such, but the implementation in the car was a mechanical challenge. The



CAD drawing of the unique construction using Fresnel lenses

engineering design



wing rests on roll bars that are mounted to the chassis of the car. With the help of rod-ends in the wing it becomes possible to make it tilt over the brackets of the chassis. This is not done by the driver, however. An actuator, connected to the chassis and the wing, adjusts the position of the wing towards the sun. This actuator is controlled using PWM from a board that also takes care of the whole dashboard. There is an engineer in the support vehicle who decides what the position of the wing should be. The required value is sent to the car electronics, which then adjust the panel to the correct position.

Fresnel lenses

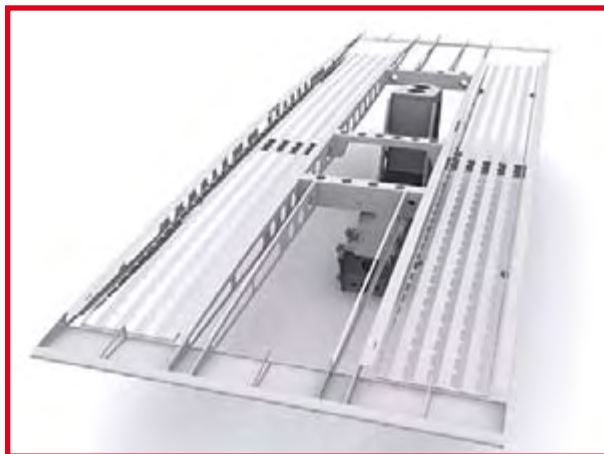
Fresnel lenses are special types of lenses that can also be found in overhead projectors, for example. The lenses used for the Twente One differ from normal ones in that they have a focal band instead of a focal point. Placing the solar cells underneath the lenses increases the light intensity. The new regulations limit the area of solar cells to 6 m². However, the use of the lenses has made the collected power equivalent to that of a panel of about 7.5 m²! As a result of the 'movement' of the sun, the focal band will not always fall onto the solar cells. To overcome this, a system was designed that can move the solar cells underneath the lenses. The cells are mounted on a carrier that moves over a spindle mechanism. Simply put a large bolt connected to an electromotor. This motor is driven by a board designed specifically for this task. A number of photo diodes connected to a microcontroller are used to determine where the sunlight is most concentrated. This information is used in a PID controlled system to make the motor move the carrier to the correct position. The system operates completely autonomously. Solar Team Twente has applied for a patent on this technique. The technique is new and innovative and it surely has a lot of promise in the future.

Semi-conductors

The solar cells are made from GaAs (Gallium Arsenide) and have an efficiency of over 27%. They have an internal protection system: the cell with the smallest yield determines the current through the rest of the panel. To prevent the whole panel from becoming unusable because of a single broken cell, each cell is fitted with a bypass diode in parallel. This also stops the yield from dropping too much when a shadow covers part of a panel.

Batteries have been used to improve the efficiency of the power collection. Maximum power transfer is achieved with the help of Maximum Power Point Trackers (MPPT). The devices make sure that the optimum voltage and current is used to extract energy from the solar panels. When the solar panel is loaded with a small current, the voltage will be higher, but the power transfer (the product of the two) will be low. When the panel is loaded with a high current, the voltage will drop and the power will again be low. The optimum is somewhere in between and is called the 'maximum power point'. The MPPT determines several times a second where this point lies and delivers a voltage and current that is dependent on the light falling on the panel.

The next circuit in the electronic system is the start-up box. The most important function of this box is the 'pre-charging' of the car. This means that when the car is turned on, the battery is initially connected via a resistor to the electronic circuits. This is needed because nearly all of the circuits in the car have a large suppression capacitor at the supply input. The combined capacitance of these capacitors is so great that if the car was turned on with an ordinary switch, an enormous current would flow. This would be enough to fuse the contacts of the switch or relay together and it would be impossible to turn the car off again.



Chassis of
the Twente One

Batteries

More than 5 kWh of Lithium Polymer batteries have been connected in series to provide the energy for the car. The danger of putting the batteries in series is that some may get out of balance with the rest. When a battery is out of balance, its cells are charged at a different level to the

Nice to know

- ✓ The power used by the solar cars to travel at 130 km/h is about the same as that used by a household electric kettle or vacuum cleaner.
- ✓ If you convert the power used by the electromotor into horsepower, you get about 7.5 hp.
- ✓ An average car contains about 1500 metres of cabling inside, the Twente One has only 100 metres.
- ✓ The Twente One has 29 'computers', including the onboard computer, motor controller and battery management system.
- ✓ The batteries in the solar cars have a capacity equivalent to that of 2200 mobile phone batteries.

others. That also results in a different voltage and internal impedance. And if this impedance limits the current it could result in the cell being charged the wrong way round. In extreme cases the cell may even explode or catch fire. The Battery Management System (BMS) monitors all cell voltages and gives an alarm if any cells ap-



Solar Team Twente hopes
their tilting wing concept
will get them on the
winners' podium.

pear to become undercharged or overcharged. The car is said to use '(energy) regenerative braking'. The batteries are charged by the solar panel when the current consumption of the motor is lower than that can be provided by the panel. The batteries are mounted onto two sturdy trays. Ventilation is provided by an NTC controlled fan. The control is part of the BMS.

There is also a shunt resistor in the battery connector, which is used by the BMS to keep track of how much charge has gone into and come out of the batteries. It needs this information to predict when the batteries are nearly discharged or fully charged.

Communications

To control everything requires reliable communications between all modules. For this we've used the CAN bus. All control buttons on the dashboard are connected to this bus. However, not all modules come supplied with this useful protocol, and several boards had to be designed to pass on the control signals.

During the race there is a need to analyse a large amount of data from the solar car. In the new car there are nearly 200 measurement signals on the CAN bus, which can be inspected by the engineer in the support vehicle. (The temperature of the tyres is measured with infrared sensors, the temperature of the batteries with thermo-couples, the load on the shock absorbers with potentiometers, the values from the motor come via the motor controller, etc.) A complete arsenal of sensors is therefore available in the car. To process all these signals properly we've used CRONOS from IMC [4]. This clever device provides all the required inputs and outputs, which are controlled via DSPs. Many of the calculations can be programmed and the resulting data is sent wirelessly to the engineer. From these, the optimal driving conditions can be determined. This completes the circle and the new information is sent back to the Twente One.

Speed

A CSIRO Surface motor [5] is used to convert the generated electrical energy into motive energy. This is a 6 kW electromotor with a permanent magnet, connected inside the rear wheel. The motor is virtually directly coupled over the complete revs range. Because the rear axle is driven directly there is no energy lost in the transmission. The efficiency of the CSIRO (98%) is a bit higher than that of the NGM motor (94%) that was used by the previous Twente team. This motor has already proven itself in the World Solar Challenge in 2005, so is perfect as a spare. The CSIRO motor is supplied in kit form: a coil, two magnetic rings and a sensor board for the Hall effect sensors. The design had to take account of the electronic aspects as well as all the mechanical and strategic aspects. Quite a challenge!

It is interesting that Solar Team Twente has used the motor in a smaller wheel than the one it was intended for. Instead of 16", it was made to fit into 14". When the revs of the motor increase its efficiency also increases, which results in a more efficient car. A consequence of the smaller wheel is that the car's top speed isn't very high.

Notes from the editor

There are of course many other teams hard at work. Students from all over the world are racking their brains to

Two concepts compared

	Nuna4	Twente One
		
Dimensions (LxWxH)	472 x 168 x 110 cm	500 x 180 x 140 cm
Weight (excl. driver)	< 190 kg	< 230 kg
Number of wheels	3	3
Innovations	Very light construction	Tilting solar panels Lens system with Fresnel lenses and moveable solar cells
Speed	Not given	Average 75 to 90 km/h Top speed 120 km/h
Solar cells	2318 GaAs triple-junction cells Efficiency > 26%	2073 GaAs triple-junction cells Efficiency > 27%
Motor	InWheel Direct Drive Electromotor Biel/CSIRO Efficiency 97-99%	InWheel Direct Drive Electromotor CSIRO/NGM Efficiency 95-99%
Steering	Carbon fibre steering wheel	Steering wheel made from aluminium tubing, roughly A5 sized
Bodywork	Carbon fibre and Twaron (aramid fibre) Integrated composite roll cage	Carbon fibre sandwich construction (body) Box construction using aluminium plate Roll bars made from chrome-molybdenum steel
Suspension	Front suspension: Double wishbone suspension made from carbon fibre and aluminium Carbon fibre shock absorbers Lightweight aluminium rims Ceramic ball-bearings Rear suspension: Carbon fibre horizontal wishbone Aluminium mounting points	Front suspension: Double wishbone suspension made from chrome-molybdenum steel Horizontal racing shock absorbers Lightweight aluminium rims Ceramic ball-bearings Rear suspension: Trailing-arm construction made from chrome-molybdenum steel
Tyres	Michelin Solar Radial 16" (slicks)	Bridgestone/Maxxis radial 14" (slicks)
Brakes	Front: Lightweight, custom disc brake with Brembo brake pads Lightweight aramid brake lines Rear: Regenerative braking using the motor	Front: Disc brakes Pneumatic brake lines Rear: Regenerative braking using the motor
Air resistance	6 times smaller than a normal car	5 times smaller than a normal car
Telemetry	WiFi connection to support vehicle	Wireless connection to support vehicle

come up with a winning design for their car. We've compared the specifications of the Twente One car with those of the team from Delft, the Nuna4, which can be seen in the table below. The cars are well matched and we wonder which of the designs turns out to be the better one in the competition.

In the next article we have a report of the race itself and give an account of how well the cars did in practice. Now we just have to hope that the innovative designs show their full potential and result in a place amongst the top finishers.

Web Links

- [1] www.wsc.org.au
- [2] www.solarteam.nl
- [3] www.ansys.com
- [4] <http://www.imcdata-berlin.de/en/>
- [5] www.csiro.au

(070468-1)

Inexpensive ARM Kit

ARM yourself with a new microcontroller

Paul Goossens

Embedded-system designers work in a very dynamic world, and a wide range of products are dependent on their efforts. However, the average embedded-system designer is not so dynamic when it comes to selecting a microcontroller. He tends to remain loyal to a specific type. But for anyone who is considering switching to a modern ARM7 microcontroller, iSystem has put together an inexpensive ARM7 kit.

LPC2138 features

- ARM7TDMI-S microcontroller
- 60 MHz clock rate (using internal PLL)
- 512 kB flash program memory
- 32 kB RAM
- Two 8-channel, 10-bit ADCs (2.44 μ s conversion time)
- Two 32-bit timers
- six PWM outputs
- two UARTs
- I2C, SPI and SSP interfaces
- 9 interrupt inputs
- 3.3-V supply voltage
- All I/O lines 5-volt tolerant

The predominant trend in electronics is to combine a variety of functions in a single piece of equipment. This trend is actually nothing new. As early as 20 years ago, even the simplest thermometer was fitted with a clock to keep it (and its owner) current. All these extra features (useful or otherwise) require additional processing power.

The latest trend is to equip everything possible with USB, Bluetooth, WLAN, and so on. You see these new 'extras' in mobile phones, PDAs, and other types of equipment (usually bearing three-letter abbreviations). It won't be long before the marketing wizards will also want to have these modern goodies in their newest thermometers. After all, they sell better that way.

Is 8 bits no longer enough?

A modern 8-bit microcontroller is adequate for most embedded applications. The speed of these controllers has been boosted considerably by techniques such as reducing the number of clock cycles per instruction. You'll also have a hard time finding an 8-bitter nowadays without internal flash memory or RAM. The component count can be kept nice and small, production costs can be minimised, etc., while embedded-system developers can still use their old familiar tools and expertise to get the job done.

USB, IrDA, and the like can all be handled by an 8-bitter as well. Unfortunately, in most cases only a small amount of memory is left over, and the processor is nearly pushed

to its limit. This is not necessarily a problem – until the time comes to add a few more functions to the equipment. In many cases, the only option here is a complete re-design. It doesn't cost much more now to use an ARM7 microcontroller than it does to use a modern 8-bit microcontroller. Creating a new design with 'room to grow' thus offers an inexpensive way around the generally dreaded total redesign..

New tools

If you're interested in ARM7 microcontrollers, you'll be glad to know that iSystem has put together a complete development kit for ARM7 microcontrollers that goes by the name iF-DEV-RTK and sells for around £ 50 (€ 70). The software in the package includes a GNU ARM7 compiler, a real-time debugger and a project manager.

There is also a USB to JTAG interface and a small microcontroller PCB fitted with an LPC2138, which is an ARM7 microcontroller from NXP with 512 kB of flash memory and 32 kB of RAM.

The board has only minimal I/O hardware, consisting of a single LED driven by one of the microcontroller's I/O pins. However, all essential signals are available via headers. This makes it easy to add your own I/O circuitry.

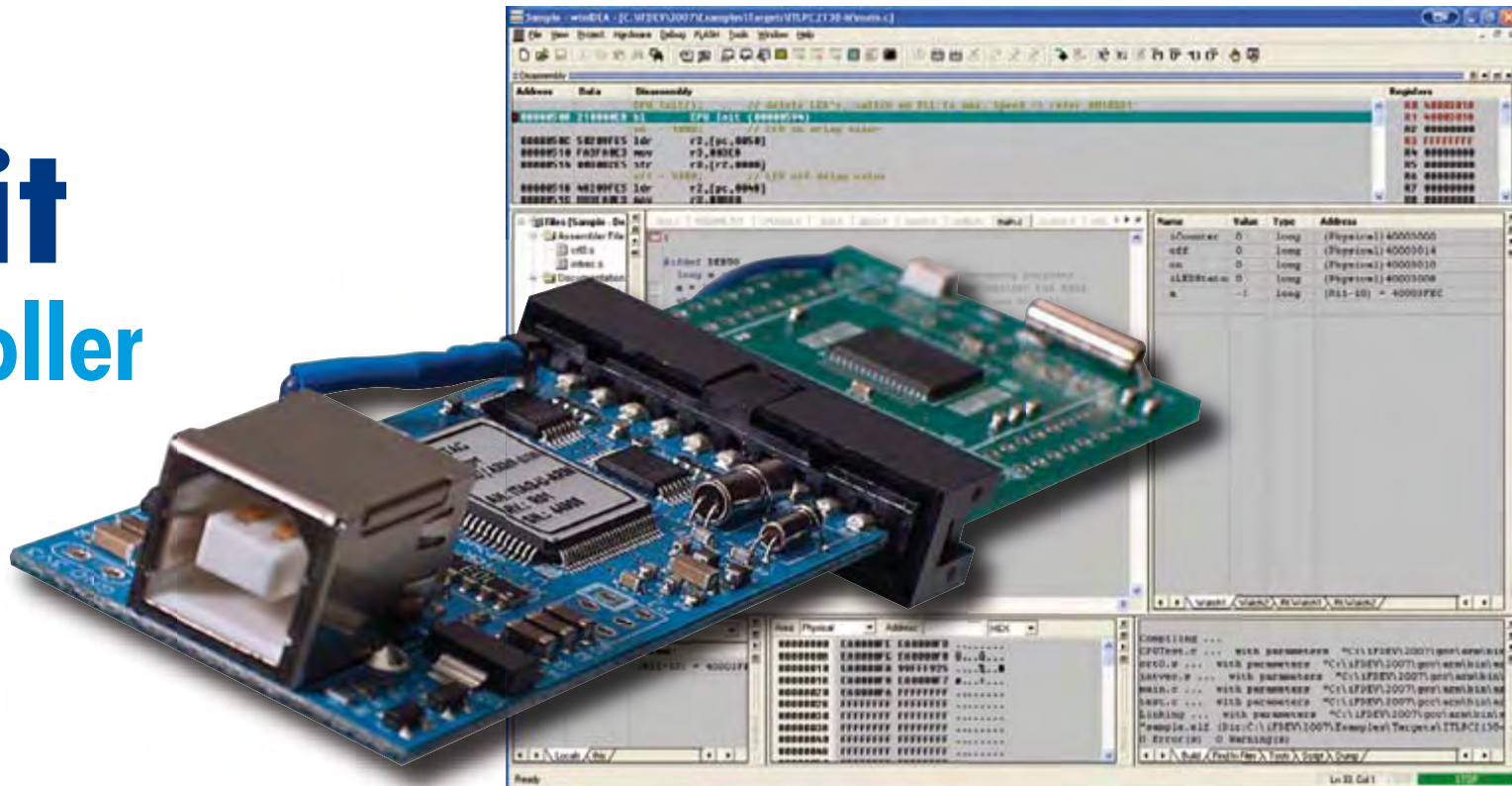
Use

There's not much we need to say about installing the software included in the kit. It goes the way it should, which means simple and straightforward.

After the software has been installed and launched, the winIDEA development environment appears on the screen. The capabilities of this program are exactly what you would expect. You can edit source code, compile it, download it and debug it – all with the same program.

Compiling the first sample program is easy. Just select 're-build' in the 'Project' menu. Any problems that occur during compiling or linking can be viewed in the 'output' window. If everything goes without a hitch, the program will download the new software directly to the microcontroller and put it in the 'reset' state.

You can then press the F5 key to start running the software in the microcontroller. You can stop and restart the microcon-



troller whenever you wish. Single-step program execution is also possible. This can be done at C level or assembly-language level. You can also view and modify memory contents. All this is what you expect to find in a modern development system.

Another nice feature is setting hardware breakpoints. This does not affect the operation of the microcontroller. Program execution is stopped automatically when a breakpoint is reached. Hardware breakpoints are possible thanks to the Embedded ICE interface of the ARM7 microcontroller.

Sample programs

The kit comes with two sample programs. The objective of both of them is to cause the LED to blink and demonstrate a large variety of routines. These routines show how easy it is to debug software using winIDEA.

The main difference between the two sample programs is how they cause the LED to blink cheerfully. In the first sample program, the wait time is determined by a large FOR loop. By contrast, the second sample program uses an internal hardware timer and an interrupt to drive the LED.

Comments

Although we were quite satisfied with the development kit, there are definitely a few comments we feel obliged to make.

During our experiments, we occasionally received a message advising that the debugger could not stop the CPU, which is an annoying 'obstacle'. The only recourse in this case is to issue a reset via a button on the toolbar. This forces the microcontroller into the normal reset state. After this, we could continue debugging the microcontroller in the usual manner. We were not able to determine the cause of this problem. Fortunately, this situation occurred only very sporadically, and in any case it's something you can live with.

Our second (and last) criticism relates to loading and saving projects. We spent a fair amount of time trying to figure out how to load and save projects. After a bit of sleuthing, we found that each workspace is linked to a project. When you open a new workspace, you automatically open the associated project. Saving a workspace causes your

project settings to be saved at the same time. This is rather non-intuitive at first. Once you know how it works, it's not a problem.

DIY

If you would like to build the hardware yourself (despite the low price of the kit and the fact that it uses small SMD components), you can. The manufacturer offers a free download on its website under the name iF-DEV SBK, where 'SBK' stands for 'Self-Build Kit'. It contains all the schematic diagrams, component lists, PCB layouts and firmware for the USB-JTAG interface and the microcontroller board. This download also includes all the software and documentation.

The 32-bit era

If you would like to try out an ARM7 microcontroller, whether simply out of curiosity or for some other reason, this development kit is definitely worthwhile. Thanks to the included USB-JTAG interface, you can also continue to use it long after you have completed your first experiments.

The same applies to the development environment. It is certainly suitable for developing small to medium-sized projects.

Not bad for a development system costing around 50 pounds!

(070240-1)

Web Link <http://www.isystem.com/ifdev>

iF-DEV RTK contents

- USB-JTAG interface
- complete toolset and documentation on CD
- ARM7 microcontroller board
- USB cable
- Quickstart guide

Data Books

Farewell to paper copies

Luc Lemmens

At the time of writing, we're one month away from a change of premises for *Elektor Electronics*' head office. After around 40 years, we're leaving the town of Beek, Limburg (Netherlands) and moving to Limbricht, near Sittard. And as with every relocation, it's a good idea to take as few things as possible with you to the new location and throw away as much as possible before the packing starts. This is sometimes accompanied by a bit of heartache and/or pangs of regret, but you have to be realistic. If something has been sitting unused in a cabinet or on a bookshelf for a few years, the chances that you will need it sometime later on are vanishingly small. So why should you bother to pack it and take it with you? Still, it's not easy to throw so many things away, especially when you think about how much you paid for them.

Our collection of data books is one of the victims of our recent house-cleaning frenzy. They were once the 'bibles' of electronics, but in light of the fact that they have very rarely left the shelves in recent years, it's understandable that no space was allocated for them in our new premises.

There was a time when companies found it rather difficult to obtain data for components such as ICs, transistors and diodes, and hobbyists could only dream of putting their hands on such books. In some cases, data books were actually quite expensive, but over the years they followed the same trend as other products, such as microcontroller software development tools. At first they were nearly unaffordable, but later on they were free of charge – at least for commercial users.

After the introduction of data CDs, many data books appeared in the form of CD-ROMs, which are much less expensive to reproduce and take up much less space. At that time, the idea of throwing away the real books and installing a PC with a hefty CD jukebox in their place was discussed in the *Elektor* labs, but nothing ever came of it. However, with the advent of CDs the contents of our bookcases were updated and augmented much less frequently than before, for the simple reason that semiconductor manufacturers made less and less use of printed media.

Nowadays everyone can

easily find individual datasheets on the Internet. Every manufacturer (with a few exceptions) has its own website, where you can download complete data, application notes, errata sheets and the like to your PC with a simple mouse click. You can always find the most recent data on the website, so you no longer have to worry about whether changes have been made to a component. Many websites also show you right away whether the component concerned is still in production, so you can quickly decide whether it is advisable to use it in a new design. Given all this, what's the point of having an old-fashioned data book in the lab or even in your hobby room?

One of the reasons to want a real book is purely practical in nature. Nothing else is as pleasant to read as an 'old-fashioned' printed page. Besides this, you can easily scribble notes on paper or add your own comments. A datasheet for a simple component consists of just a few pages, and if you wish you can print it out, staple the pages together, and voilà: your mini-book is ready for use. With more complicated components, the 'datasheet' can easily amount to several hundred pages, and the amount of paper and ink necessary to print it out is often reason enough to abandon the idea – not to mention the trouble it takes to convert such a thick pile of paper into a handy reference document. In such cases, a real book certainly not be a luxury, but of course it is understandable that distributing PDFs is a lot easier and less costly for semiconductor manufacturers.

Another reason for keeping old data books involves a completely different aspect, and it relates primarily to discrete components such as transistors. For example, take the data sheet for the BC557, a garden-variety transistor. In the 1987 version of the Philips data book, the datasheet for this transistor included 15 characteristics charts documenting the performance of the device with various parameters. The 1999 version of the datasheet for the same transistor from the same manufacturer has a grand total of *one* chart: a plot of h_{FE} versus I_C . Admittedly, this is not exactly a transistor that is intended for top-end analogue applications, and it is questionable whether the BC557 deserves such a wealth of data, but this dilution of data is a

trend that has become increasingly common in transistor datasheets in recent years. Are people no longer interested in the data, or are discrete components in general no longer interesting?

The company that empties our paper skip here was not particularly enchanted with our clean-up campaign. The skip was full to the brim with books and so heavy that it took three people and a lot of effort to roll it from its position. The tipping mechanism at the back of the lorry also had visible difficulty lifting the skip, but in the end the entire library disappeared into the lorry container.

Did we really throw everything away? No, a few of us kept aside some special items and added them to their personal libraries, in some cases for nostalgic reasons. Perhaps they will become valuable collector's items some time in the future!

(075086-1)





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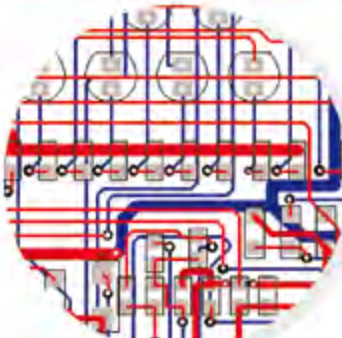


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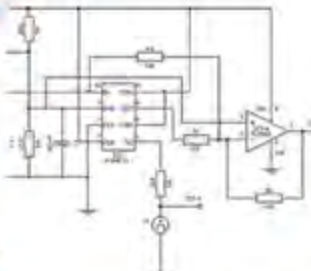
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Retirement home for alkaline batteries

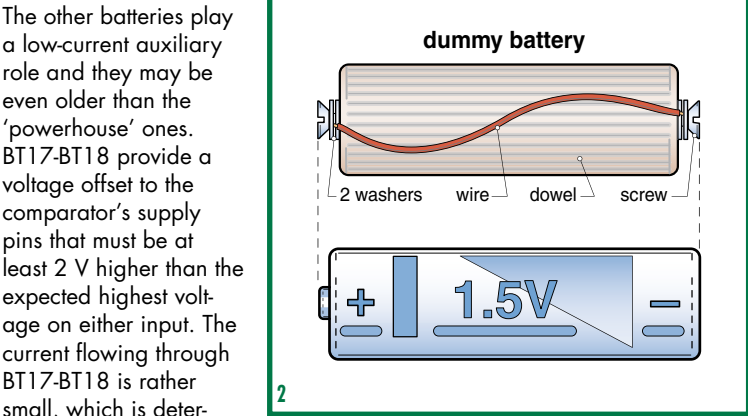
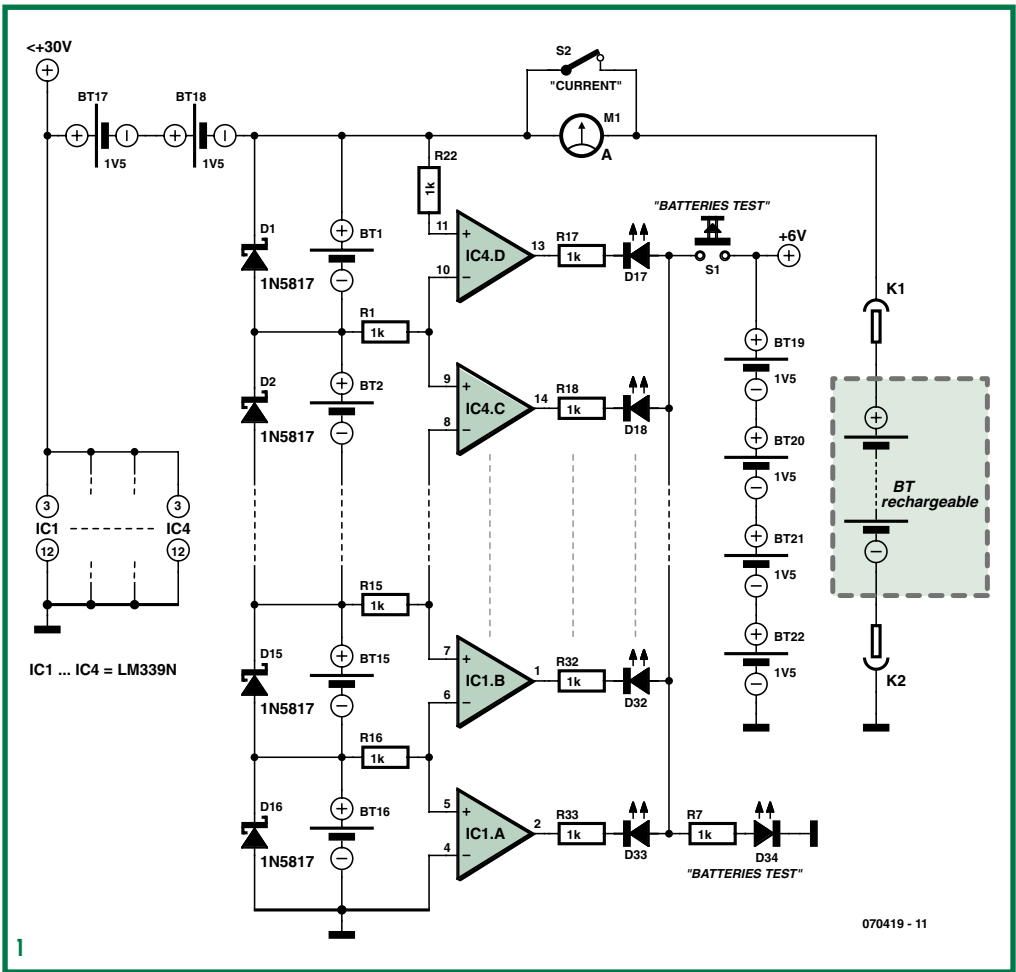
Alexander Pozhtikov

A large collection of half-empty batteries does not automatically mean that you have a nice source of energy similar to the fact that a swimming pool of lukewarm water (huge energy reservoir) can't be easily converted into a small cup of steaming hot coffee. In order to induce energy transfer from the old batteries into the rechargeable ones, a voltage difference must be established. Obviously, we can simply connect the old batteries in series and thus increase the voltage, making the system able to transfer its energy into the rechargeable battery. As always, there are number of pitfalls associated with such a simplistic solution.

First, when one of the batteries in the series 'dies', a significant voltage drop quickly occurs at the terminals of this battery and overall current drops very rapidly. Usually, it's just one battery that stalls the entire process. The dead battery starts to work against the others; developing a lot of heat and sometimes its shell bursts open releasing gas and/or electrolyte.

The second problem is to establish an automatic system that is capable of monitoring voltage for each battery in the series and when one of the batteries is dead, the system must inform the operator which battery needs to be replaced. Such a system must be tolerant of the operator not immediately replacing the dead battery.

The circuit in **Figure 1** overcomes the above problems. All the batteries shown are old ones! The ones designated BT1, BT2, ... BT16 supply the desired current. Their internal resistance being substantial, the current flowing through the rechargeable battery is modest. Experiments involving 16 batteries with two AAA-size 700 mAh rechargeable batteries connected in series to K1-K2 showed a maximum charging current of about 200 mA.



The other batteries play a low-current auxiliary role and they may be even older than the 'powerhouse' ones. BT17-BT18 provide a voltage offset to the comparator's supply pins that must be at least 2 V higher than the expected highest voltage on either input. The current flowing through BT17-BT18 is rather small, which is determined by the comparator ICs. Batteries BT19-BT22 power the indicator LEDs; these batteries are idle most of the time. Their status is indicated by LED D34; if this LED does not light when the 'Batteries Test' button (S1) is pressed, these batteries need replacement.

Comparators (4 in each of IC1-IC4) monitor the voltage at the terminals of each battery. When

the voltage approaches zero (i.e. the battery doesn't contribute to the process anymore), the output of the comparator toggles to Low (open collector) thus enabling a corresponding indicator LED to light when S1 is pressed. Diodes D1-D16 are Schottky devices, serving to bridge a dead battery before it is replaced. These diodes have a very small forward voltage

drop of about 0.2 V, thus being extremely helpful for neutralizing the adverse effects of the dead battery. Overall current is assessed via moving-coil meter M1 when S2 is opened.

In case you do not have enough batteries to fill up all positions (i.e. 16 batteries), it is wise to insert a dummy into the empty battery slot to short the associated diode (Dn), thus cancelling the voltage drop across it and so increasing the overall current. A dummy can be made from a wooden dowel cut to the size of the AA or AAA batteries (see **Figure 2**). Wooden dowels are available at home improvement retail stores.

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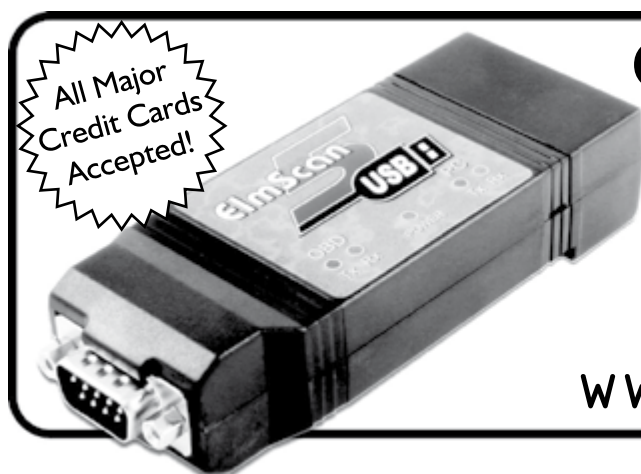
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EasyControl I/O

ECIO: a super low-cost USB-enabled PIC18 development system

John Dobson

Many readers who are familiar with the PICmicro range of products will be aware that several of these wonderful devices have a USB port already built in. So why do you need a special programmer for a PIC if it already has a USB port? The answer is that you don't. Read on...

In the old days, life was simpler. All computers one could afford had a parallel port and a serial port. You could put together a simple circuit to program a microcontroller using the PC's parallel port and then you could use a microcontroller's USART (universal serial asynchronous receiver transmitter — sorry for that) to communicate back to the PC via the serial port. Then USB came along to 'make life easier' for us all. Now the fact that parallel ports and serial ports are often left off modern PCs, means that you need to buy a USB microcontroller programmer. Fortunately, microcontrollers are now catching up: many microcontrollers have an internal USB port, which implies that once again it is possible to plug the microcontroller straight into the PC. Well, nearly...

Whilst it is not possible to make a full microcontroller programmer with just the USB lines, it is possible to do the next best thing: to develop a piece of software called a 'bootloader' which resides inside a USB-enabled microcontroller and allows the microcontroller to download a program via the USB lead.

Circuit details

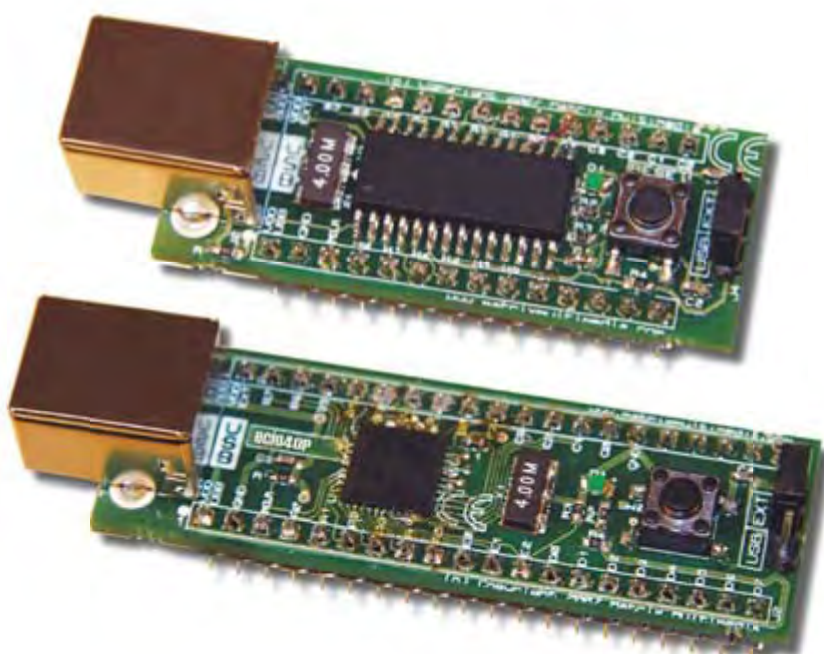
With the PICmicro range of products there are now several microcontrollers in the 18 series range of products

that have USB ports integrated into the chip, in particular the 18F4455 40- or 44-pin device and the 18F2455 28-pin device. Setting this up in a circuit can be quite simple: get off MSN, switch off the telly, take the PIC, add a 4-MHz oscillator to the resonator pins, connect the two PIC USB lines to the PC's USB lines, add a reset switch and power it up.

With the power supply, you have a choice: you can source 5 V from an external power supply, or you can use the PC's own power supply on the USB port. There is a small caveat with this plan: you are not guaranteed more than 100 mA to be available on your USB port as availability depends on how many USB devices are plugged in. However in most circumstances around 250mA will be available.

The circuit diagram of ECIO40P using the 44-pin PIC18F4455 device is given in **Figure 1**. LED D1 indicates when the USB lead is plugged in, and the power jumpers allow you to select power to be taken from the PC or from an external source.

The circuit for the smaller (28-pin) device (ECIO28P) is very similar — you just get less I/O (input/output) lines. There you have it: **Easy Control I/O**, in short, ECIO.



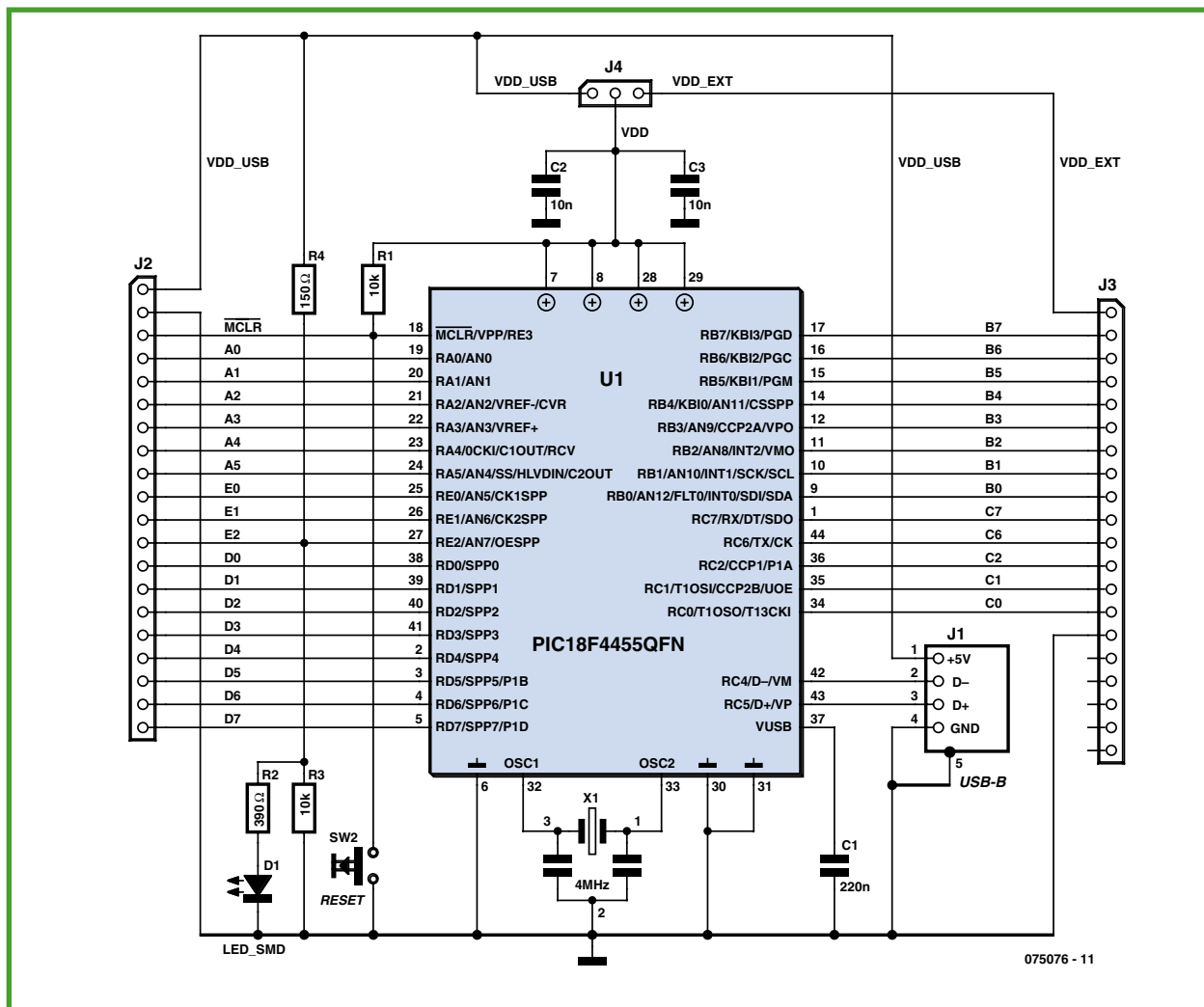


Figure 1.
Complete circuit diagram
for the 18F4455 ECIO
version.

Bootloader details

The bootloader software for a system like ECIO needs to be simple but effective. It was decided that only one switch for both Reset and Program would be convenient. The software was written in such a way that when the Reset switch is pressed the bootloader software looks at the USB leads to see if the USB lead is plugged in. If it detects the presence of USB then the bootloader software implements a download program that allows the PC to communicate to the PIC and send it a new program. If no USB lead is detected, then the bootloader goes off and runs the user program. Yes that will be your very own program eventually! Besides the bootloader software, a Windows-based application is needed to allow users to send hex code to the microcontroller. You can see this in **Figure 2**. In line with Elektor's presence around the globe, the ECIO software application is available in five main languages: English, French, Dutch, Spanish and German. It allows users to locate a hex file on the computer and then download it to the device.

Putting it all together

For convenience we have designed and assembled a small circuit board which includes the PICmicro device, a

resonator, a USB socket and a reset switch. For each of the 28-pin and 40 pin devices pictured in **Figure 3** this provides a 'ready to go' component that can be plugged directly into an application board, or into a breadboard.

For both ECIO devices an **E-blocks compatible application board** is also available — this allows you to take advantage of the large range of E-blocks that are now in existence.

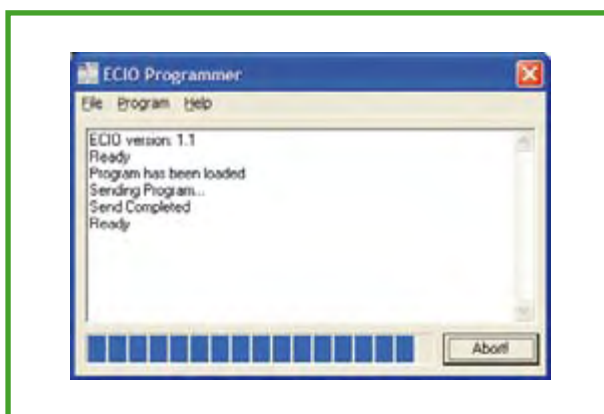


Figure 2.
Windows download
software for ECIO.

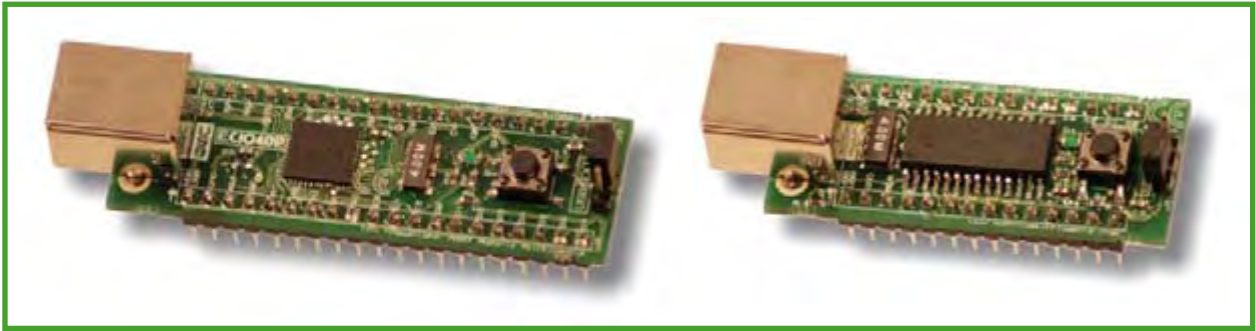


Figure 3.
Photograph of the ECIO40P
and the ECIO28P

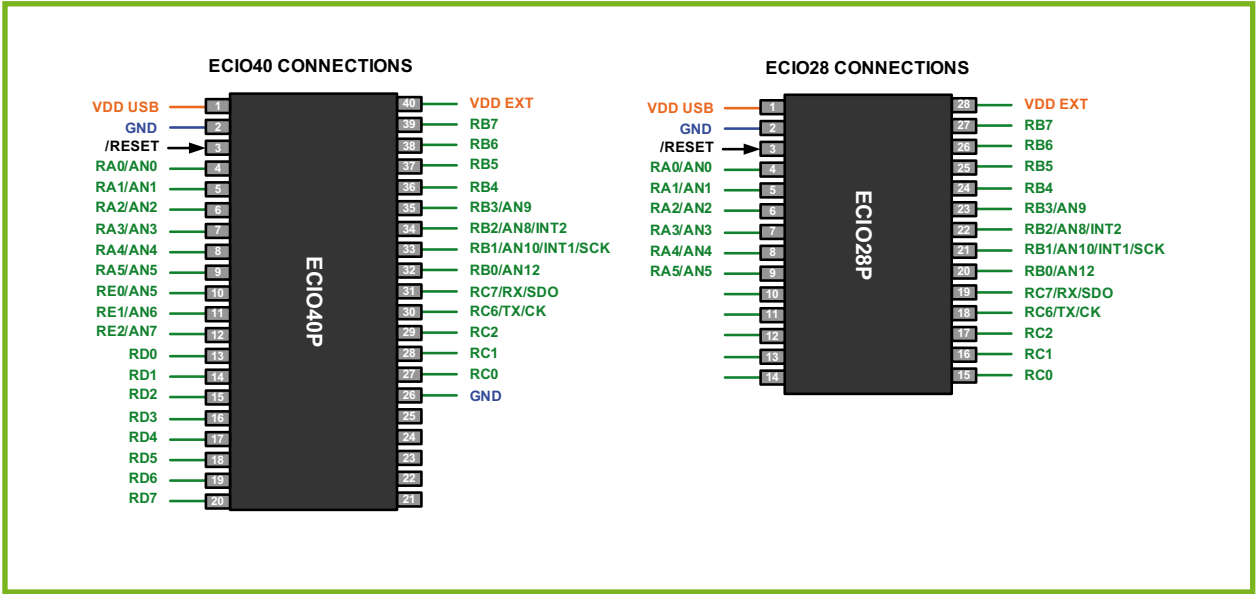


Figure 4.
Pin connections for the
ECIO40P and ECIO28P

Reader's offers

This month we are happy to supply readers with ECIO boards from as little as £20.30 (€ 29.50) each.

We are also offering a bundle of an ECIO-40P, application board, LED board, Switch board, LCD board, Relay board, and Opto-isolator board and Flowcode Professional at a discount of 30% from the retail price. This pack is ideal for those that want to develop a Programmable Logic Controller based on an ECIO.

Item(s)	Price (£)	Price (€)
ECIO28P (1 pc)	20.30	29.50
ECIO28P (4 pcs)	60.60	89.95
ECIO40P (1 pc)	24.80	36.50
ECIO40P (4 pcs)	74.60	112.00
E-blocks Adaptor Board	24.80	36.50
E-blocks ECIO Starter Pack	206.50	299.00

All prices are inclusive of VAT; excluding P&P.
For further details, see the Elektor SHOP section elsewhere in this issue, or visit our website at www.elektor.com

The diagrams in **Figure 4** show the connections to the 28-pin (ECIO28P) and 40-pin (ECIO40P) DIP footprints. Note that these are simplified representations of complex chips — see the datasheets on the PICmicro devices for full details. As you can see, the 40-pin ECIO has six bits from port A, a full port B, five bits from port C, a full port D and three bits from port E. Unfortunately much of port C is not available: the internal USB module uses bits 3, 4, and 5 of this port. The 28-pin ECIO device is very similar with just fewer I/O lines. The choice between the 28-pin and the 40-pin... is yours.

Development software

The ECIO devices can be used with any software that generates hex code for the 18 series of PICmicro devices.

So, if you have a compiler or assembler that's compatible with the 18 series of Microchip PICmicro devices then you have all you need to get started. Note that the bootloader resides in the PICmicro between locations 0x000 and 0x7FF, so your code needs to begin at location 0x800 (this can usually be achieved with a simple command to the Linker tool).

If you don't have any software then don't despair: a free version of Flowcode is available with both ECIO devices that will allow you to create quite functional programs. This free version of Flowcode is the same as the full ver-

sion with several limitations: it can only compile projects up to 2K of code, includes a small subset of components, allows a maximum of 64 flowchart icons and cannot be used for commercial purposes. Of course, an upgrade to Version 3.2 of Flowcode (compatible with the ECIO40) is available to allow users access to all features, including CAN bus, Bluetooth, TCP/IP and many more. Those with Flowcode 3 and above can get a free upgrade which is compatible with the ECIO family.

Prototyping with the ECIO-28P

Getting a circuit up and running with the ECIO could not be easier: you can either use an E-blocks adaptor board or a prototype board (**Figure 5**). When using a prototype board you simply plug the device into a standard prototyping panel and connect the circuit you want to test. With a price of just £ 20.30 (€ 29.50) each for the ECIO28P, this is probably the cheapest route to USB PIC programming in the world.

More ambitious projects

If you have larger projects, or you want to connect more advanced systems together, then you can use the E-blocks adaptor panel shown in **Figure 6**. This allows you to connect a large range of boards from simple LED's and switches through to CAN sub-systems, etc.

Next time

In the November 2007 issue we will look at how you can use the ECIO to develop a fully operational Programmable Logic Controller (PLC).

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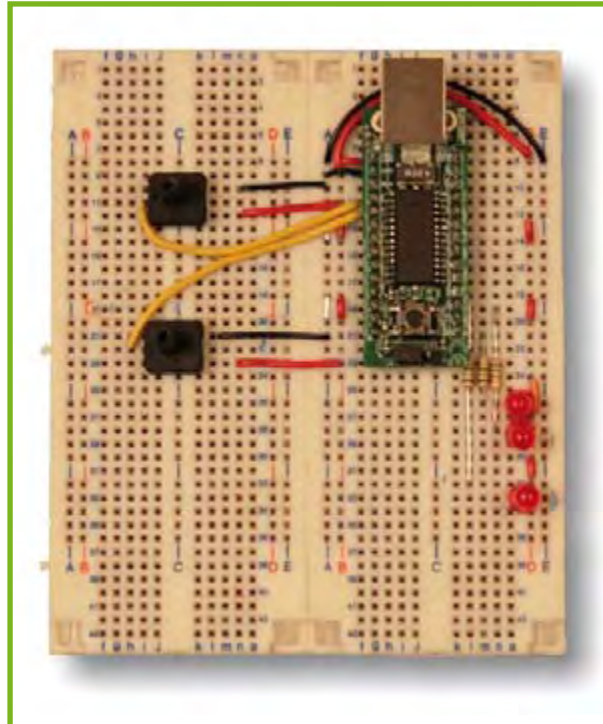


Figure 5.
Using the ECIO for project development with a prototype board.

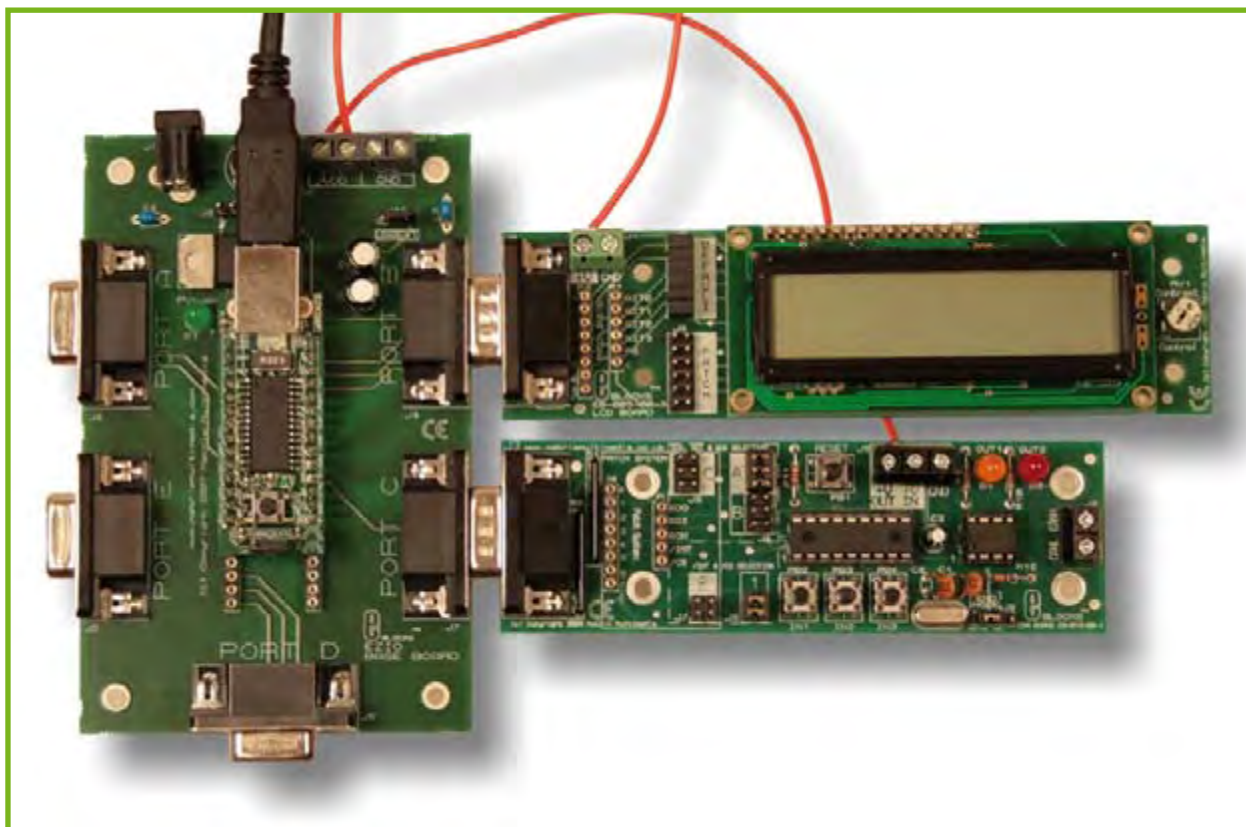


Figure 6.
An ECIO with adaptor board and E-blocks.

Hexadoku

Puzzle with an electronics touch

Hello all Hexadoku fans, here's another exercise to keep the odd brain cell active. Eminently suited for a rainy day (or two) in Autumn! Send us your solution and enter a prize draw for one of the prizes: an **E-blocks Starter Kit Professional** and three **Elektor Shop** vouchers.

The instructions for this puzzle are straightforward.

In the diagram composed of 16 x 16 boxes, enter numbers such that **all** hexadecimal numbers 0 through F (that's 0-9 and A-F) occur once only in each row, once in each column and in each of the 4x4 boxes (marked by the thicker black lines).

A number of clues are given in the puzzle and these determine the start situation.

All correct entries received for each month's puzzle go into a draw for a main prize and three lesser prizes. All you need to do is send us the numbers in the grey boxes. The puzzle is also available as a **free download** from our website.

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Alternatively, by fax or post to: **Elektor Hexadoku
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The closing date is **1 November 2007.**

PRIZE WINNERS

The solution of the July/August 2007 puzzle is: **LVC4ZM1.**

The **E-blocks Starter Kit Professional** goes to:

Andy Hartley (UK).

An **Elektor SHOP voucher worth £35.00** goes to:

Manne Tallmarken (SE), Rotondi Silvia (IT) and
Sudhir Kumar Gupta (IN).

Congratulations everybody!

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R	B	G	9	S	5	T	L	V	U	C	O	Y	2	M	4	H	N	1	Z	D	K	W	6	J	1	7	3	F	O	E	8	X	A	Q	P
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N	7	I	W	P	A	R	F	G	X	E	S	6	9	U	S	8	O	J	H	L	V	C	4	Z	M	1	Q	B	2	T	Y	D	3	K	
Z	D	M	X	O	C	3	6	P	4	I	H	K	V	R	F	L	J	U	A	G	6	2	5	Q	W	S	8	Y	E	1	O	9	B	7	N
U	J	Y	H	E	K	5	Z	Q	A	1	8	3	I	X	S	D	O	8	T	7	N	F	R	V	P	9	C	G	2	L	4	W	M	6	0
M	F	U	8	H	Y	N	R	1	J	3	C	T	7	W	D	K	G	2	4	X	V	O	5	S	E	B	P	1	L	6	A	Z	W	Q	9
4	K	R	J	V	3	A	M	B	G	D	Y	P	L	S	6	9	E	H	Q	8	I	Z	O	F	N	I	O	W	T	7	2	C	S	U	X
B	S	Q	G	X	W	P	U	O	Z	5	T	1	C	O	3	J	F	N	R	9	6	E	M	A	2	Y	7	4	H	V	L	K	B	I	D
I	9	5	D	T	6	5	7	E	F	O	W	2	Q	8	H	V	M	Y	C	1	A	L	G	U	R	Z	K	X	J	P	N	B	4	0	3
C	E	O	2	A	Z	X	K	L	I	6	Q	U	Y	5	N	R	4	3	J	W	P	B	7	G	O	8	D	V	9	S	H	F	T	M	1
L	N	P	O	1	7	2	4	H	V	8	9	O	A	I	B	X	Z	F	K	U	D	T	S	C	M	6	5	3	Q	J	W	G	E	R	Y

The Revophone (1922)

A W Simpson

I first experienced a crystal set as a child in the late thirties when my father dug out his old set to show my brother and I. The result was unforgettable, voices and music coming out of a small wooden box via, what I thought at the time, a very heavy pair of headphones. This was especially fascinating as we had neither a wireless (radio) nor a gramophone (CD player). I particularly remember hearing several programs fading in and out, quite loud and sometimes two or more at a time. Presumably we were then listening at dusk. A few years ago I rediscovered my father's set and again was delighted by its performance and simplicity, especially as crystal sets don't use batteries. I have been researching crystal sets ever since. However I have chosen here to describe a simpler crystal set, the Revophone, which I recently obtained.

The set, complete with a pair of 4000 ohm headphones, is in pristine condition and appeared to have had little use and probably has remained untouched for over 80 years. It is built into an elegant mahogany box, and both the box and the headphones are labelled to indicate that they are approved by the Post Master General, no less. Confirmation of his approval is indicated by the BBC symbol as shown in the photograph. Inside the box is a variable inductor, connected between the aerial (antenna) and earth (ground) terminals. This can be adjusted using the two rotary switches to produce series resonance with the aerial capacity at the frequency of the required program. It consists of a cylindrical coil of wire 55 mm in diameter and 85 mm long with twelve tapping points. These are connected to two six-position rotary switches mounted on the front of the box. The tapping connections to the coarse switch are widely spaced and cover roughly two thirds of the length

of the coil. The connections to the fine control switch are spaced closer, allowing smaller changes in the coil inductance. The two rotary switches between them give an 11:1 range in inductance from 30 to 350 μH , which, with a typical outside aerial, cover the medium wave band.

The only other component in the set is the crystal detector. This is essentially a point contact Schottky diode and is connected between the aerial and the headphones. The other headphone lead is connected

to the earth terminal. The crystal itself, shown on the left, consists of a lump, roughly 5 mm in diameter, of polycrystalline synthetic galena (PbS) soldered in to a small brass cup using a low melting alloy (70 °C) called Wood's Metal. The point contact is made using a spiral of fine wire, called the cat's whisker, which is mounted on the end of an insulated rod to enable the user to place the tip on any part of the surface of the crystal. Only certain regions give good rectification and it generally takes some time to find a suitable point to give good reception. The left hand side of the box is open to hold the headphones when not in use. A list of instructions and a diagram of a suitable aerial are given inside the set lid. The recommended aerial shown would have been too long at the time to be legal and would not have pleased the above mentioned Post Master General! He insisted that the total length of wire used to make the aerial, including the down lead, should not exceed

100 feet (30 m).

As soon as the set was delivered I immediately tested it by temporarily bypassing the crystal/cat's whisker arrangement with a modern point contact germanium diode (OA91) and connecting it to an aerial and earth system. I soon picked up the four local AM stations loud and clear. The loudest program was produced by a 1000 watt transmitter 24 km away. I then removed the modern diode and used the original crystal detector and, after quite a time, again received the local stations. Not bad for an 85 year old electronic device! Surprisingly I, and other crystal set enthusiasts, have found the galena/cat's whisker combination can give a slightly better performance than any modern diode. However, an appropriate diode is much preferred as finding a suitable position for the cat's whisker can take ages. Also the slightest vibration or knock loses the precious connection.

It is perhaps worth noting that no present day radio has any chance of surviving for 80 years: maybe not even 8 years! Also even when brand new, if damaged it is impossible to repair, especially if it is a digital radio. In sharp contrast, a crystal set can generally be repaired with a Swiss Army Knife! If any of the many future disasters that the 'experts' are constantly predicting do occur — such as a large asteroid hit or Yellowstone National Park caldera's long overdue explosion — having a crystal set could be very useful for the few survivors! Any batteries that remained would not last very long and the electromagnetic shock wave would probably destroy all but the old valve (tube) radios. Perhaps the world governments should provide all village elders (local politicians) with long, medium and short wave crystal sets!

(075088-1)



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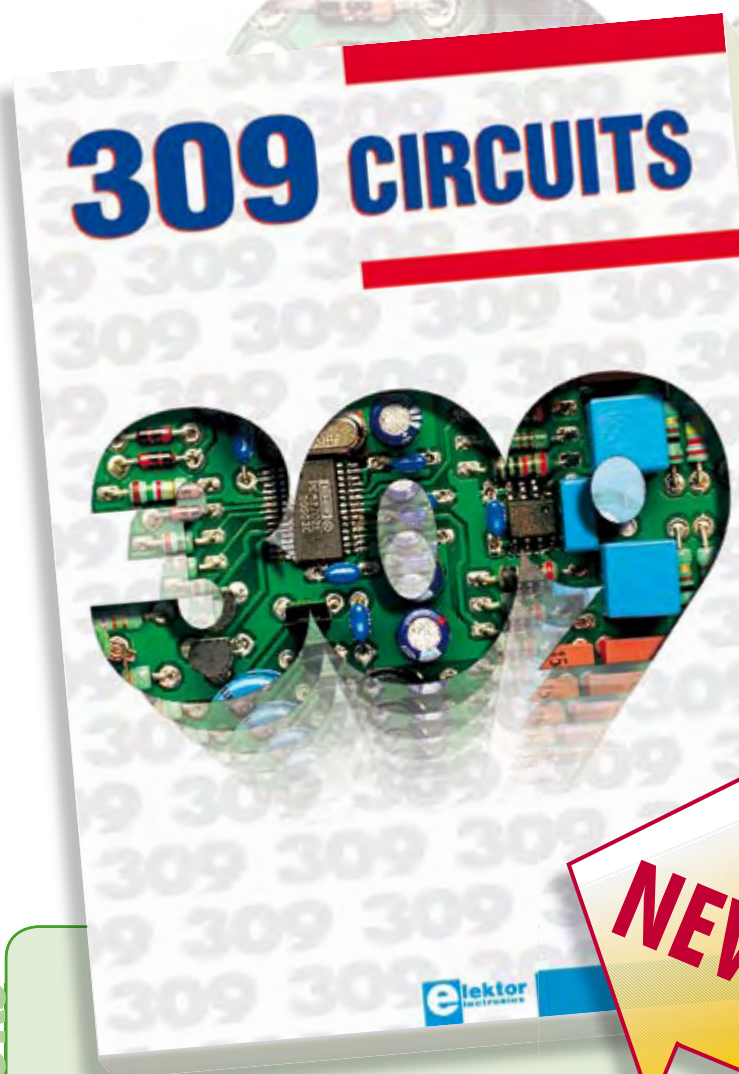
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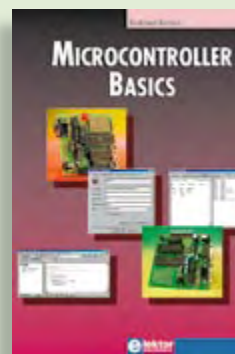


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(June 2007)

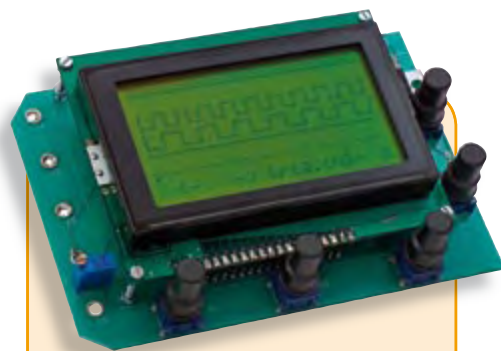
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