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SAPS-400

SMPSU for audio amps

£ 2·00 RLC Meter

can't beat that price

Thermo-Snake

128 thermometers on a string

SATISFACTORY RESULTS

nine soundcards on the rack

R26
06

More than audio

Looking at this month's magazine cover might suggest an overabundance of audio projects. The balance is mote delicate however, although it can be argued that a fair number of articles are related in some way to audio.
The pages on the SAPS-400 describe a switch-mode power supply unit (SMPSU) specially designed for audio power amplifiers. This compact lightweight unit can supply a hefty 400 watts continuously. The main symmetrical output voltage is adjustable across a wide range and a separate ±15-V auxiliary supply is incorporated for powering a preamplifier or similar. SAPS-400 at last enables high-power, high-end audio amps to be built where the enclosure is not 75% filled with bulky transformers and reservoir electrolytics.
SMPSUs are now used in lots of consumer and industrial equipment because of their small size and high efficiency. Still, many designers hate them for their design complexity and non-standard parts. Typically, the solution in these cases is to use a drop-in supply. Our theoretical backgrounder on SMPSU design on page 40 goes to show that things might be less complex than you think.
Our bench test of nine soundcards is not about sound quality in the first place. Lots of electronics enthusiasts use the soundcard in their PC to do low-frequency measurements and for that it's essential to have a linear amplitude response and a known-good frequency characteristic. That's why we did extensive measurements on the technical specs for these soundcards.
A handy application of the soundcard is described in the article '2-pound RLC Meter'. In it we show how an exquisite RLC meter can be built using no more than your PC, the soundcard, three components and a little Java program — very useful.
Happy reading!

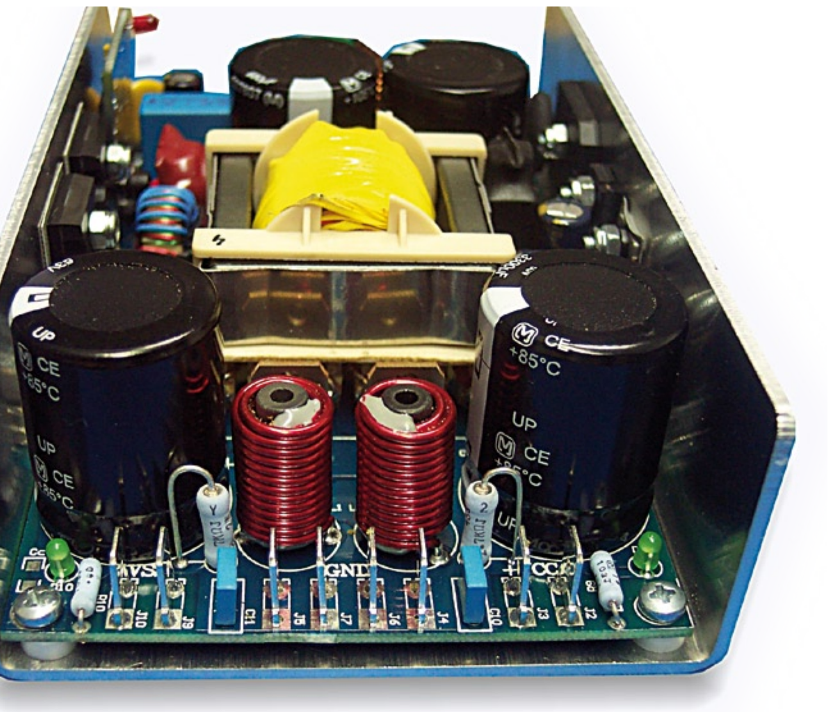
Jan Buiting
Editor

SCORE: 7.5

A comparative

The quality of A/D and D/A converters makes it quite tempting to use a sound card for audio equipment measurements, especially as it fits quite nicely in the Windows environment. However, it takes more than good converters to make a good

26 SAPS-400



With the SAPS-400 we offer a powerful, adjustable symmetrical supply that's ideal for lightweight audio power amplifiers and happily sits in less than a quarter of the space taken by a comparable supply of conventional design.

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instrument, as we all know. Our test shows how well a number of sound cards score with real signals.

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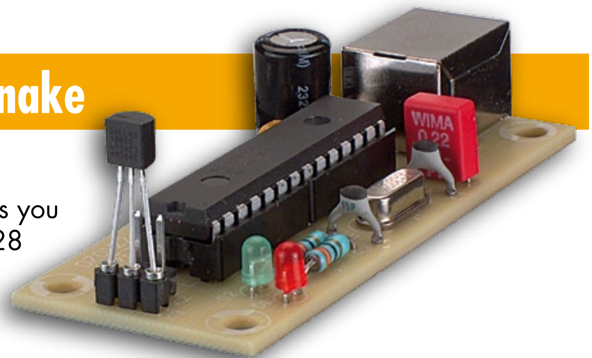
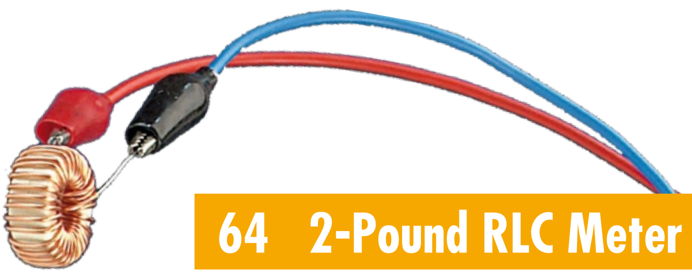


This low-cost project allows you to connect from 1 up to 128 digital thermometers like the Dallas DS18B20 directly on a single two-wire cable. All temperature values are recorded on your PC through a USB port without memory space limitation. Using the software manager developed for the project you can monitor the temperature in real time and set an alarm threshold value for each individual thermometer.



64 2-Pound RLC Meter

Is it possible to make an RLC meter for less than two pounds? In this article the authors answer this question with a resounding 'yes' in the form of a simple and compact circuit that will enable you to make RLC measurements rapidly, accurately, and, above all, cheaply.

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

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Software Formant

Hi Elektor — I would like to respond to your Retronics article on the Formant synthesizer in the April 2008 issue. I have been reading Elektor since 1976. In the early 1980s, when I was 19, I built the Elektor Formant synthesizer, to my considerable satisfaction.
Now, many years later, I have acquired the freedom to work creatively and innovatively with technology, including audio technology. I am presently developing my own surround format, which I call 'Heptaverton Surround'. A prototype decoder and a suitable speaker arrangement have been completed, and the results are amazing. To further enhance the capabilities of Heptaverton Surround, I wanted to build a (soft) synthesizer with surround features.
I still had the Formant music synthesizer book in my bookshelf, so I went to work with it. I originally wanted to build the synthesizer in C++ with the Steinberg VST SDK (since I used this to write the code for the Heptaverton Surround decoder), but then I discovered the Synthmaker development environment. With this program, it took me only a short time to learn how to copy and extend the Formant. Ultimately, the project grew beyond its original objective and I now have a complete remake of the Formant with many new features, named 'HV Formant'.

A demo version of this VSTi softsynth can be downloaded free of charge from my website (www.ftec-audio.com). Anyone who is interested in the full version can purchase a licence key for €69. Although the Synthmaker development environment is intended to be used for developing audio applications, in my opinion it can also be used for many other applications. For instance, you could build a data acquisition system that communicates via MIDI. It would then be fairly easy to use Synthmaker to create a program that processes the data.
Another strong point of Synthmaker is that it is easy to write and test DSP code in this environment.
Using Synthmaker and the information available on the forums, I have acquired considerable expertise in developing digital filters. A demo version of Synthmaker that works for one month can be downloaded from www.synthmaker.com. I would also like to mention that as a tribute to Formant, I am presently developing 'Formant Classic', which can be downloaded free of charge from my website along with the Synthmaker source code. Maybe it would be an interesting idea to publish a full article on Synthmaker in the magazine sometime, possibly in combination with Formant Classic.
Eef Fonken (www.ftec-audio.com)

Thanks for that Eef. A whole lot of Formant fans would probably enjoy seeing their old love reincarnated in digital form. Meanwhile 'the real thing' can be seen and heard on Elektor's very own YouTube channel. Location: Retronics Dungeon at Elektor House. Performing artist: Denis Meyer. Awesome!

The 'Dekatron' decimal counter valve (2)

Dear Editor — in the PS to the above article, the author, Mr. Jean Herman, states that he is on the lookout for Dekatron display valves. If you would be so kind to give me Mr. Herman's address I will be pleased to send him free of charge, a dozen together with their (chassis mounting) sockets.
Roger Ellis (UK)

That's a very kind offer, Roger, showing community spirit. Mr. Herman's address has been communicated to you and we will compensate your P&P expenses.

EIR schematic

Dear Jan — yesterday I had an opportunity to admire the EIR in the latest issue of Elektor (April 2008, p. 24, *Ed.*). Now I wonder what software you use to generate the schematic diagrams.
Marc Priggemeyer (Netherlands)

For some time now we have been using Altium Designer (a PCB design program formerly known as Protel) in the Elektor lab. The schematic diagrams produced and edited with Altium Designer are also used in the project articles in the magazine. We previously used a combination of Ultimate and OrCAD for many years. Ultimate has now been acquired by National Instruments. In addition, we still use McCad (www.mccad.com) for the graphic design of the schematic diagrams typical of Elektor, in combination with a symbol library generated in-house. This was also the case with the schematic for the EIR. This was because the 'original' document was not generated in the Elektor lab with Altium Designer, but instead produced by Harald Kipp (at Egnite) using Eagle 4.16.

Reset switch on CO2 meter

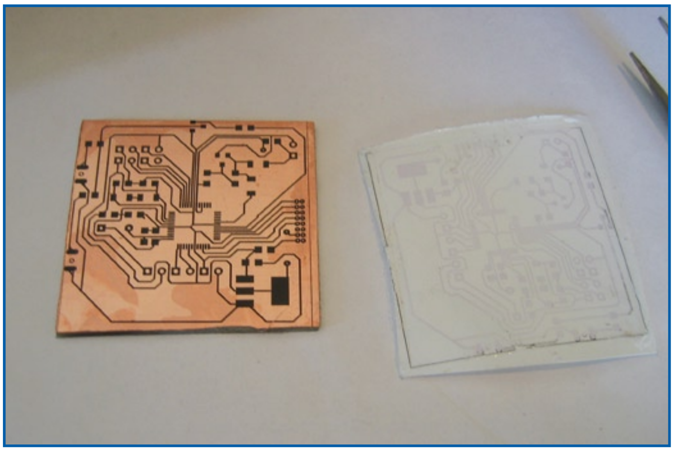
Dear Editor — I have soldered together the kit for the CO2 Meter (Elektor January 2008, p. 16, *Ed.*), and it works

perfectly. However, I have the CDM4161A version (without the LED) and I'm not sure where to connect the Reset switch. Could you help me out here?
Walter Sands (UK)

Connect the Reset switch between pin 4 (Reset input) and pin 1 (5-V supply voltage) of the CDM4161A CO2 meter module. When the switch is closed, a voltage of +5 V (High level) is applied to the Reset input (pin 4) to trigger a reset.

Making PCBs with a laser printer — a sequel

Dear Jan — there exist methods for using photo paper and a laser printer to make PCBs. I was happy to know, since the boards I made with photo resist usually did not turn out OK. I would like to know how I can find out whether the photo paper I have is suitable for use with a laser printer. As far as I know, you have to be careful in choosing materials to be printed with a laser printer due to the heat used in the printing process. Is all photo paper for ink-jet printers sufficiently heat resistant? I certainly don't want to destroy my laser printer!
Jacques Thurlby (UK)

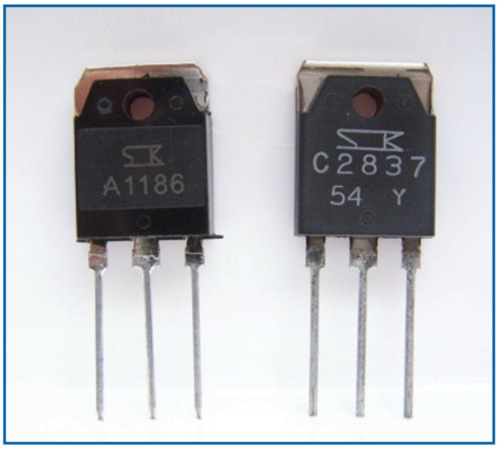


Hi Jan — I have an old HP LaserJet 4L that I have used to print hundreds of letters and related documents in the last years, and it still works perfectly. Although a laser printer can handle 240-gram paper quite well, the powder does not adhere very well. Especially not if you print double-sided.
This afternoon I experimented with papers ranging from 20 to 240 gram. Heavy papers are not only thicker than thin paper, but also smoother and more glossier. I printed a reasonably fine Elektor PCB layout with the highest possible print density. I then scrubbed a piece of Conrad Electronics PCB material with pumice and ironed the paper print onto the board using an iron at various heat settings. As a preliminary result, I can say that the highest heat setting gives the best results. Some parts are already acceptable. I got some photo paper from a chemist's – matte paper, 170 gram.
It passes through my printer without any damage, and it releases the powder completely at a low iron temperature ('synthetic fabrics').
Chelsea

Derar Jan — I have now discovered that poor results are mainly due to the large temperature variation (hysteresis) of the iron (as measured with a cannibalised oven thermometer). Now I set it to the highest temperature and use a dimmer to control the power. This gives me a much more constant temperature.
The results now with HP Premium Plus Photo Paper C6832A look very promising. If the paper sticks to the circuit board, you have to lower the temperature.
Jacques

Bogus transistors

Dear Jan — it's been some time since Elektor published an article on bogus components on the market (September 2004, *Ed.*)
Early 2007 I bought a set of hefty Sanken power transistors. I haven't used them till now however because I do not trust the pnp device. I suspect this to be a fake, see the accompanying photograph. Is the subject of bogus parts still topical?
Chris Johnson



It sure is, Chris. Lots of bogus parts are manufactured and sold, both transistors and ICs. Looking at the photo you sent along with your email clearly reveals two different transistors. Still, that does not necessarily mean that one of them is a bogus part. Possibly the two devices come from different production batches and it's even possible that they were not manufactured in the same plant. This could go some way to explain the differences between the casings and the print. We do agree there is reason to be suspicious though. The only way to get certainty is to do extensive testing on these transistors or take them apart to reveal the silicon inside.
The photo is printed here with an invitation to our readers to send us their experiences with these specific transistors.

A stable audio signal

Dear Elektor — in my home lab I do a lot measurements on audio circuits. One of the problems I'm faced with time and again is insufficient stability of the audio generator output signal, particularly with varying load impedance and/or frequency. I recall having seen a circuit some time in Elektor that solved the problem by maintaining a constant output voltage of the audio generator. Unfortunately I am unable to find any reference to the circuit on your forums or in the Elektor archive. Can you help me locate the circuit?
J. H. Monteban

We do not remember such a circuit but then that does not mean it was never published in Elektor. A simple solution to your problem could be to add a small audio power amplifier at the output of the audio signal generator (1 watt or less is sufficient). The output impedance of such an amplifier will be low enough for the output level to remain constant even with varying or relatively heavy loads.

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Elnec BeeHive8S stand-alone multiprogramming system

BeeHive8S is an extremely fast universal 8x 48-pindrive Stand-Alone concurrent multiprogramming system designed for high volume production programming with minimal operator effort. The chips are programmed at near maximum programming speed. The programmer consists of 8 independent isolated universal programming modules, based on popular single-site BeeProg+ programmer hardware. This allows sockets to run asynchronously (concurrent programming mode). Each programming module starts programming the moment the IC is detected when it is properly inserted in the socket — independent of the status of other programming modules. As a result, seven programming modules can work while the operator is replacing the programmed IC at the eighth module.

The Graphics control unit with touch screen provides basic information about programming flow and allows a basic level of controlling of the BeeHive8S programmer. Modular construction of the hardware allows the operation to continue when a part of the circuit becomes inoperable. It also makes service quick and easy. Hands-free operation is asynchronous and a concurrent operation, allowing ICs to be programmed immediately upon insertion. The operator merely removes the programmed IC and inserts a new one. Operator training is therefore minimized.

The BeeHive8S supports all kinds of silicon technologies of today and tomorrow, covering programmable devices without a family-specific module. The programmer features an extensive library of over 36,000 devices. The BeeHive8S's device library is constantly updated. Users can be sure that future devices are supported by a software update and (if necessary) a simple package converter (programming adapter), minimizing ownership costs.

An important feature of the BeeHive8S is its programming speed. It is a very fast programming due to high-speed FPGA driven hardware and execution of time-critical routines inside the programmer. As a result, the programmer waits for the operator, rather than the other way around. The BeeHive8S provides is competitively priced, coupling excellent hardware design to reliable programming. In this class it might well be the best 'value for money' programmer.

www.elnec.com

(080144-I)

Highest-Accuracy multifunction data acquisition devices with USB connectivity

National Instruments announced a new line of M Series USB data acquisition (DAQ) devices with 18-bit analogue input accuracy at sampling rates up to 625 kS/s. The NI USB-6281 and USB-6289 feature an 18-bit ADC, which provides a 4x increase in resolution over traditional 16-bit devices, equivalent to more than 5½ digits of resolution for DC measurements. These devices also offer enhanced analogue output channels that feature programmable range and offset settings. In addition to standard screw terminal or mass termination connectivity options, board-only OEM versions are also available for integration with embedded systems and include 34- and 50-pin insulation-displacement connectors (IDC) for easy board mating

To ensure accuracy at all available sampling rates, these devices incorporate the NI-PGIA 2 custom amplifier and NI-MCal self-calibration to minimise settling time and guarantee maximum accuracy. An onboard lowpass filter can be programmatically enabled to further improve measurement accuracy by eliminating high frequency noise. With the NI USB-628x devices, engineers can deliver an absolute accuracy of 980 μV at a range of ±10 V and 28 μV at a range of ±100 mV at a sampling rate of up to 625 kS/s.

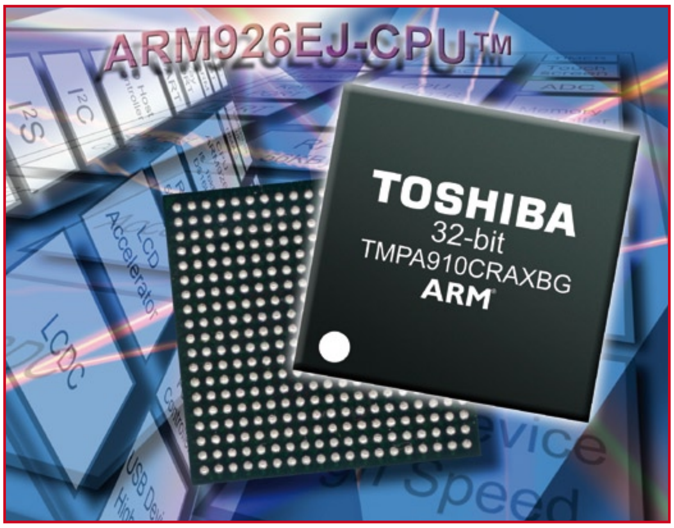
The USB-6281 features 16 single-ended (SE) and eight differential input (DI) analogue input channels, two analogue output channels and 24 digital I/O (DIO) channels, while the USB-6289 features 32 SE and 16 DI analogue input channels, four analogue output channels and 48 DIO channels. Both devices offer 18-bit analogue inputs at up to 625 kS/s (500 kS/s when scanning) and 16-bit analogue output at 833 kS/s.
The new USB-628x devices are shipped with NI-DAQmx driver software and NI LabVIEW SignalExpress LE, an interactive measurement workbench for quickly acquiring, analysing and presenting data without additional programming. The NI-DAQmx driver also provides time-saving features such as code generation for both the LabVIEW graphical development environment and text-based languages such as ANSI C/C++, C#, Visual Basic .NET and Visual Basic 6.0; more than 3,000 measurement examples; device simulation; and connection diagrams.

www.ni.com/nati

(080144-V)

In 1 micro: 32-bit ARM, graphics control and processing

Based on the ARM926EJ-S™ CPU core operating at up to 200 MHz, Toshiba's new TMPA910CRAXBG uses a 7-layer multibus architecture. This architecture significantly improves performance compared to other devices operating at similar processor speeds. The built-in LCD controller offers support for TFT and STN display sizes up to 1024 × 1024 pixels. An LCD data processor accelerator delivers image scaling, filtering and blending functions and offers real time processing for movies at speeds up to 30 frames per second.



The new micro has a CMOS image sensor interface that simplifies the implementation of applications requiring image capture. A touchscreen interface further reduces the need for external components in man machine interface (MMI) designs. Additional connectivity includes SPI, UART, I^2C, I^2S, and a high-speed USB device (480 Mbps).

Toshiba has incorporated 56 kBytes of built-in embedded RAM for program, data and display memory, Boot ROM, and a memory controller that supports SDR and DDR SDRAM. Up to 2.5 GBytes of linear access space can be addressed. An SD host controller supports high-speed mode SD cards with capacities up to 32 GB.

The new microprocessor is supplied in a 361-pin FPGA package. Additional built-in peripherals include a 10-bit ADC, a six-channel, 16-bit timer, a watchdog timer, real time clock and alarm functionality.

In addition to extensive software support that includes graphics libraries and embedded operating systems, the new device is supported through the availability of a Starter Kit that will further speed application development and prototyping.

www.toshiba-components.com

(080144-VII)

New Cypress CapSense Express(tm) is fastest button and slider replacement

Cypress Semiconductor Corp. introduced the CapSense Express(tm) capacitive touch sensing solution for button and slider replacement. The CapSense Express solution enables designers to implement up to 10 buttons and/or sliders in as little as five minutes — with no coding. The PSoC Express(tm) visual embedded system design tool and CapSense Express configuration tool allow designers to monitor and tune the performance of the buttons and sliders in real time using a graphical user interface. Competing solutions require designers to program and test each adjustment, adding design time and cost.

Cypress' PSoC(R)-based CapSense devices have implemented over 2.5 billion buttons, sliders and other touch sensing interfaces in systems worldwide. The CapSense portfolio offers unmatched flexibility and integration, addressing a broad range of designs from complex, feature-rich applications to simple button replacement. More information about the new solution is available at the link below.

The CY8C201X0 and CY8C201X2 CapSense Express devices offers up to ten capacitive and/or general purpose I/Os (GPIOs), allowing design flexibility to implement combinations of buttons, sliders, and general purpose functions like LED control and interrupt outputs. For battery-powle button replacement. More information about the new solution is available at the link below.

The CY8C201X0 and CY8C201X2 CapSense Express devices offers up to ten capacitive and/or general purpose I/Os (GPIOs), allowing design flexibility to implement combinations of buttons, sliders, and general purpose functions like LED control and interrupt outputs. For battery-powered applications, the devices offer low power consumption of just 1 mA active current and 2.6 μA in sleep mode. The new devices offer a wide operating voltage of 2.4 V to 5.25 V and an industrial temperature range of –40 ºC to +85 ºC. In addition, 2 kB of Flash memory and an I^2C communication interface are provided so designers can choose whether to store tuning values in Flash or load them over I^2C at power-up.

The new CY8C201X0 and CY8C201X2 CapSense Express devices are available now. They are packaged in 8- and 16-pin SOIC and 16-pin QFN pakkages. Cypress is offering three evaluation kits for designers using the CapSense Express solution. The CY3218-CAPEXP1 kit features three CapSense buttons, three backlighting LEDs, three LEDs for status and one mechanical button. The CY3218-CAPEXP2 kit offers a 5-segment slider with four status LEDs and one mechanical button. The CY3218-CAPEXP3 features two CapSense buttons with two status LEDs using the smallest package, the 8-pin SOIC. The kits are available from the OnLine Store at www.cypress.com and from authorized distribution partners. The three kits are priced at USD $45 each.

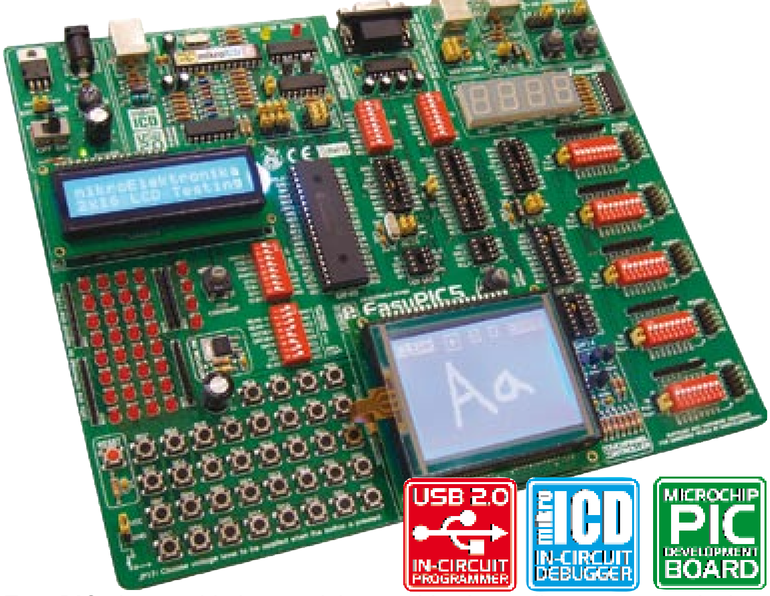
www.cypress.com/capsense

(080144-IV)

mikroElektronika

DEVELOPMENT TOOLS | COMPILERS | BOOKS

EasyPIC5 with on-board In-Circuit USB2.0 programmer & debugger

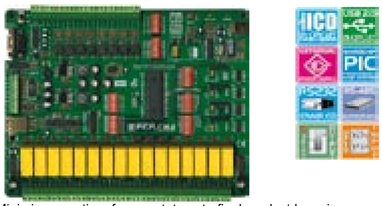


EasyPIC5 is a world-class tool that enables immediate prototype design. Thanks to many new features of this development tool, you can start creating your great devices immediately. **EasyPIC5** supports 8-, 14-, 18-, 20-, 28- and 40- pin PIC microcontrollers (it comes with the PIC16F887). The **mikroICD** (In-circuit Debugger) enables very efficient debugging. Examples in **C**, **BASIC** and **Pascal** language are provided with the board. EasyPIC5 comes with the following printed documentation: EasyPIC5 Manual, PICFlash2 Manual and mikroICD Manual.

Evolving product features and modern input design require the use of touch screens. The **Touch screen controller** with connector available on EasyPIC5 is a **display overlay** with the ability to display and receive information on the same display. It allows a display to be used as an input device. Touch screens are popular in the industry, where standard inputs such as switches do not work very well.

PICPLC16B Development Board

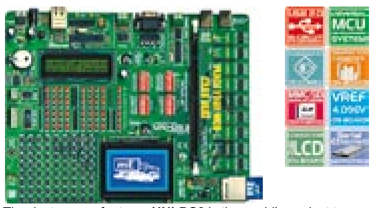
Complete Hardware and Software solution with on-board USB 2.0 programmer and mikroICD



Minimize your time from prototype to final product by using market-proven **PICPLC16B** development board. **PICPLC16B** is a system designed for controlling industrial systems and machines. 16 inputs with **optocouplers** and 16 **relays** (up to 10A) can satisfy most industrial needs. The ultra fast **mikroICD** (In-circuit Debugger) enables very efficient debugging and very fast prototype development. Features: **RS485**, **RS232**, **Serial Ethernet**, **USB 2.0** programmer and **mikroICD** (In-Circuit Debugger) are available on-board.

Uni-DS 3 Development Board

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



Thanks to many features **UNI-DS3** is the world's easiest to use development board for different types of microcontrollers.The system supports **PIC**, **dsPIC**, **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 swich a card. You can choose between USB or External Power supply. Each MCU card has its own **USB 2.0** programmer!

mikroElektronika Compilers

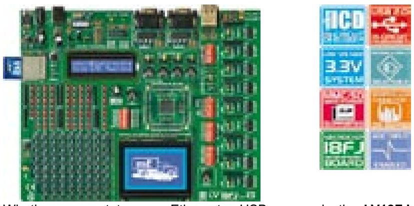
Pascal, Basic and C Compilers for PIC microcontrollers

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 mikroICD, 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.

LV 18FJ Development Board

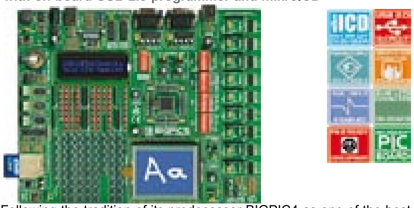
Complete Hardware and Software solution with on-board USB 2.0 programmer and mikroICD



Whether your prototype use Ethernet or USB communication **LV18FJ** development board will definitely satisfy your needs. 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 with the Microchip PIC18FxxJxx development system. The on-board **USB 2.0** programmer with **mikroICD** (In-Circuit Debugger) enables very efficient debugging and very fast prototype development. Examples in **C**, **BASIC** and **Pascal** language are provided with the board.

BIGPIC5 Development Board

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



Following the tradition of its predecessor BIGPIC4 as one of the best PIC development systems on the market, the **BIGPIC5** provides newly revised features for the same price. System supports the latest (**64**) and **80-pin** PIC microcontrollers (it is delivered with PIC18F8520). Many of these ready to go made examples in **C**, **BASIC** and **Pascal** language guarantee successful use of the system. A **Touch screen** controller with connector is available on-board. This development board has an on-board ultra fast **USB 2.0** programmer, **mikroICD** (In-circuit Debugger) and integrated connectors for MMC/SD memory cards, 2 x RS232 port, RS485, CAN, on-board RTC, PS/2 connector, DAC etc...

Special Offers - Save time & money!

Special Offers include all you need to start your development: Software, Development Board, Printed Manuals and Accessories.

The main reason for choosing our special offers is their very favorable price and the ease of use. Reduce prototype development and testing time to hours or minutes. Our special offers include all the tools you need to get your project up and running fast for various types of microcontroller.

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.

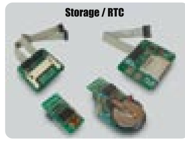
CAN-1 Board - Interface CAN via MCP2551.

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.

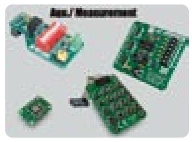


CF Board - Easy way to use Compact flash in your design.

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 mikroICD now supports more PIC MCUs giving developer a wider choice of PIC MCU for further prototype development.

mikroICD 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.

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SOFTWARE AND HARDWARE SOLUTIONS FOR EMBEDDED WORLD

Microchip: 32-bit PIC32 MCU family gets USB on-the-go

From Microchip comes an addition of integrated USB 2.0 On-The-Go (OTG) functionality to their 32-bit PIC32 microcontroller family. The PIC32 family brings more performance and memory to embedded designers while maintaining pin, peripheral and software compatibility with Microchip's 16-bit microcontroller and DSC families. The maximum operating frequency for the PIC32 family has been increased to 80 MHz, which further extends the performance reach of the new 32-bit PIC32 microcontroller family. To further ease migration and protect tool investments, Microchip's is the only complete portfolio of 8-, 16- and 32-bit devices to be supported by a single Integrated Development Environment — the free MPLAB® IDE.

Some USB products, such as PCs, operate only in a host role, whereas others — for example, USB Flash drives — operate only as devices. Products with OTG functionality can operate in either role — even auto-negotiating which will be the USB host or device when encountering another OTG product. The new PIC32 microcontrollers with integrated USB OTG provide designers with the flexibility to add all three modes of USB operation to their products. The new MCUs also include the USB OTG PHY, enabling even lower costs and smaller PCB real estate.

All PIC32 family products are supported by Microchip's world-class development tools, including the MPLAB Development Environment, the MPLAB C32 C compiler, the

MPLAB REAL ICE™ emulation system, the MPLAB ICD 2 in-circuit debugger, and the MPLAB PM3 universal device programmer.

Microchip also provides free source code for USB software stacks and class drivers to enable designers to get a head start on the development of their USB applications. Microchip's free USB Host Stack, Device Stack, and Class Drivers (HID, MSD, CDC, Custom) are available at the website below. The free USB OTG Stack is currently in beta, with full release scheduled for the Q2, 2008.

The PIC32 family also enjoys broad tool support throughout the industry. Complete tool chains are available from Ashling, Green Hills, Hi-Tech and Lauterbach — including C and C++ compilers, IDEs and debuggers. RTOS support is available from CMX, Express Logic, FreeRTOS, Micrium, Segger and Pumpkin. Graphics tools providers include EasyGUI, Segger, RamTeX and Micrium. A full list of third-party support for the PIC32 family can also be found at the website below.

The PIC32 USB Starter Kit comes complete with everything that developers need to get started, including the USB-powered MCU board, the MPLAB IDE and MPLAB C32 C compiler, documentation, sample projects with tutorials, schematics, and 16-bit compatible peripheral libraries. Application expansion boards are also being made available, which plug into the expansion slot on the bottom of the MCU board. The PIC32 USB Starter Kit (part number DM320003) is expected to be available in Q2, 2008 at www.microchipdirect.com.

Elektor readers having the Microchip's Explorer-16 development board can purchase a USB OTG PIC32 plug-in module (part number MA32002) and a USB PICtail™ Plus Daughter Board (part number AC164131). Both can be ordered from microchipdirect.

The four new PIC32 family members with USB OTG have Flash program memory sizes from 128 kbytes to 512 kbytes in 64- or 100-pin TQFP packages.

www.microchip.com/PIC32

(080144-X)

u-blox GPS powers LandAirSea miniature GSM-based tracker

LandAirSea Systems, announced today the launch of a miniature, battery-powered, GSM-based real-time vehicle tracking unit featuring u-blox 5 GPS technology.

LandAirSea's new 8100G tracking device incorporates the latest in GPS and wireless technology to accurately determine the exact location of a vehicle, and can be used to track individual vehicles or entire fleets. Based on the highly successful CDMA-based 8100, the innovative 8100G now additionally offers GSM network operability. As the prevalent mobile communications standard worldwide, GSM operability significantly widens the device's geographical reach.

The 8100G will provide fleet managers, government agencies, business

owners, as well as consumers real-time vehicle and asset tracking device that uses the immensely popular Google Earth program for high-resolution satellite imaging. Since GSM is the most prevalent mobile communications standard worldwide, the new 8100G will allow LandAirSea to expand its customer base beyond the USA and Canada.

The 8100 tracking unit features a u-blox GPS receiver boasting 2-meter position accuracy and –160dBm sensitivity, which enables accurate, reliable tracking, even in difficult signal environments.

The self-contained device measures approx. 1″ × 2″ × 3¾″ (2.5cm × 5cm × 9.5 cm), and is battery-powered and completely portable. It also can be hard-wired for permanent applications. Other key features of the 8100G include live 1-second updates, a built-in lithium-ion rechargeable battery, a motion sensor, a wiring harness for permanent installation, in and out of zone geo-fencing with text message and/or e-mail notification and a data logging features that enables remote downloads.

www.landairsea.com
www.u-blox.com

(080144-VIII)

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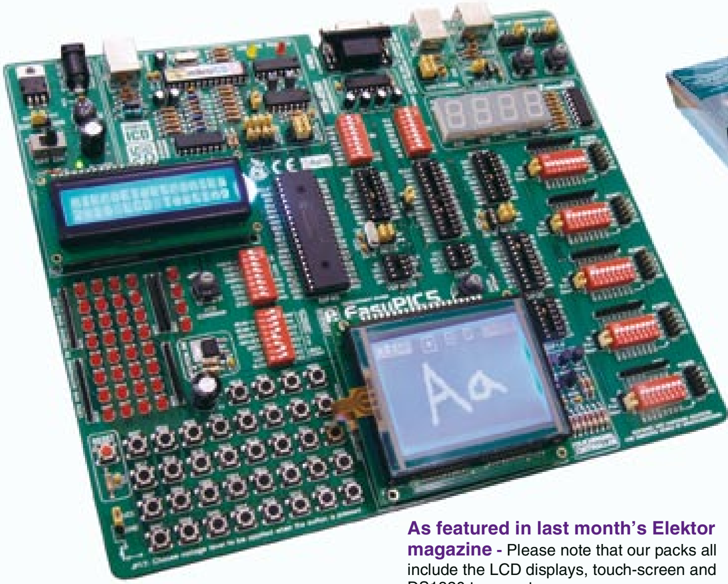
☎ 0845 226 9451

EasyPIC5 Starter Packs—everything needed to learn about and develop with PIC microcontrollers from only £99



Four starter packs available, all of which include the EasyPIC5 development board, USB power/programming lead, blue backlit 16x2 character and 128x64 graphic LCDs, touch-screen overlay for GLCD, RS-232 lead, PIC16F877A 40-pin microcontroller and DS1820 temperature sensor plus manuals and software.

EasyPIC5 Starter Pack - £99
Our EasyPIC5 Starter Pack is ideal for those wishing to learn about and program using assembly language or other makes of compiler. The pack contains the EasyPIC5 board, all required leads, character and graphic LCDs, touch-screen, PIC16F877A MCU and DS1820 temperature sensor. Exclusive to Paltronix, the pack also includes a getting started guide, tutorials and example programs—ideal for newcomers to microcontrollers.

EasyPIC5 BASIC Starter Pack - £149
EasyPIC5 C Starter Pack - £189
EasyPIC5 Pascal Starter Pack - £149
Get off to the best start with the EasyPIC5 and save money with one of our compiler starter packs, which include the contents of the above EasyPIC5 Starter Pack plus a full version of MikroElektronika's mikroBASIC, mikroC or mikroPascal PIC compilers. These user-friendly compilers feature in-circuit debugging when used with the EasyPIC5 and also provide library routines to support all the EasyPIC5's built-in I/O devices and optional add-on boards.

As featured in last month's Elektor magazine - Please note that our packs all include the LCD displays, touch-screen and DS1820 temperature sensor.

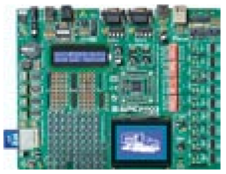
MikroElektronika's EasyPIC5 development system simply must be the most versatile and best value PIC development system on the market. The board supports Flash-programmable devices in the PIC10F, 12F, 16F and 18F families in 8, 14, 18, 20, 28 and 40-pin packages and features a fast built-in USB2.0-based programmer. Also on the board are a useful range of I/O devices such as LEDs, pushbutton switches, potentiometers, RS-232 interface, USB and PS/2 connectors and provision for the easy fitting of character and graphic LCDs, touch-screen and DS1820 temperature sensor (all of which are supplied in our starter packs). Clearly labelled DIP-switches and jumpers allow any I/O devices not being used to be disabled and all of the PIC's I/O lines are available on IDC headers for easy expansion using MikroElektronika's extensive range of add-on boards or for connection to your own circuits. Detailed documentation and example programs and our own getting started guide and tutorial make the EasyPIC5 ideal for beginners and experienced users alike.

UNI-DS3 Universal Development System

Work with various MCUs using one development board with the **UNI-DS3**. Currently supporting PIC, dsPIC, AVR, 8051, ARM and PSoC devices, the UNI-DS3 has a wide range of I/O features from £109 including main board and one plug-on MCU card.

We stock all MikroElektronika development and add-on boards and PIC, dsPIC/16-bit PIC, AVR and 8051 compilers.

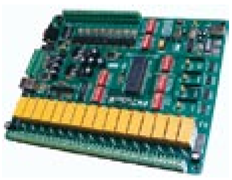
dsPICPRO3 Development System



The new **dsPICPRO3** is a development system for the dsPIC with advanced I/O and communications devices including RS-232, RS-485, CAN, Ethernet, real-time clock, SD card reader and displays. Starter packs priced from £149.

We stock a large range of similar development systems for PIC, dsPIC, AVR, 8051, ARM and PSoC microcontrollers.

PICPLC16B Control System



The **PICPLC16B** makes an ideal platform for developing and implementing control and automation applications. This PIC microcontroller-based board has 16 relay outputs, 16 opto-isolated inputs plus RS-232, RS-485 and Ethernet interfaces for £99.

A wide range of microcontroller and PC-based control boards and add-ons are also available.

PoScope Multi-Function Instrument

The **PoScope** features a 16-channel logic analyser with I2C, SPI, 1-wire and UART serial bus decoding, dual-channel oscilloscope, pattern generator, spectrum analyser, chart recorder and square-wave/PWM generator in one low-cost instrument for £79.

We also stock a range of probes and test leads suitable for use with the PoScope as well as money-saving bundles.

LAP-16128U Logic Analyser

The **LAP-16128U** from ZeroPlus is a powerful 16-channel 200MHz logic analyser with UART, I2C and SPI protocol decoding priced from £195. Further protocol decoding options available including 1-wire, Microwire, CAN, LIN, PS/2 and USB.

We can supply all ZeroPlus logic analysers and advanced protocol decoding options.

Leaper-48 Universal Device Programmer

The **Leaper-48** is a USB-based universal device programmer supporting an extensive range of memories, programmable logic devices, microcontrollers and digital signal processors at a low price of £295. Please see our website for full list of supported devices.

We also stock Leap device programmers for EPROM/EEPROM/Flash EPROM, 8051 and PIC.

Robo-PICA Robot Experiment Pack

Start experimenting with robotics with the **Robo-PICA** robot experiment pack. Contains everything required to build various PIC microcontroller-based robot projects and carry out a large range of fun experiments for £89.

Similar robot kits stocked based on 68HC11, 8051, AVR and BASIC Stamp plus large range of accessories.

NX-51 V2 Microcontroller Trainer

Designed specifically for teaching 8051 microcontroller interfacing and programming, the **NX-51 V2** incorporates a useful range of I/O devices and comes complete with detailed example programs for £99.

Other training systems available for microcontroller and electronics teaching.

IDL Series Circuit Labs

The **IDL-400** Logic Trainer, **IDL-600** Analogue Lab and **IDL-800** Digital Lab all feature a large solderless breadboard, built-in DC power supplies, switches, displays and useful logic gates or test features and are priced from just £179.

We have a large range of prototyping products from breadboards to advanced digital and analogue circuit labs.

Please see our website at www.paltronix.com for further details of these and other products
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Atanua real-time logic simulator for educational use

Atanua sports an intuitive, OpenGL accelerated user interface, which allows the user to place components and wires. Components include all common logic blocks, including gates, latches and flipflops.

Additionally Atanua simulates about 30 different 74-series chips, as well as an 8051 microcontroller variant. Simulated and pure logic parts can be mixed in the same circuit.

Additional parts can be made using the plug-in interface. As an example plug-in, driver for the Velleman K8055 USB experiment board is provided, with which the user can mix simulated and real-world components.

On the I/O front, Atanua includes several different frequency clock inputs, constant level inputs as well as buttons which are bound to the user's keyboard. LEDs in various colors as well as 7-segment displays are also included. There's also a simple logic probe for debugging.

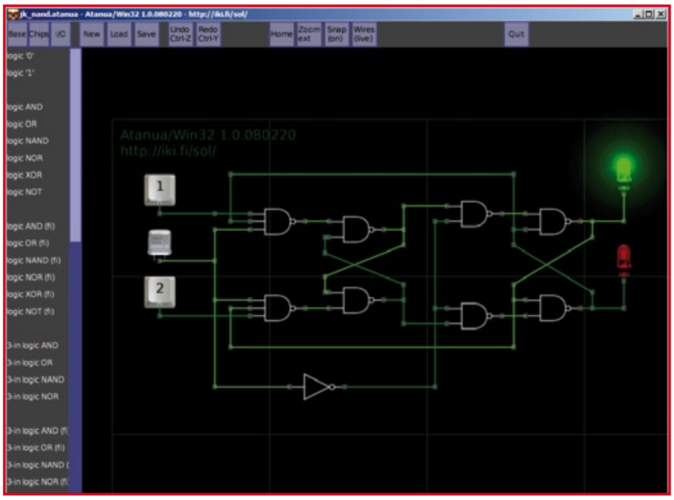
The simulated parts are designed to resemble their real-world counterparts, which is more attractive for the students than pure schematics. The students can practise lab experiments using the simulated chips. An anti-cheating tool is also available for teachers who wish to use Atanua for homework.

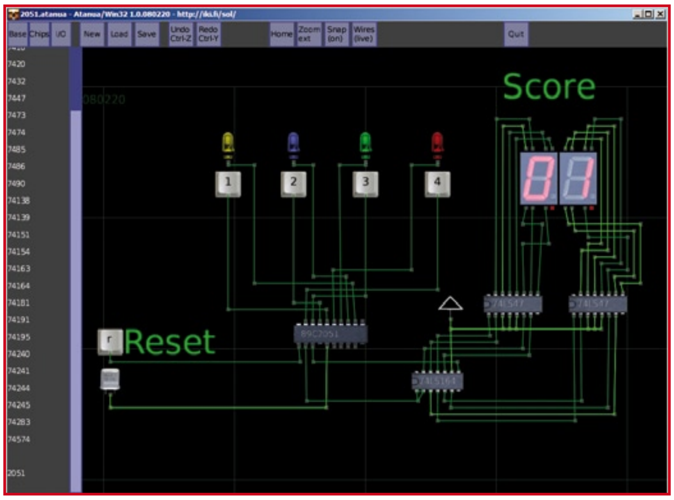
The simulation shows the signal state of each wire in real time. In addition to high and low signal level, parts may output an 'invalid' signal, stating that there is a problem with the circuit, such as outputs connected together, or missing wirings from some chip.

Versions for Windows, Linux and OS X are available.

http://atanua.org.

(080144-III)





Fmicro NTC thermistor sensors for catheter & medical applications

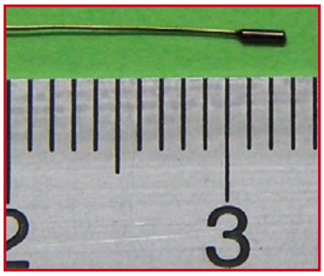
NTC manufacturer SeMitec's newest product is a micro thermistor sensor designed primarily for use in medical applications.

Utilising the latest FT thin-film technology combined with laser-trimming techniques, the Fmicro thermistor sensor is only 0.5 mm diameter by 2.3 mm long. The Fmicro is based on one of the smallest FT thermistors encapsulated in a polyamide tube and fitted with #38 AWG insulated leads.

The Fmicro is accurate to ±0.2 K at 37 °C and is small enough to be incorporated within a catheter probe for internal body temperature measurement. The operating temperature range is –10/+70 °C.

www.atcsemitec.co.uk

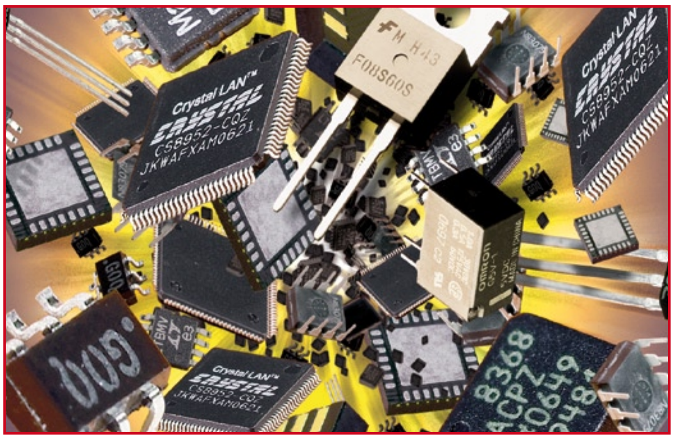
(080144-II)



Farnell adds over 50,000 new products in 12 months

Based on feedback from its customers and consultations with its suppliers Farnell carefully selected new product additions to product categories including semiconductors, passives, connectors, Emech and optoelectronics. Many new and innovative, high-end technology products from niche manufacturers have been identified and introduced with the aim of giving design engineers access to the latest technology as well as the broadest choice.

In addition, the introduction of price reductions on 36,000 of the most popular component ranges backed by extensive technical support makes Farnell the ideal cost competitive, single source for electronic design engineers across Europe.



As Farnell continues to add new products, customers can quickly find out about them by visiting the 'What's new?' section of the company's website. Accessed via the navigation bar on all websites, it includes brand new products to market, new niche suppliers of high-end technology, and a monthly 'hot' product.

(080427-I)

NI LabVIEW SignalExpress Tektronix Edition 2.5 Adds Support for New DPO3000 Oscilloscopes

National Instruments has announced support for new Tektronix value line oscilloscopes in the latest version of LabVIEW SignalExpress Tektronix Edition, an interactive PC-based measurement software for quickly acquiring, analysing and presenting data without programming. Engineers and scientists can use LabVIEW SignalExpress Tektronix Edition 2.5 to connect to and control all value-line Tektronix oscilloscopes including the new Tektronix DPO3000 and TDS3000C digital phosphor oscilloscopes as well as the MSO4000 mixed-signal oscilloscopes from their PCs with an easy-to-use, drag-and-drop environment. The latest version of the software also introduces time-saving features such as measurement and waveform logging and new interactive reporting capabilities.

LabVIEW SignalExpress Tektronix Edition provides plug-and-play setup with Tektronix oscilloscopes as well as more than 400 additional modular and benchtop instruments, making it easy for users to connect their stand-alone instruments to PCs and configure all instrument communication, view live measurement data and take control of the oscilloscope. With a few additional mouse clicks, users can log their data to a disk and export the data directly to a spreadsheet application, such as Microsoft Excel, for easy analysis and reporting. The software also offers advanced data-logging features such as alarm monitoring and condition logging as well as the automation of common measurement tasks such as circuit characterisation and frequency sweeping. Additionally, LabVIEW SignalExpress Tektronix Edition provides users with more than 200 analysis and processing functions.

The latest version of LabVIEW SignalExpress Tektronix Edition introduces measurement and waveform logging capabilities that make it possible for users to record their measurements directly to their PCs, automating an often tedious and time-consuming task. LabVIEW SignalExpress Tektronix Edition 2.5 also adds new interactive reporting features such as a drag-and-drop report that displays live data as well as the ability for users to save and print their reports as HTML pages.

LabVIEW SignalExpress Tektronix Edition LE, a limited feature version of the software, is shipped as part of the standard configuration with all Tektronix value-line oscilloscopes and AFG3000 arbitrary function generators including the new AFG3011 high-amplitude model. Tektronix customers can upgrade to the full version for advanced signal processing, analysis, documentation and data logging. Readers can learn more about LabVIEW SignalExpress Tektronix Edition view an interactive tutorial and download technical white papers at **www.ni.com/tek.**

(080427-II)

Cypress's PSoC(r) CapSense enables touch-sensitive media console in Acer Aspire 6920 and 8920G notebook PCs

The single-chip Cypress CapSense solution enables touch-sensitive buttons, sliders and shuffle controls that provide users with a stylish, convenient way to access and control a rich array of multimedia capabilities. The CapSense device also controls LED indicator lights on the new laptops.

The CapSense device offered Acer a programmable, flexible solution for the CineDash media console, a key feature in the new Aspire models. The CapSense solution allows designers to make last-minute changes, add features and control additional functions beyond the capacitive touch interface — capabilities that are not available from other capacitive sensing products.

A single CapSense device can replace dozens of mechanical switches and controls with an elegant touch-sensitive interface, and the solution supports touch screens and proximity sensing for superior product differentiation. CapSense-based 'button' and 'slider' controls are more reliable than their mechanical counterparts because they are resistant to environmental wear-and-tear from temperature change and moisture. Cypress has garnered hundreds of CapSense design wins worldwide in applications that include mobile handsets, portable media players, white goods, computers, printers and automotive, among others.

A single PSoC device can integrate as many as 100 peripheral functions saving customers design time, board space and power consumption while improving system quality. Customers can save as much as $10 in system costs.

www.cypress.com/psoc
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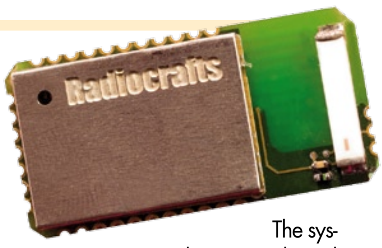
(080427-III)

ZigBee®-based wireless system for parking lots



Radiocrafts and Innovative Technologies jointly announce the successful implementation of a novel ZigBee-based wireless system for parking lots. The intelligent parking lot system has been designed by Innovative Technologies based on the Radiocrafts RC2300 RF module using ZigBee technology.

The European urban population struggles on a daily basis with underground parking lots and related challenges. Innovative Technologies singled out this arena as a prime application area for automation. Already experts in RFID, Innovative Technologies recently expand their portfolio with ZigBee, a growing standard for wireless sensor monitoring and control.

The parking automation system is based on placing Vehicle Detection Modules (VDM) above the parking space. Each VDM can control up to 2 parking spaces. Displays are set up at the entrance of the car park and will indicate to the drivers the number of available parking spaces and the ones which are the closest. Data management software provides the operator with a graphic map of each parking level showing in real time free parking spaces. The system brings both operators and users of parking lots major benefits.

The system architecture is based on a low power compact ZigBee radio module, RC2300, provided by Radiocrafts, a pioneering supplier of ZigBee technology.

www.radiocrafts.com

(080427-IV)




SCORE: 7.5

A comparative test of nine sound cards

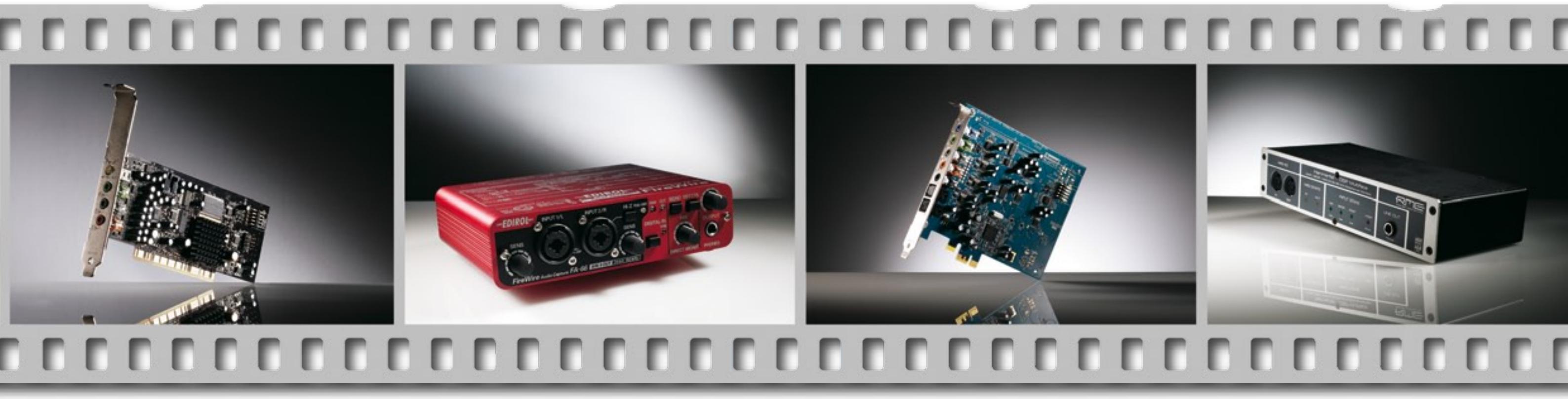
Rolf Hähle

Modern sound cards are fitted with A/D and D/A converters that a few years ago could only be found in top-end measuring instruments. This makes it quite tempting to use a sound card for audio equipment measurements, especially as it fits quite nicely in the Windows environment. However, it takes more than good converters to make a good instrument, as we all know. Our test shows how well a number of sound cards score with real signals.

There is a wide variety of sound cards available. There are sound cards oriented to the needs of musicians, which are designed for connection to an electric guitar or a microphone. This naturally requires large jack sockets or XLR connectors, makes balanced inputs desirable, and of course requires adequate amplification because the input level is only a few tens of millivolts.

Cards for home users are naturally quite different. Here Cinch connectors or small phone jacks are suitable because the cards are intended to be connected to a stereo system, a home cinema system, or an iPod. There is practically no need for signal amplification, since the available signal sources supply signals in the range of several hundred millivolts to several volts (CD players), which lies at the upper end of the typical input voltage range of an A/D converter (2.5 V). A few decibels of additional gain – to improve the signal to noise ratio – are only helpful if you want to use signals from portable MP3 players. And if you want to finally realise your long-cherished ambition of digitising your collection of LPs, an integrated preamplifier is also a good idea.



The third category consists of internal sound cards (with the emphasis on *sound*), which are optimised with special drivers and DSPs to reproduce the artificial sound worlds of modern computer games as impressively and 'surround-ingly' as possible. Here 'optimised' means offloading the computational work necessary for sound generation from the CPU. Although the cards in this category have inputs for external signals, the main focus is on the software side and reproduction of multichannel digital signals (keyword: Dolby Digital).

Several types of cards are available in all categories: internal cards and cards with their own bus interface for connecting external devices via an external breakout box, USB (common), or FireWire (relatively rare). The price structure is rather clear: internal cards are the least expensive, with the price rising (sometimes quite distinctly) if an external breakout box is included, and external devices are usually even more expensive. With the latter type, the price is proportional to the elaborateness and robustness of the enclosure. Unfortunately, the price is not always a good indicator of the quality of the technical specifications.

Measuring setup

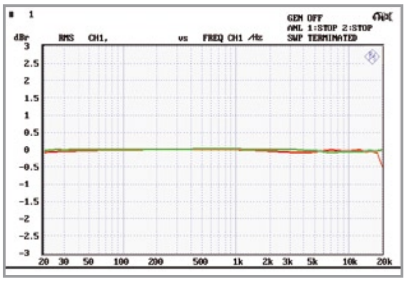
As we wanted to measure the performance for conversion in both directions, part of the test consisted of sending the same test signals (16-bit, 44.1 kHz) from the hard disk to all the cards. The integrated sample rate converter comes into play automatically with all cards that operate at a different clock rate. Its good or not-so-good properties thus contribute directly to the results of the measurements on the reproduced signals.

In addition, all cards were given an opportunity to convert analogue test signals at their maximum resolution and sample rate, using signals supplied by a CD player and a fairly good preamplifier. The preamplifier was used to adjust the signal level to best match the individual input sensitivity of the device under test. The measurements were made on the resulting reproduced signal. Our measuring instrument was a Rhode & Schwarz UPL, which combines a low-distortion generator and a two-channel analyser. We relied on a program used in professional sound studios for recording and playback, which can confidently be assumed to have no problems dealing with one- or two-channel signals: Wavelab from Steinberg, a producer of professional audio software. Almost all of the tested cards were supplied with an ASIO driver as well as a Windows driver. As the ASIO architecture was defined and developed by Steinberg, Wavelab is naturally well positioned to use it to access all available card functions.

Assessment

All of the measured results are presented in a large table along with charts showing the frequency response for playback (red curve) and recording (green curve). Due to the differences in the configurations of the cards, breakout boxes and drivers, only very limited comparison of the measured values is possible. Some cards have a true preamplifier on board with a gain range of 60 dB, while others have only simple impedance converters or amplifiers with very modest gain.

As a result, using distortion level measurements to determine the maximum drive level was the least of our problems. Adjusting the signal to match the input sensitivity was even more difficult because there are lots of places in Windows where the level can be adjusted. This difficulty can only be avoided – with regard to measuring the level, that is – if an ASIO driver is used to control the card. This makes the card practically invisible to Windows, because it cannot make head or tail of the Steinberg ASIO driver architecture. At least not yet – we'll have to see what happens when the patents expire next year. Maybe Microsoft will surprise us then with a new service pack including ASIO drivers.



AuzenTech X-Fi Prelude 7.1

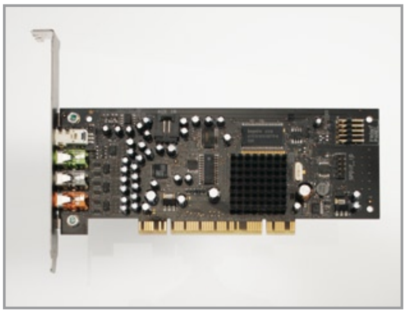
When you first see the package, you might get the impression that the Prelude is a Creative product. This is in good part due to the prominently displayed X-Fi logo, which is rightfully present. AuzenTech (Santa Clara, California) is the first licensee of Creative's X-Fi-CA20K sound processor that has developed its own card. The card that emerges from the box makes a distinctly good impression. The high component density and high-quality SMD electrolytic capacitors testify to attention to maintaining a stable supply voltage, and the audio amplifiers are among the better types.

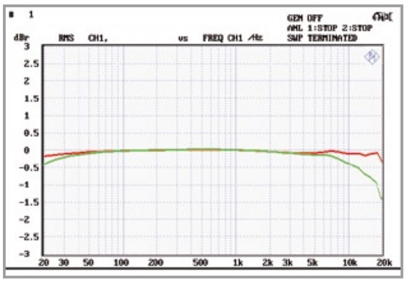
Aside from 64 MB of RAM available exclusively for audio purposes, the card is fitted with a 24-bit, 96-kHz A/D converter (AK5394A) and four 24-bit, 96-kHz D/A converters (AK4396). These ICs from Asahi Kasei Microsystems, which is a respected name in hi-fi circles, offer a signal to noise ratio on the order of 120 dB(A) according to the data sheet. The converters allow two analogue inputs and eight analogue outputs to be implemented. Input and output buffering are provided by high-quality operational amplifiers (TI OPA2134), and a socket-mounted (and thus user-replaceable!) National LM4562 opamp is fitted in the output stage for the front (stereo) channels. There's thus plenty of opportunity for DIY experimenting.

The card can accept signals at all resolutions from 16 to 24 bits and clock rates of 24, 32, 44.1 and 48 kHz. The included driver supports ASIO 2.0 at all resolutions and supports direct monitoring.

Two special 'Combo' Cinch sockets at the bottom of the mounting bracket provide the SPDIF input and output for coaxial and optical signals. A matching adapter for the customary TOSLink plug is included with the card.

The Prelude is a typical game and home cinema card and boasts all possible associated sound and surround effects, but they can easily be disabled under software control for high-quality audio applications.





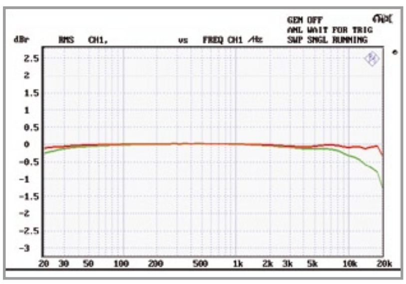
Creative SB X-Fi Gamer

The small Gamer from the Sound Blaster series is the first card from Creative in the test group. Like the other cards from this manufacturer, it is fitted with the X-Fi sound chipset developed in-house. The included driver is matched to this chip set and is the same for all of the cards. After the trouble-free installation of the included software, various modes can be selected on the audio console. We used the Audio Creation mode with all sound effect options disabled (bit-exact reproduction, no EAX, and no limiter) as the basis for our measurements.

The card can record and reproduce signals at all resolutions from 16 to 24 bits and clock rates of 24, 32, 44.1 and 48 kHz. The included driver supports ASIO 2.0 at all resolutions and supports direct monitoring.

The mounting bracket has only four 3.5-mm stereo jacks. All four of them are used for the 7.1 outputs, while one of them assumes the function of headphone operation and provision of the optical digital output. Additional inputs and outputs are only available internally: an Aux input via a 4-way pin header, a two-row header for SPDIF input and output, and a 2-by-5-way header for an Intel HD-compatible front panel.

Thanks to its low-profile format, the card is suitable for use in typical media centre PCs. In addition, the optical digital output can be use for connection to a home cinema system. With this configuration, the SB Gamer is a typical example of the game and home cinema category, and of course it supports the associated sound and surround effects. Most of the measured results score at the 'good average' level or above, but the linearity is hardly worthy of the name.



The charts show the frequency response for recording (green) and reproduction (red)

Creative E-MU 0202 USB

Several years ago, E-MU established a good reputation in the music world as a producer of synthesizers, and now it has been merged into the Creative fold.

The model 0202 is the smallest version of a series of USB sound cards with a pleasantly tidy plastic enclosure. The inputs and outputs are at the rear, while the controls, indicators and headphone output are at the front. The large number of connectors are a bit confusing at first, but a glance at the manual clears things up quickly. There are only two mono inputs and two mono outputs, which can be combined into a stereo input by pressing the Mode button on the front panel. Although outputs in the form of two 6.3-mm jack sockets (mono) and a 3.5-mm mini jack are present on the back, they supply the same signal. The small jack is thus a sort of built-in adapter.

The same holds true for the inputs: there are two large jack sockets (high-impedance mono) for two input signals, which can be amplified by 0 to 60 dB under the control of two potentiometers on the front panel (no detent position). For the microphone connection (with a 5-V phantom power supply), the left channel is implemented as a combined phone jack / XLR socket, with a small phone jack connected in parallel. Only a 6.35-mm phone jack is provided for the right channel.

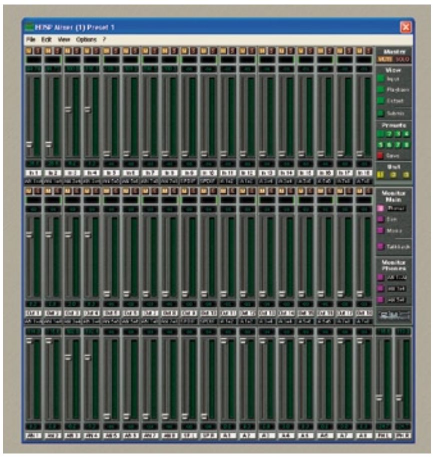
The volume control for the headphone is combined with a mechanical-detent on/off switch. All LEDs on the front panel light up briefly after the device is switched on, and when they go dark the 0202 is ready for use. A simple form of signal level indication is provided by a pair of LEDs for each channel. The green LED, which is labelled '–12', does in fact light up at exactly the transition from –12.1 to –12 dB, but the red 'Clip' LED lights up 3.8 dB too late.

During our measurements, we noticed that the E-MU rotates the phase when reproducing signals in 16-bit / 44.1-kHz mode but not in 24-bit / 192-kHz mode.

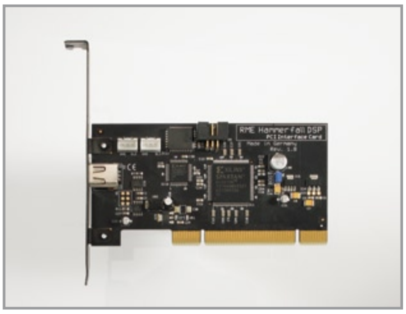
A level control is provided for direct monitoring. The two Ground Lift switches on the bottom of the enclosure (one for each channel) are a very convenient feature, which immediately proved to be useful during our measurements.

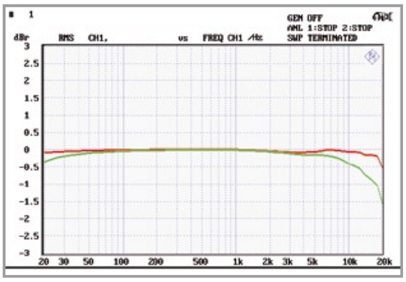
The included accessories, which have the largest scope of all the tested cards (five CDs, with Cubase LE and other music production software) include a Windows driver that installs without any trouble, but unfortunately no ASIO driver.

RME Multiface II Hammerfall

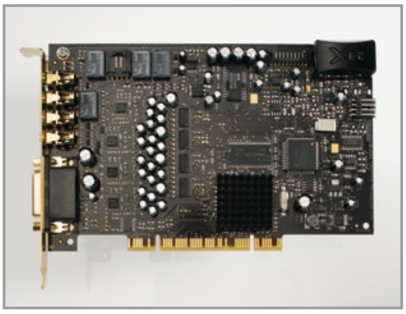


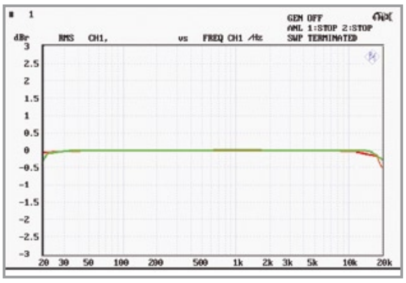
The only German manufacturer in the group unmistakeably aims its card at professionally oriented musicians, who are not put off by (in this case virtual) patch bays or matrix distributors and complex signal routing using Send, Return, or Pre- and Post-fade Listening.
The small PCI-bus card houses little more than the interface for the external breakout box, which goes by the name Hammerfall DSP Multiface II. The front panel of the very robust metal enclosure has MIDI In/Out and Line Out connectors. Eight analogue mono inputs and eight mono outputs are located on the back, all with large jack sockets, balanced, and operating at up to 24-bit resolution and 96-kHz clock rate. Other features that are at home in a professional studio environment are the ADAT, SPDIF, and Word Clock inputs and outputs. The separate high-power monitor output is at home everywhere.
The sheer scope of the configuration options in the software is enough to give an unwitting technician pause at first glance. The software generates two control panels: a matrix switch (HDSP Matrix) and a mixer (see screen shot) for the input, output, and effects path (16 channels). The user interface quickly proves to be pleasantly consistent and complete after you get used to the working method of a studio technician or musician.





The level indicator in the mixer should be used with a certain amount of caution. When the indicator shows 0 dB, the THD on the left channel is only 0.07% but the THD on the right channel is 0.15% (with the same mono signal input to both channels). However, the card can do much better than this – if you stay 0.12 dB below the maximum drive level as indicated by the display, the distortion levels are less than 0.007% and 0.005% THD for the two channels, respectively.
Aside from the aberration in the right channel, the Multiface has the best linearity of all the cards in the test. According to its own statements, RME is exceptionally satisfied with the current drivers, which are claimed to allow simultaneous recording and reproduction on all channels with 'zero CPU loading'. This means that this card should achieve the same performance in a laptop (for which a suitable PCMCIA interface card is available) as in a desktop PC.

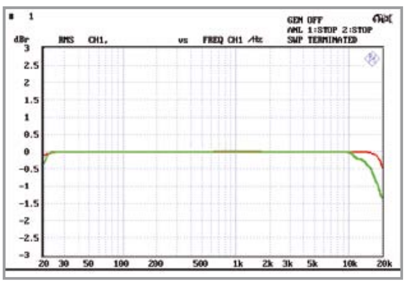




Creative SB X-Fi Elite Pro

The Sound Blaster X-Fi Elite Pro is Creative's top-end model for Xtreme Fidelity sound with a PC. The card configuration on the mounting bracket is similar to the arrangement on the SB Gamer with four small stereo jacks. The main difference is a female D-Sub connector at the bottom that provides the link to the breakout box, otherwise known as the X-Fi I/O console. The console is a rather large, low box fitted with connectors and controls at the front and rear. Most of the knobs on the front can only be used to adjust the intensity of the various sound effects (EAX, Crystalizer and CMSS 3D function for surround sound with headphones), but the gain of the built-in guitar and microphone inputs can be adjusted with the two leftmost knobs. The large knob at the other end acts as a volume control, and it mutes all the outputs when pressed lightly. In addition to MIDI, optical and coaxial inputs and outputs, the I/O console incorporates a preamplifier for magnetic pickups.

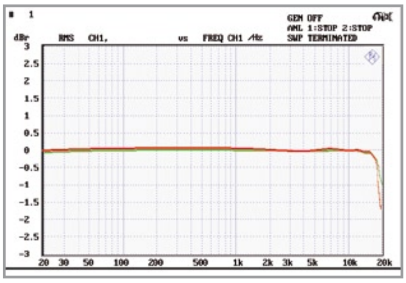
In Audio Creation mode, the card enables bit-exact ASIO recording at different sampling rates and low latencies down to 1 ms. With 24-bit effects, 24-bit SoundFont sampling and 3D MIDI, the Elite Pro (like the other Creative cards with the X-Fi DSP) is an all-round product for audio production and all types of digital entertainment with a PC. The console not only makes the essential analogue and digital connectors readily accessible, but also provides a certain amount of luxury with the included IR remote control



The charts show the frequency response for recording (green) and reproduction (red)

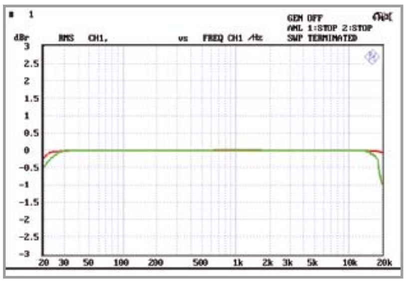
Terratec Producer Phase 22

Terratec calls this card – the smallest in its Producer series – 'Recording Interface', which clearly defines its target audience (as though there could be any doubt after you see the four large jack sockets on the mounting bracket). This product, which has a very robust mechanical construction for a PCI card, provides connections for two balanced signal sources and two balanced outputs. The included adapter cable, which implements the digital input and output and can be used for connection to MIDI equipment, mates with a D-Sub connector. The Phase 22 can handle recording and reproduction with 24-bit resolution and sample rates up to 96 kHz. This is also possible with digital recording, while reproduction of digital signals is possible at rates up to 192 kHz. The included driver CD has drivers for the entire Producer series, and driver installation is fast and easy. The card can be integrated into the system via WDM, MME or ASIO. Using the functions of the control panel is essentially intuitive, although the purpose of the 'Select' command is only clear if you know that the panel can be used to control and synchronise up to four cards in the same computer.



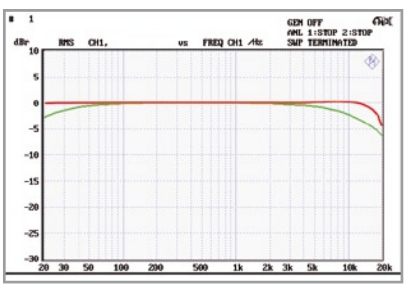
ASUS Xonar D2 7.1 Channel Audio Card

ASUS, the Taiwan-based producer of motherboards, marks its entry into the sound card business with the D2 card. This PCI card, which features gold-plated connectors and a gold-plated mounting bracket, has a conspicuously top-end appearance. All analogue connections are made using 3.5-mm stereo jacks on the mounting bracket. Cinch sockets – also gold-plated – are provided for the digital input and output. The component side of the board is almost completely covered with a black anodized aluminium sheet, which is intended to provide electrical screening. This makes it ideal for show-offs in the case-modding scene. This becomes abundantly clear after you install the card and switch on the computer: instead of using the typical colour coding arrangement for the connectors, ASUS has built LEDs with the appropriate colours into the connectors. The back of the computer thus presents a quite colourful appearance.
The included accessories are noteworthy: there are four Cinch to 3.5-mm phone jack adapter cables, an optical fibre cable with a Cinch adapter, and a separate mounting bracket with a MIDI connector and a matching adapter cable (mini DIN to MIDI). There is also an extensive software package for musicians. Electronics types will probably be more interested in the Right Mark Audio Analyzer (RMAA) program (version 5.5), which can be used to make measurements on the sound card and other audio signal sources. The user’s guide is very well organised, but it shows little more than all imaginable options for connecting loudspeakers, microphones and headphones.
ASUS uses an AV200 audio IC on the card, which is supposed to be able to operate at up to 192 kHz and 24-bit resolution in full-duplex mode, even with 7.1 reproduction. Signal conversion is handled by four 24-bit D/A converters (Burr-Brown PCM 1796) and a 24-bit A/D converter (Cirrus CS 5381). A matching ASIO driver for the D2 card is available from ASUS.



Roland Edirol FA-66 FireWire Interface

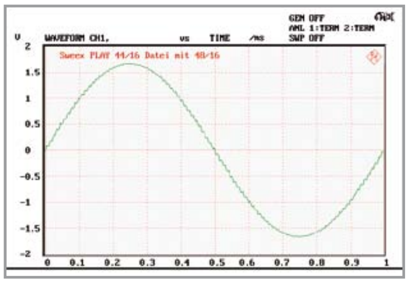
The compact FA-66 from synthesizer professional Roland, which makes an especially robust impression with its red aluminium enclosure, is also clearly tailored to the needs of musicians. The XLR/phone jack combo connectors on the front panel accept two balanced mono signals, which can be amplified by up to 60 dB using two potentiometers located conveniently close to the connectors. This is sufficient for everything from low-level microphone signals (even including condenser microphones, since the FA-66 can provide a solid 48-V phantom supply voltage) to line-level signals. Overdrive conditions are indicated by a Peak LED for each channel. The device can be powered via the FireWire connection to the PC or from an external AC adapter. There is a selector switch on the rear for this purpose, as well as switches for the phantom power supply, the sampling rate, and a limiter (which is certainly practical for a musician). Roland clearly appears to prefer slide switches and buttons to mouse clicks. As a result, using the Edirol quickly becomes second nature. If something is too loud or too soft, it can almost always be corrected with a single adjustment. The card can handle simultaneous recording and reproduction in 24-bit, 192-kHz format with up to four inputs and four outputs at the same time. The clock rate only has to be reduced to 92 kHz with six or more channels. The reproduction frequency response is the best of all the cards in the test group, and the output impedance (50 Ω) is also the best. The distortion figures are good. The only thing that prevents the Edirol from receiving an all-round recommendation is the linearity error, which is hardly tolerable for measuring purposes.



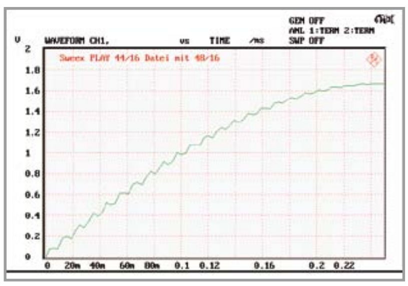
The charts show the frequency response for recording (green) and reproduction (red)

Sweex External Soundcard 5.1 (SC004)

The Sweex card is housed in a handy, small plastic case fitted with mini jacks all round. There are two microphone inputs on the left side and an optical SPDIF input/output (TOSLink) connector on the right side. The front panel features the Line In connector, headphone output, and four more outputs (including stereo) with 3.5-mm mini jacks. Three status LEDs and four buttons on the top round out the configuration.
The test computer recognised and linked the Sweex as a USB audio device without any need to install any sort of software. The card uses a C-Media chipset, and the driver on the included CD-ROM accordingly integrates the card in the system as a MME-WDM C-Media USB device and offers a demo that shows off the various surround-sound modes. Operation with Wavelab was equally problem-free.



The recorded and reproduced signals can be muted with the buttons on the top of the unit. The master volume control in the Windows mixer can also be controlled using these buttons in order to increase or reduce the volume.
The red LED on the top of the enclosure blinks when the card is reproducing a signal. With reference to its input and output, the Sweex is a sort of 0.9-dB attenuator, and it can only handle the 48-kHz, 16-bit operating mode. The rating for reproduction of square-wave signals and needle pulses, which is indicated as ‘poor’ in the table, does not relate to the waveform – which is essentially OK – but instead to the high level of clock-signal mixing products that are superimposed on the signal.



Reproduction of the standard files recorded at 44 kHz with 16-bit resolution using the internal 48-kHz clock of the Sweex unit shows a wealth of overshoots in the quantization steps of the output analogue signal, which can be seen in the two charts.

Summary

On average, the measured results are quite reasonable. However, none of the tested cards received top scores for all of the measured parameters. Either the noise level was too high, the distortion too large, the frequency response too modest, or the linearity miserable. Although almost all measuring programs for audio equipment can minimise the effects of frequency-response errors, linearity error unavoidably affects the accuracy (or lack thereof) of the measurements. Consequently, cards that score poorly in this area should not even be considered.

Without the linearity aberration, the Multiface II from RME would have clearly emerged as the top-rated card, but instead Terratec's Producer Phase 22 moved into the top spot, followed closely by the E-MU 0202 and the ASUS Xonar.

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Quantisation noise

As A/D converters naturally have a finite resolution, rounding errors unavoidably occur when analogue signals are sampled. This sort of digitisation error is equal to the difference between the digital representation of the converted analogue signal and the actual magnitude of the analogue signal at the sampling time. This error fluctuates over time and is thus perceived as noise, which explains its name. The signal to quantisation noise ratio (the ratio between the signal level and the quantisation noise level) is usually expressed in dB.

Aliasing distortion

If an analogue signal – such as a music signal – contains components at frequencies equal to or greater than half the sampling frequency of the A/D converter, low-frequency artefacts (alias frequencies) are generated during conversion, and they cannot be removed from the analogue signal by any sort of computation during conversion back to an analogue signal. Aliasing distortion can be measured by converting and back-converting a known, constant signal. After this, it is only necessary to compare the original and reproduced signals.

The Windows mixer

The software mixer built into Windows should be used with caution. Its unpleasant effect on the signal can be seen clearly by taking the Sweex USB Soundbox as an example. With the volume control set to the maximum level, the box supplies an output voltage of 1.553 V with an input voltage of 1.73 V, accompanied a moderate distortion level of 0.028%. If the level control of the Windows mixer is adjusted to reduce the output level to only 100 mV, the distortion rises to 0.11% THD, which is a factor of 4 larger.

With a more common input voltage of 775 mV, the effect is even more pronounced (a factor of 7).

Latency

The term 'latency' refers to the delay arising in the sound card due to the processing of the data. A sound card takes a certain amount of time to digitise the analogue signal applied to its input and supply the resulting data to the computer for further processing. Similarly, it takes some time for a signal from the PC to pass through the D/A converter and appear at the output of the sound card. The latency is primarily a consideration with music software, such as VST instruments, since the delay between pressing a key on a virtual keyboard and the time when the resulting sound appears at the output of the sound card should be reasonably short.

As even the most advanced computer cannot do everything at the same time, sound cards use a buffer (intermediate memory) for signal output. Otherwise the digital processing steps would be audible in the form of noise. The smaller the buffer, the faster the signal arrives at the output, but the demands on the driver also increase accordingly. Similar considerations apply to signal input.

Windows XP comes with drivers for sound cards, which are called MME (for Multi Media Extension) drivers. In many cases, these standard drivers increase the latency. You should expect latencies of around 750 ms.

Even more problems occur with Windows Vista due to its different driver structure, which creates severe problems for developers of computer games in particular because it prevents direct access to sound effects that are only available in hardware. Steinberg (www.steinberg.net) introduced a new standard called 'ASIO 2' in 1999. ASIO stands for 'Audio Stream Input/Output'. The main objective of ASIO drivers is to increase the speed of the sound card or reduce its latency. For example, they include 'direct monitoring' mode, which allows the signal on the input to be linked directly to the output without requiring the input signal to first pass through the entire signal-processing chain (Windows, driver, etc.). However, this is only possible if the hardware is compatible with the ASIO 2 standard.

To keep the delay as short as possible (unfortunately, it cannot be eliminated entirely), you can experiment with the buffer settings. Naturally, the smallest achievable latency depends on the sound card, but also on the drivers and the raw processing power of the PC. The actual latency is thus determined by the selected settings. If you minimise the latency, problems may occur with the reproduction of multichannel sound, even if stereo reproduction works OK. If this happens, you must increase the latency slightly and select a larger buffer size.

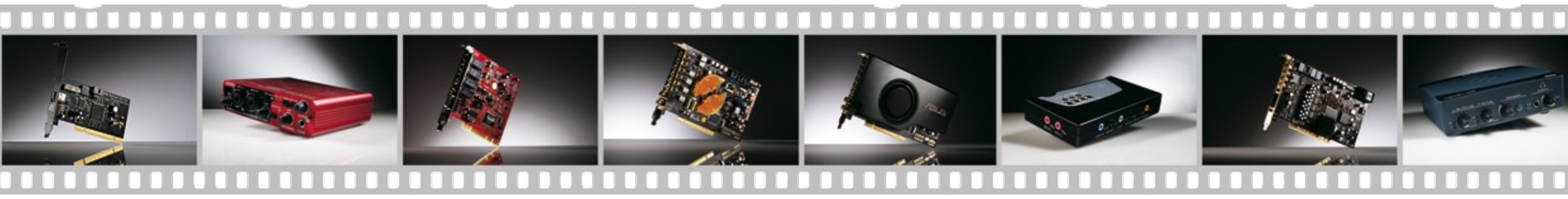
Delays of less than 10 ms are not humanly perceptible. There are now especially fast cards available that advertise latencies of only around 0.3 ms. To give you an idea of what this means, sound waves in the air travel only 10 cm in 0.3 ms.

The main conclusion here is thus that an ASIO driver is essential for low latency. Depending on the hardware that you use, you may then be able to reduce the delays so far that they are no longer audible.

Thijs Beckers

		Typical Value *	AuzenTech	Creative	Creative
			X-Fi Prelude 7.1	**SB Xtreme Gamer**	**E-MU 0202 USB**
Manufacturer website			www.auzentech.com	www.creative.com	www.creative.com
Price (high-street price)			£ 145 (€ 180) and up	£ 55 (€ 70) and up	£ 80 (€ 100) and up
			L ch / R ch	L ch / R ch	L ch / R ch
Reproduction of .wav file from hard disk, analogue out (D/A converter)					
Frequency response; max. level deviation 20 Hz___20 kHz	dB	0.2..1	–0.1 __ –0.5	–0.2 __ –0.4	–0.1 __ –0.4
Square-wave / pulse response			Poor / Poor	Poor / Poor	Mediocre / Poor
Distortion, 400 Hz at 0 dB	%	0.2..5	0.0046	0.006 / 0.003	0.076
Distortion, 400 Hz at –60 dB	%	0.2..5	0.26	0.07	0.11
Aliasing distortion at –30 dB	%	0.03..1	0.012	0.012	0.18
Converter linearity; max. deviation	dB	0.5..5	0.1	4.3	1.3 / 0.1
SNR at digital zero	dB(A)	106..88	99 / 107	92 / 98	88 / 109
Quantisation SNR, 400 Hz / 0 dB	dB	95..77	95	90 / 93	87 / 98
Recording via analogue input; analogue in/out (A/D converter)					
Frequency response; max. level deviation 20 Hz___20 kHz	dB	0.2..1	0 __ –0.1	–0.4 __ 1.4	0.3 __ –1.4
Square-wave / pulse response			Poor / Poor	Poor / Poor	Good / Good
Distortion, 400 Hz at 0 dB	%	0.2..5	0.0036	0.012 / 0.006	0.009 / 0.006
Distortion, 400 Hz at –60 dB	%	0.2..5	0.4 / 0.3	0.06	0.18
Aliasing distortion at –30 dB	%	0.03..1	0.018	0.012	0.19
Quiescent SNR	dB(A)	95..86	96 / 106	94 / 97	83 / 96
Quantisation SNR	dB	95..77	89 / 91	90 / 92	83 / 90
Converter linearity; max. deviation	dB	0.5..5	4.6	3.5	2.1
Input/output characteristics: maximum signal level, analogue in / analogue out					
Input sensitivity	mV		955	2.28	2.4 V (2120)
Input impedance	kΩ	50..10	4.1	0.036	2.05
Output voltage at 0 dB	V		3.52	2.26	2.2
Max. channel deviation	dB	0..0.2	0.03	0.1	<< 0.1
Output impedance at 1 kHz	kΩ	0.2..3.2	0.222	10.85	0.556
Configuration					
PC interface			PCI bus	PCI bus	USB 2.0
Analogue inputs			2 Mic / 2 Line (mini–jack)	2 (jack) / 2 internal Line via 4–way Molex conn.	2 (mono jack / mini–jack / XLR)
Analogue outputs			7.1 / 3.5–mm mini–jack	7.1 / 3.5–mm mini–jack	2 (mono jack and mini–jack)
Digital inputs			1 (optical/coax)	Internal	–
Digital outputs			1 (optical/coax)	Yes / Combined with Mic/Line stereo input	–
Breakout box connector			Yes, internal	–	–
MIDI In/Out			–	–	–
Headphone output			Yes	Yes	Yes
Max. Sampling rate for recording			96 kHz	96 kHz	192 kHz
Max. Resolution for recording			24	24 bits	24 bits
Remarks			• Socket-mounted output opamp 64 MB X-RAM	• Intel HD-compatible front panel header (2x 5-way)	• Headphone preamplifier with front-panel level control • Direct monitoring with front-panel level control • Clipping indicator

* Blue = better; red = worse



RME	Terratec	ASUS	Edirol	Sweex	Creative
DSP Multiface II	**Producer Phase 22**	**Xonar D2**	**FA-66**	**External Sound Card 5.1**	**SB X-Fi Elite Pro**
www.rme-audio.de	www.terratec.net	www.asus.com	www.roland.com	www.sweex.com	www.creative.com
£ 520 (€ 650) and up	£ 65 (€ 80) and up	£ 95 (€ 120) and up	£ 240 (€ 300) and up	£ 15 (€ 20) and up	£ 170 (€ 210) and up
L ch / R ch	L ch / R ch	L ch / R ch	L ch / R ch	L ch / R ch	L ch / R ch
–0.1 __ –0.5	–0.1 __ –0.5	–0.1 __ –1.7	–0.2 __ –0.1	–0.1 __ –5	–0.1 / –0.5
Good / Good	Good / Good but 180°	Good / Good	Good / Good	Poor / Poor	Poor / Poor
0.003	0,0037	0.0039 / 0.0028	0.009	0.025	0.07 / 0.04
0.3 / 0.2	0.45 / 0.19	1.1 / 0.6	0.6 / 1.2	0.8	0.4 / 0.8
0.012	0.012	0.012	0.04	0.15	0.011
0.1 / < 0.1	0.5	1.3 / 0.2	4.6	4.6 / 1	0.2
100 / 109	93 / 109	90 / 103	91 / 82	76 / 96	100 / 90
96 / 98	90 / 98	84 / 89	87 / 78	85 / 87	82
–0.3 __ –1.5	–0.3 __ –1.3	–0.1 __ –1.2	–0.5 __ –1	–2.7 __ 6.4	–0.2 / –0.2
Good / Good	Good / Good but 180°	Good / Good	Poor / Poor	Poor / Good	Poor / Poor
0.007 / 0.003	0.006	0.07	0.013	0.09	0.1 / 0.09
0.5 / 0.3	0.4	0.8	0.9 / 1.8	1.4	0.3 / 0.6
0.01	0.012	0.011	0.04	0.16	0.011
95 / 98	95	94 / 95	89	83 / 93	76 (Master: 109)
88 / 90	91	88 / 90	84 / 77	81 / 89	93 / 81
0.4 / 3	1	1.1 / 0.4	6	2.4 / 0.3	–6.2
3650	290 (2.343 V w/o boost)	2020	45	1730	529
7.5	94.85	3.83	21.2	5	46.9
3.468	2.16	2.012	2.3	1.17	1.63
<< 0.1	< 0.1	0.1	< 0.1	< 0.1	< 0.1
0.05	0.08	0.098	1.028	0.001	35.8
PCI bus / PCMCIA	PCI bus	PCI bus	FireWire	USB 2.0	PCI bus
8 (6.3–mm jack socket)	2 (mono, balanced, large jack socket)	2 Line / 2 Mic, via 3.5–mm mini–jack	4 (mono, Combo/Cinch)	2 (3.5–mm jack)	2 Line / 2 Mic, via 3.5–mm mini–jack
8 (6.3–mm jack socket)	2 (mono, balanced, large jack socket)	8 (via 3.5–mm mini–jack)	4 (mono, balanced, jack socket)	7.1 (3.5–mm jack socket)	7.1 / 3.5–mm mini–jack
1 (optical/coax)	1 (coax)	1 (Cinch/optical combo socket)	1 (optical)	1 (optical)	1 / 1 (optical/coax)
1 (optical/coax)	1 (coax)	1 (Cinch/optical combo socket)	1 (optical)	1 (optical)	1 / 2 (optical/coax)
	–	CD / Aux	–	–	Yes, on mounting bracket
Yes / Yes	Yes (5–way DIN socket)	Yes / Yes	Yes / Yes	–	Yes / Yes
Yes	–	Yes	Yes	Yes	Yes
96 kHz	96 kHz	192 kHz	192 kHz	48 kHz	96 kHz
24 bits	24 bits	24 bits	24 bits	16 bits	24 bits
• Headphone preamplifier with front-panel level control • Selectable input sensitivity Misc. status LEDs		• Illuminated colour-coded connectors	• Front-panel headphone output with level control • Direct monitoring with front-panel level control • 48-V phantom power supply	• Control buttons • Status LEDs	• Front-panel headphone output with level control • Equalisation preamplifier for MM phone cartridge • Remote control

SAPS-400

a 'powerhouse' switch-mode supply for audio amps

Sergio Sánchez Moreno (Coldamp, Spain)

The switch-mode power supply unit (SMPSU) is renowned for its efficiency but notorious for its design complexity, compared with its predecessor the linear supply. With the SAPS-400 we offer a powerful, adjustable symmetrical supply that's ideal for lightweight audio power amplifiers and happily sits in less than a quarter of the space taken by a comparable supply of conventional design.

In a fit of curiosity, if you open a piece of mains-powered modern electronic equipment, you will almost certainly find that it contains a switch-mode power supply unit (SMPSU). PCs, laptops, TVs, DVD players, set-top boxes, etc. routinely rely on this kind of power source for many reasons: low cost, high efficiency, low weight and small size are the main ones.

However when you look inside an audio amplifier, you will probably find a linear power supply unit (PSU), based on a large and heavy transformer (very often not as large as it should be to match the power rating of the amplifier!). There seems to be a traditional belief that switching power supplies (that do not operate at 50/60 Hz but at a much higher frequency, from 30 to 200 kHz, typically) are too noisy for those cherished amplifiers to produce a clean output, or that they don't behave correctly with wide-range dynamic signals, such as audio. A question arises here… then, why do you find switching PSUs in top-range high quality DVD players for example, that are very often the source of signal for our audio chains? In this case, things are even more critical, as all the signals involved have low amplitude and high impedance, hence in principle are more sensitive to perturbations.

Specifications

- 400 W continuous
- Symmetrical output voltage, adjustable between 35 V and 60 V
- Compatible with 100-120 and 200-240 VAC (50-60 Hz) line voltage.
- Auxiliary volatge 15 V symmetrical, 500 mA
- Short-circuit resistant
- Efficiency: 92%
- Dimensions just 90 x 150 x 40 mm
- Weight: 450 g

Motivation

However, some time ago the ideas arose that a switching PSU would be very useful and advantageous for powering medium to high power audio amplifiers, obviating the need for that enormous (toroidal) transformers commonly used so far. As an example, a typical Class-AB 400+400 W amplifier uses (or should use) a toroidal transformer of around 1.2 kVA that weighs nearly 7 kg, without taking into account the rest of supply components (the reservoir capacitors will be big, too!).

Some market research was done looking for suitable commercial switching PSUs, but the disappointing outcome was that the typical voltages needed (symmetrical rails in the range from ±30 V to ±100 V, with auxiliary smaller outputs) were not available, forcing the designer to use two units in series to get both rails, but within this range, only 48 V (±10%) is available, as it is commonly used for communications equipment. Even in that case, the rails showed a lot of noise and were not powerful enough to cope with the amplifier's dynamic current demand, leading to audible noise and poor bass response mainly, not mentioning the cost issue.

So finally it was decided that it was time to try and design a PSU, keeping in mind all the special requirements of an audio amplifier from the start: it should be capable of producing clean supply rail(s) with low noise, low ripple and regulate tightly even at high current demands. However, at the same time it must be able to operate efficiently and quietly at very low current demands, when there is low or no input signal. These requirements are often somewhat conflicting, requiring that the PSU operates correctly both in continuous and discontinuous modes (see the SMPSU theory article elsewhere in this issue) but it can definitely be done, and the PSU we present here has indeed demonstrated that a switching PSU for amplifiers are not only feasible, but also offers important advantages over standard linear supplies, not only in terms of weight, size or cost, but also in sound quality!

General description

The presented PSU offers an adjustable dual output from ±35 V to ±60 V with up to 400 W continuous power capability (up to 800 W music power), an efficiency above 92% for an input voltage range from 100 to 120 and 200 to 240 VAC. It is short-circuit protected and features an inrush current limiter, auxiliary isolated ±15 V at 500 mA aux. output, and EMI filtering (ElectroMagnetic Interference). SAPS-400 provides a clean and powerful sound with conventional Class-A, A/AB and AB amplifiers and also with more modern Class-D output stages.

SAPS-400's has a modest size of just 90×150×40mm, allowing it to be fitted inside 1-U 19-inch racks, and weighs around 450 g. It substitutes and even outperforms a complete linear PSU of at least 10 times its weight, 4 times its volume, and almost twice its cost.

The possible topologies to choose from are not that many, and not essentially different to the ones used for 'general-purpose' SMPSU. The PSU **must** be isolated for obvious safety reasons. Also, given the power level we are aiming to achieve (around 400 W), common sense and experience tell us that the choice is a half-bridge AC/DC converter. This is, indeed, the same topology used in almost every PC PSU, but the main differences are in the transformer, secondary circuit, control and feedback design.

Note that we are now talking about feedback: linear PSUs for amplifiers usually don't have any feedback. Due to the power level involved, designers usually don't even include linear regulators for stabilisation of the rails, so these tend to sag quite badly under load, unless vast amounts of reservoir capacitance are provided as the DC filter. Even in that case, any line voltage variation will produce the same percent of variation in the DC rails, causing a change in the amplifier's characteristics (power rating, mainly) when you plug it in in places with different line voltages.

On the other hand, the circuit we propose employs a feedback scheme to measure the output and compensate for line and load variations to provide as rigid as possible an output voltage, regardless (within limits!) of the line voltage and load variation. SAPS-400 can provide an output that is constant within 3-5% from no-load conditions to rated full DC load. Based on lab tests, this definitely translates in a cleaner sound, with deeper and tighter bass, as the PSU contributes significantly to have a low amplifier output impedance Z_{out}, resulting in higher damping factor ($DF=Z_{Load}/Z_{out}$), and hence more control of the cone excursion of the woofer.

Building blocks

Now, we will start describing the circuit. You can find the block diagram in **Figure 1**.

The basic operation is that of the half-bridge converter: once the AC voltage reaches the circuitry, it is filtered, fed trough some protection circuits, and rectified by a diode bridge. Then, the output is smoothed by a capacitor bank, so we now have a high-voltage DC bus.

This DC bus is split, generating a mid point $V_{bus}/2$, and switched by means of two MOSFET transistors through a high-frequency transformer. It has two main secondaries, plus two smaller ones. Due to its turns ratio, the two main secondaries produce a waveform that is equal to the primary voltage multiplied by the turns ratio and also depends on the duty cycle ($V_{out} \sim V_{in}, D, N_{sec}/N_{pri}$). The output of the secondaries (that are joined in a centre point that will become the amplifier's ground reference) is full-wave rectified and filtered by an *LC* network, then producing two symmetric DC voltage rails. The total DC voltage is sensed by a feedback network that includes an adjustable voltage reference, and optically coupled to the control circuit, that adjusts the duty cycle of both MOSFET switches, in order to increase or decrease the output, thus implementing voltage regulation.

The control circuit needs some power (12 V at 80 mA max.) to operate (as it is in the primary side of the circuit, this power is isolated from the output for safety reasons). It gets its power from the startup circuit first, and once the PSU has cranked up, from a special housekeeping regulator.

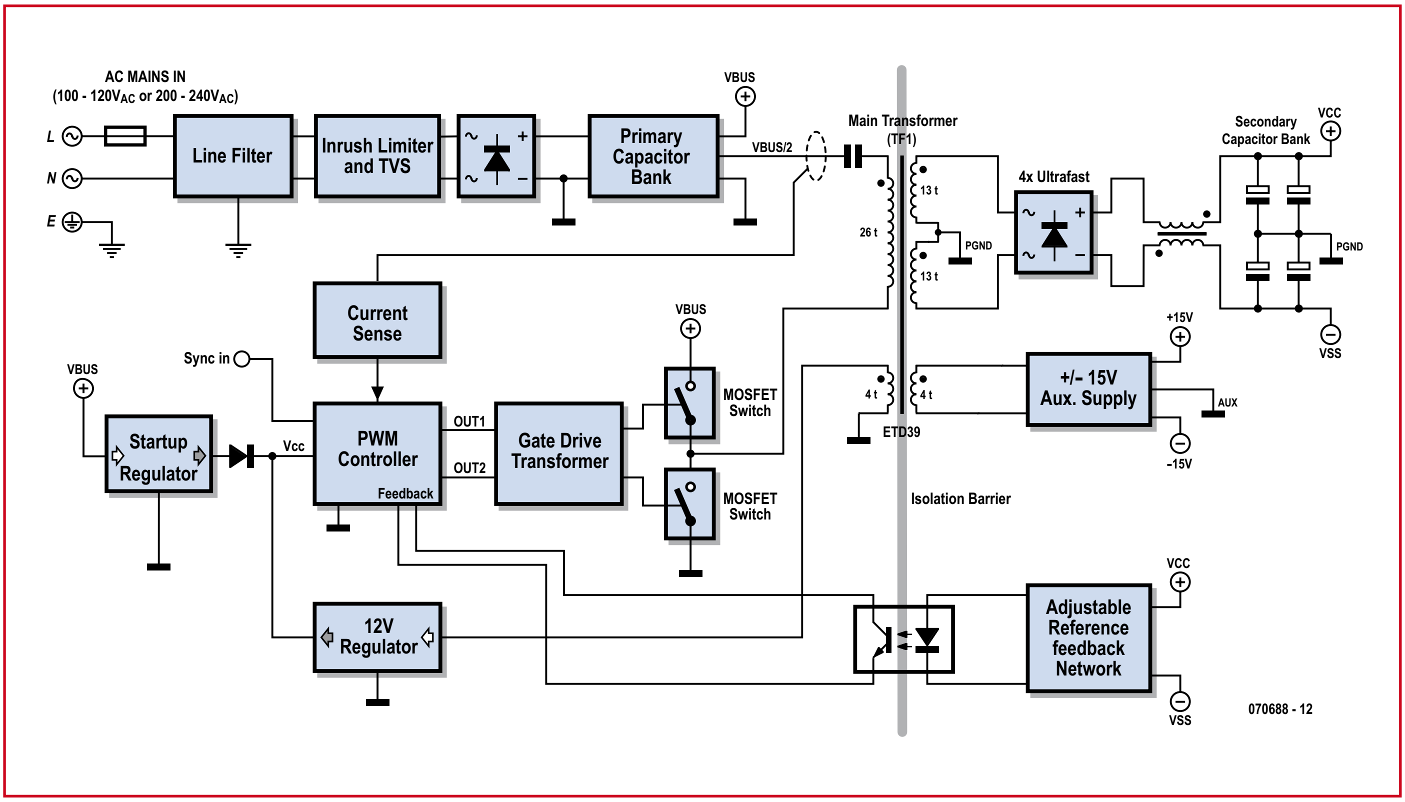
There is also another small winding that is half-wave rectified providing a symmetric and isolated ±15 V output, with a maximum current of 500 mA, very useful for preamplifiers, crossovers, controllers, etc.

Detailed description: input

The full schematic of SAPS-400 is shown in **Figure 2**. The mains input, connected to J1, passes through the protective fuse F1, then goes to the EMI input filter, formed by a common mode choke, L3, and a capacitor network. This filter suppresses the greater part of the switching noise, preventing it to travel back to the line. It also reduces gereneted RF noise that may upset the operation of the PSU. Note that C14, C17 and C18 are 'Y2' and 'X2' class capacitors. Capacitors connected directly to the live mains voltage must have this certification; the one connected between Line and Neutral (C18) must go short-circuited in case of failure, so the fuse opens and everything is safe. It must be Y2 or X2 class (the latter being smaller for the same capacitance). On the other hand, the ones connected to Earth are Y2 types, and should 'fail open' so no current is shunted to Earth, that you may possibly be touching. This way, electric shock is prevented even in case of component failure.

The component marked RT1 is a special NTC (negative temperature coefficient) resistor that has a moderate resistance at ambient temperature (around 10 ohms) which drops considerably when the temperature of the NTC increases. Its function is to limit high inrush current peaks caused mainly by the sudden charge of the large reservoir electrolytics when the PSU is switched on. Needless to say, this NTC must be rated for a large impulse energy and a proper continuous operating current, at least the maximum current expected at the input (worst case is up to 4 A with 100 VAC input). Once the PSU is working normally, the current flowing through it makes it hotter and present a smaller impedance, thus its effect in the circuit is negligible once equilibrium is reached.

You can also find a transient voltage suppressor (TVS1). Its function is to cut any voltages above its rated voltage (and thus absorb lightning strikes and fast high voltage transients). If the input spike has enough amplitude or duration, it may eventually cause the



Figuur 1. Block diagram of the SAPS-400. The bulk of work is done by the MOSFETs and transformer TF1; the control goes mainly on account of the PWM controller.

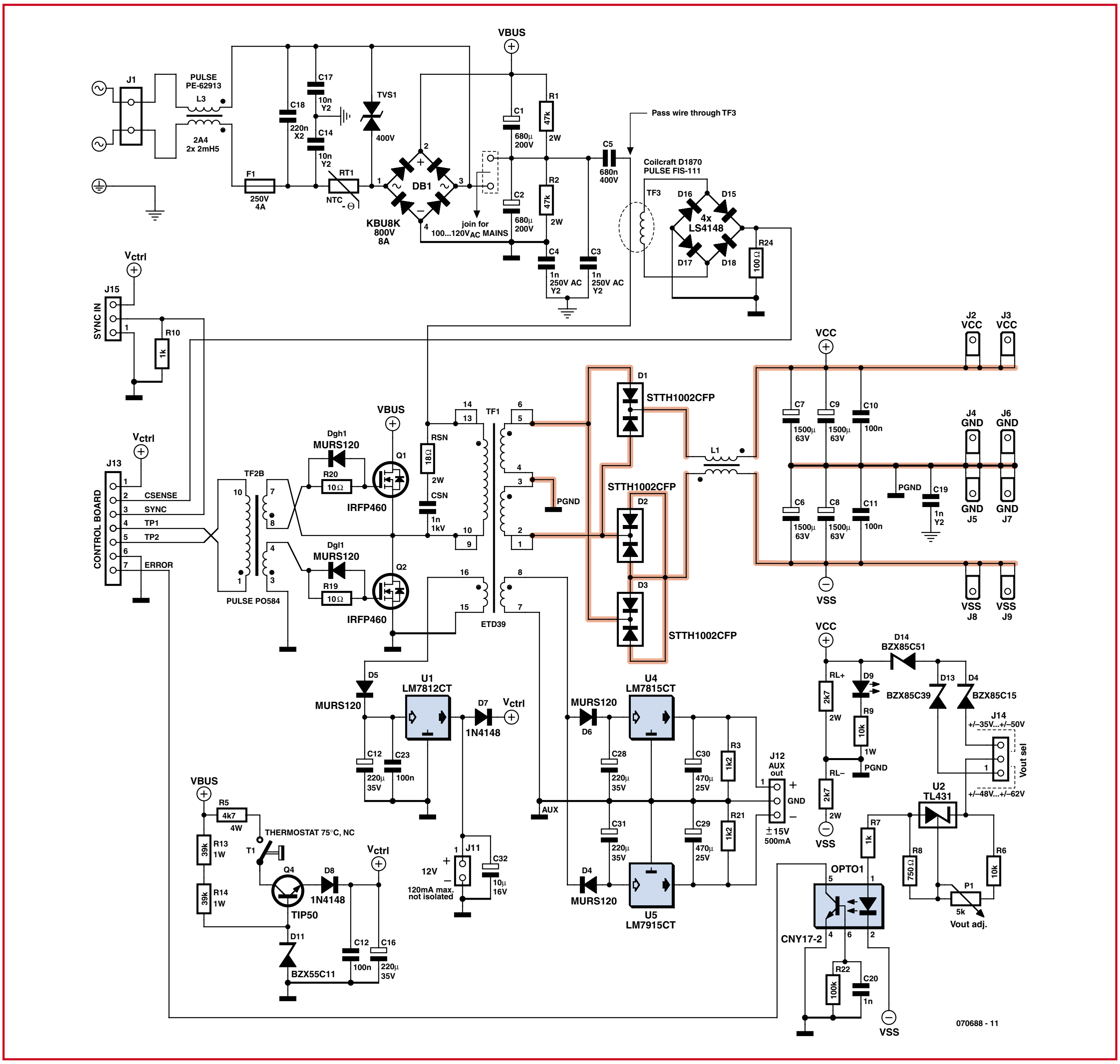


Figure 2. The circuit diagram shows the topology used, as wells as all added controls and protections.

fuse to blow, protecting the rest of the circuit. Note that this component is bidirectional; it clips positive and negative peaks whose instantaneous excursion exceeds the rated value.

Rectification and DC bus

After the filtering and protection circuitry, the AC signal is rectified by a diode bridge. Note that we are still operating at line frequency (50 or 60 Hz), so no need for fast diodes here! Only a part with a proper current and voltage rating has to be selected. In this case, we use an 800 V/8 A bridge, that is quite oversized.

The DC output is filtered by C1 and C2. These capacitors are in series, creating a midpoint $V_{bus}/2$. Two bleeder resistors (R1, R2) help in creating exactly half the bus voltage. This is a common arrangement to ease the implementation of a 'voltage doubler', that allows us to use lower mains (100 to 120 VAC). When this mains range is used, a switch or wire must join one of the AC inputs of the bridge to $V_{bus}/2$, thus doubling the voltage on the bus (that would otherwise be only 140 to 170 VDC approx.). The points to join for 100-120 VAC mains are marked 'A' and 'B' on the PCB.

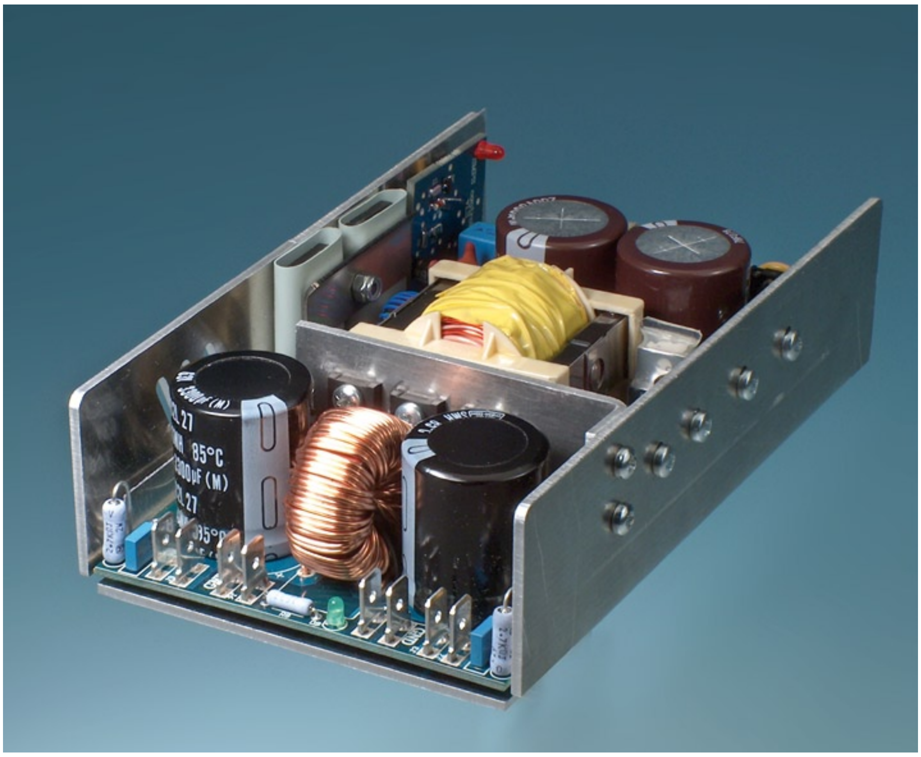
Note that the connection between A and B must not be made if the circuit is to operate from a mains voltage higher than 120 VAC. Erroneuosly doing so may end up with a bus voltage of up to 240 V×1.414×2 = 678 V that would destroy the PSU.

So far, this is very similar to the secondary part of a linear PSU! We now have a bus DC voltage equal to the peak of the input waveform. If we assume that the AC input waveform is more or less sinusoidal, the DC voltage will be $\sqrt{2}$ = 1.414 times the input RMS voltage: that is, for 230 VAC, we have around 325 VDC here! When loading increases, we will start to have the typical 100/120 Hz ripple here. The capacitor's size is designed so this ripple is under 30 V_{pp} or so at max. load. This will have little effect on the output, as it is regulated.

There is an important difference with regard to a conventional supply: the current involved in the primary side is much smaller for a given power than when rectifying in the secondary part, so bus capacitors are much smaller in capacitance than in a linear PSU, and hence the peak charging currents are also smaller. These peaks are the main source for the annoying 100/120 Hz 'buzz' noises, that won't be a problem now.

Primary power stage

The main transformer, TF1, has a single primary that's AC coupled to half the bus voltage ($V_{bus}/2$) by means of coupling capacitor C5. The other leg is connected to a half-bridge formed by two MOSFET switches, Q1 and Q2, that alternatively connect it to V_{bus} or 0 V.



It's worth saying that the MOSFETs are driven by a gate drive transformer (TF2B) with two separate windings; each one connected between gate and source, plus a gate resistor. This gate resistor has a diode connected in anti-parallel to speed up turn-off of the MOSFETs and further prevent cross-conduction (both MOSFETs on at the same time, leading to a dangerously large current). The primary of this transformer is driven by a high-current driver IC in the control board.

The main transformer sees no DC component (due to C5, that must be large enough to avoid excessive droop during the flat top and bottom of the square waveform), but an AC switching waveform that swings from $+V_{bus}/2$ to $-V_{bus}/2$). With this in mind, and reviewing the power capability we need, we can now start to choose a suitable core and bobbin. RF transformers for half-bridge converters are usually made with ferrite cores, and usually have no gap between both halves, as they are not required to store energy, as happens in flyback converters (limited to around 100 W and widely used for small adapters, chargers or TV HV stages).
In this case, we have chosen an ETD39 core. It can be checked in some references that its size (related to the W_aA_c parameter, where W_a is available core window area, A_c is effective core cross-sectional area) is enough for the 400 W we are aiming at, at a frequency >80 kHz in a half-bridge topology. Details on the calculations on the transformer are in the textbox. We proceed in the same way to calculate the number of turns for the housekeeping and aux. secondaries, keeping in mind the headroom required for the linear regulators (we design for an output of 18 V with the min. input, leading to four turns).
The physical design of the transformer is critical for the performance of the converter, and some guidelines are exposed here:
- We must have as low leakage induct-

ance as possible. That means as tight as possible coupling between primary and secondary and between windings and the core. To help this, we have split the primary in two parts, 13 turns each, and the main secondary is tightly wound between them. This is called 'sandwich winding'.

- The wire cross-sectional area must be enough to have low resistance and produce low copper losses at the power level we want. But we cannot simply use as thick as possible wire: *skin effect* is an effect that makes current flow only in the surface of the entire conductor when frequency goes higher. At 85 kHz, it is pointless to use wires above 1 mm dia. or so, so we will use two wires in parallel for the primaries and also for the main secondaries.

- Isolation and safety is a main concern. Under no circumstance may the primary and secondary wires be shorted. Moreover, a typically 3 kV voltage shouldn't produce an arc from one to another, that's why some distances and materials are defined. We use supplementary isolation (special triple insulated wire in the primary) and tubing in the ends so the proper creep distances and clearances are kept. Note that the primary and secondary pins are assigned to opposite ends of the coil former, so the PCB clearances can also be met (this PSU features 8 mm between primary and secondary, more than what regulation requires for this class of product).

- And… of course: we must be able to fit all the wires in the bobbin! This may seem trivial but it is not. This transformer has been tightly and tidily wound, otherwise it wouldn't fit.

There are many more considerations to be kept in mind during the design, such as Eddy currents, varnishing to avoid vibration or mechanical noises, etc, but these fall out of the scope of this description.

Secondary sub-circuit

Regarding the secondary part of the circuit, full-wave rectification has been used, with a central tap in the transformer that becomes the GND reference for the amplifier. Note that three dual ultrafast diodes have been used, as now we are rectifying a waveform of 85 kHz and standard-recovery diodes would have too high losses. It swings from up to 160 V_{pp}, so we have selected 200 V diodes. The worst-case average current that will flow through each diode is

$(P_{max} / 2) / 35\ V = 5.8\ A.$

We have selected 10 A diodes.
Following rectification, an *LC* filter is used. The coil has a function of storage of energy when there is no voltage switched to the transformer (when duty-cycle is below 50%), hence smoothing it with the aid of the capacitors, so it must have enough inductance. Typically used cores are made of ferrite or iron-powder.
We have wound both inductors on the same core (but with opposite directions as the voltages have opposite sign). This increases cross-regulation drastically (if they were not coupled, the voltage in one rail will drop and the other one will rise slightly if the current drawn is not balanced for both rails). Using a toroidal core also has the advantage of having a closed magnetic loop, thus providing little radiated EMI.
The capacitor bank (also present in linear PSUs), is designed in a different way in switching PSUs: capacitors are refreshed at 2 f_{switch}, which is far more than 100 Hz. This results in a much more constant output voltage (less voltage ripple) for a given total capacitance. For this reason, typical SMPSs can use output capacitors one or two orders of magnitude lower in capacitance than linear PSUs. However, for good reliability, the maximum ripple current rating must be high, and it is usually better to use two smaller caps in parallel than a single larger one, in terms of equivalent series resistance (that ultimately determines ripple current capability).
Additionally, despite the higher refresh rate of the capacitor bank, for audio amplifiers it is very important to have a great immediate energy reserve available right at the output terminals of the PSU. That's why we have chosen a relatively large capacitance, as opposed to other audio SMPS manufacturers. This also allows for a relatively slow but very stable feedback loop, while still keeping output quite stiff even with widely varying dynamic loads. This feedback loop is one of the keys in the design of a good (audio) SMPS.

Feedback, regulation and V_{out}

The total output voltage (from $+V_{CC}$ to $-V_{SS}$) is sensed with a resistor and selectable zener chain, plus an adjustable 5 V to 30 V stage built around the TL431 (U2), that sets a reference and drives an optocoupler photodiode.
The phototransistor is connected to the control circuit, providing the necessary information so it can control the duty

Transformer calculations

For the calculation of the primary, we should use the fundamental equation of the transformer flux density, identified for a square waveform that's related to the input voltage swing, frequency and section of the core:

$\Delta B = E / (4\times10^{-8}\times A_e\times n_{pri}\times f_{switch})$

or

$n_{pri} = E / (\Delta B\times4\times10^{-8}\times A_e\times f_{switch})$

where

E = peak voltage in volts;

A_e = effective cross-sectional area in cm²;

ΔB = the peak flux density in Gauss;

n_{pri} = the number of turns of the primary;

f_{switch} = the switching frequency in Hz.

We have to ensure the frequency is as close as possible to the desired value of 85 kHz. Too high a frequency, and you will have high core losses and switching losses in the MOSFET transistors. Too low a frequency, and you will have excessive flux density, also resulting in higher core losses and reduced power capability for a given core size, as well as bigger secondary-side components (inductors and capacitors). A conservative number for ΔB is around 1500 Gauss (0.15 Tesla) for Ferroxcube 3C90 material, at this frequency, producing around 2W core losses. Given that E is around 155V for 220Vinput (or 110VAC input using the proper voltage setting switch), this means that:

$n_{pri} = 155 / (1500\times4\times10^{-8}\times1.25\times85000)$

$= 24.31$ turns

≈ 25 turns.

We will split the primary in two halves making it 13 turns each, for a total of 26 turns. This allows for a somewhat higher voltage input and still have a low enough flux density. (with these numbers ΔB will change from 1300 to 1538 gauss from 200-240 Vac, or 100-120 Vac).

Now, we have to calculate the secondary turns. In order to do that, we take the worst conditions to have some margin for the controller to be able to produce the maximum required output voltage. For the minimal nominal input voltage (say 200 VAC or 100 VAC with proper setting), we'll have a total of 280 V bus voltage. Assume that we need an output voltage of max. 60 V, and that the controller can put a max. duty cycle of D = 45% (it needs some dead-time). Then the required number of turns for each secondary will be:

$V_{out} = V_{in}\times D\times N_{sec} / N_{pri}$

$= V_{in}\times D\times TR;$

$TR_{min} = V_{out\text{-}max} / (V_{in\text{-}min}\times D)$

$= 0.476$

so

$N_{sec} = 0.476 \times N_{pri}$

$= 0.476 \times 26$

$= 12.38$ turns,

we will round off to 13 turns per secondary.

(we should really ad up for the bridge rectifier drop, (two diodes drop around 1.4 V), and for the output rectifier drop, (two fast diodes drop around 1 V), but that's negligible compared with the input and output voltages and we have already provided some margin.

cycle of the switching MOSFETs and readjust the output voltage as necessary so it is kept constant. Besides improving line and load regulation drastically, this also allows us to tailor the output voltage to our requirements. It can be adjusted in two ranges (selectable by means of jumper J14 and fine-tuned with the aid of potentiometer P1), between ±35 V and ±60 V.

The feedback network and its compensation are also critical and the key to success in the applicability of this PSU to audio. We have kept the control board confidential as it is a key part of our technology, but its basic function can be understood quite well as a PWM controller with a feedback input and some protections.

Startup and housekeeping circuits

The control board needs 10 to 15 V at 70 mA approx. There is a start-up regulator, built around Q4, connected as an emitter follower with an 11 V zener acting as the reference at its base. This puts out around 10.3 V from an input between 300-350 V, with current limited by R5 to around 75 mA and connected through diode D8 to the control board supply. When the "housekeeping" supply (simply a 7812 12 V regulator fed from an auxiliary winding of the transformer) produces 12 V, D8 gets reverse-biased, so no current flows across Q4, and hence no dissipation is produced (apart from that of the biasing resistors of the base zener, R13 and R14).

If for some reason (failure, continued short-circuit, etc), the supply cannot start, R5 will warm-up until a thermally-coupled thermostat, T1, opens, preventing an overheating of the startup circuitry. If this happens, the supply won't start again until T1 closes; this may take several minutes, providing additional protection.

Overcurrent protection

The current that passes through the primary of TF1 is sensed by means of a high-frequency current sense transformer formed by a single turn primary and a 100 turns secondary (actually resembling a wire crossing a toroidal coil). When rectified by a fast diode bridge (D15 to D18) and loaded by a 100 ohm resistor, it supplies 1 V/A, and goes to a comparator inside the control board that triggers the protection for 2 seconds when the sensed voltage is higher than approx. 4 V (4 A primary current, equivalent to around 400 W at 100 VAC). Note that the overcurrent limit is only approximate and its main purpose is to make the PSU short-circuit proof.

Auxiliary ±15V supply

The auxiliary and housekeeping supplies are very similar, comprising a secondary of the transformer (that puts out around 20 V, as its number of turns is 4), followed by a half-wave rectifier and linear post-regulators (7812 for the house-keeping and 7815/7915 for the aux. ±15 V output).

If the aux. voltage needs to be extra-clean, an additional LC filter can be added at each output. A 10 to 100 µH inductor in series with the output, followed by a capacitor of 1000 µF to ground will do the job.

Note that this auxiliary supply is protected against overcurrent and overtemperature by the 7x15 regulators themselves.

Also note that AuxGND reference is floating, so it is NOT connected to the main output GND (you can do this if you need it), nor to mains EARTH.

Installation, operation at low output voltage, etc.

The PSU should be mounted on a flat aluminum base (such as a case for an audio amplifier), unpainted and totally clean, for proper thermal transfer. There won't be any problems with audio use regarding to temperature, as the PSU is very efficient, but if continuous power capability tests are made, it is important to provide some forced cooling to the transformer and/or output diodes.

In order to fix the PSU to a chassis with base thickness W (mm), use four M3 screws with a length between W+2 and W+4 mm, so it gets secure enough but doesn't touch the PCB bottom.

The power dissipation of the entire PSU with no load connected is around 5.5 W, including the output bleeder resistors.

The chassis must always be connected to mains Earth, as is prescribed for Class-I equipment. Use one of the screws near the input connector for that purpose.

Although this PSU has been specifically designed for symmetric output, it can still be used for single output, by taking the negative terminal from $-V_{SS}$ and the positive from $+V_{CC}$ (GND terminals must be left unconnected). This way, it can be adjusted from 70 V to 120 V.

If a lower voltage is required, please ask and we will help you determine if it is doable by simply changing one of the zener diodes or if some other part (such as the transformer itself) needs to be replaced.

Note that when working in the lower voltage ranges, the supply may produce some noise or even shutdown with no load, so additional bleeder resistors (there is one per rail, RL+ and RL–, already installed) may be needed, calculated so they dissipate around 1.5 W max. (if the idle consumption of the circuit you are trying to feed is not enough).

When debugging such applications, it is useful to carefully connect two wires to header J8 and measure with a multimeter. **WARNING**: J8 is **not** isolated from the mains, so respect all electrical safety regulations. Connect the PSU with no load, and the voltage shouldn't go lower than 11 V. If so, it needs additional loading to keep operating.

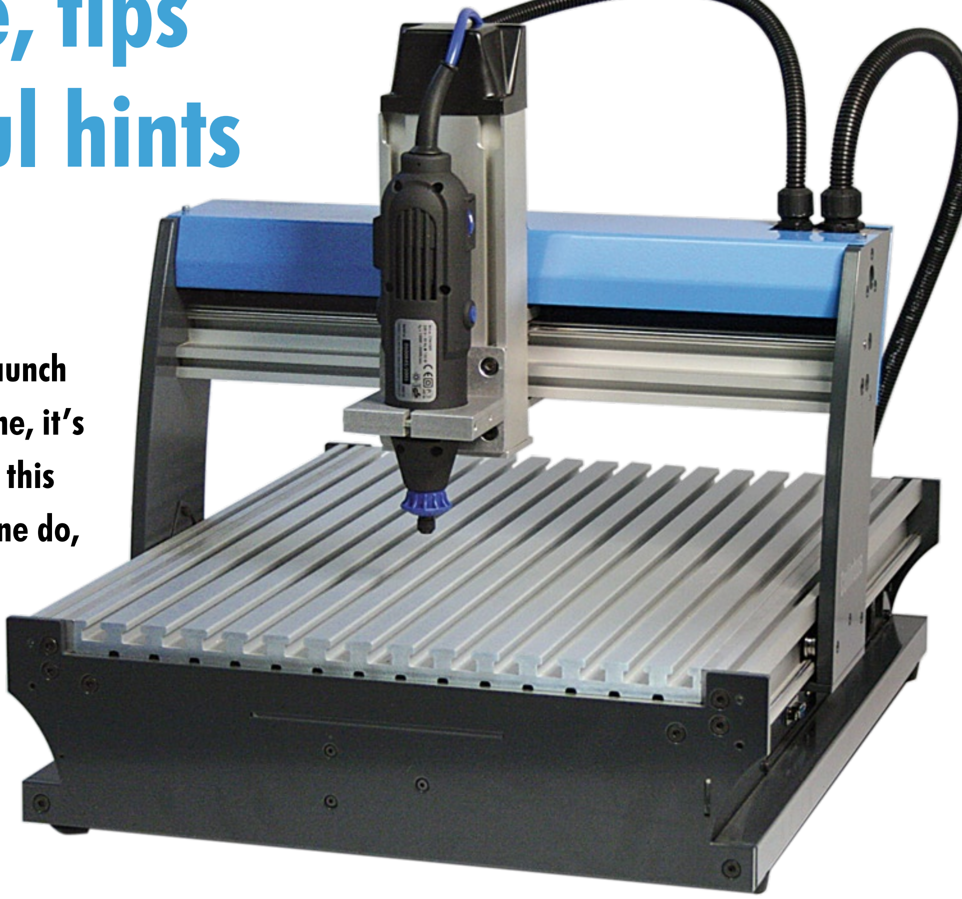
(070688-1)

Profiler Update

Experience, tips and helpful hints

Frank Jacops (Colinbus)

A year and a half after the launch of the Profiler milling machine, it's time for a brief look back on this project. What can this machine do, and what experience have its users acquired with it? We also want to mention a few tips and helpful hints here.



The Profiler projected initiated by Elektor in cooperation with Colinbus in January 2007 has proven to be an overwhelming success. At last there was an affordable milling machine available that could handle diverse jobs. Unfortunately, this machine proved to be more difficult to build and use that some of its purchasers expected. This led to a few unhappy users, especially in the early days. However, most users went to work enthusiastically and managed to produce true works of art with their Profiler within almost no time, which they exhibited on websites and in Elektor forums for the whole world to see.

In this article, we want to summarise the experience of the past one and half years and discuss a few important aspects of using milling machines in general and the Profiler in particular.

What did we have in mind?

The Profiler is a robust machine that is suitable for relatively substantial engraving and milling work. However, it has its limitations, just like all other machines on the market. What did people expect and what did they receive, what experience did users have with machine tools, and how much time were they willing to invest in making up for any lack of experience? Many of the early purchasers clearly had unrealistic expectations about how easy it is to use a milling machine of this sort, and they were thus disappointed with its capabilities or the results.

When we put together the Profiler kit, what we had in mind was the following: the design and construction of the kit must be clear, so that everyone with a bit of technical knowledge could easily assemble the machine. The resulting machine must be sturdy and sufficiently robust for machining light materials, and accurate enough for standard engraving work. In other words, it should be a general-purpose tool for model builders as well as electronic hobbyists.

The kit idea had one major advantage: the price could be reduced drastically. However, it had the immediate disadvantage that the ultimate quality of the product was determined by the builder. Within a few weeks after the launch, it became clear that this was a major factor. For example, quite early on there were a few dissatisfied customers who couldn't manage to put together a properly working Profiler, even after many fruitless telephone conversations and e-mail communications. They were invited to visit the Colinbus factory for personal assistance, and in most cases correct adjustment or better alignment turned out to be the answer to their problems. These users later proved to be the best promoters of the Profiler kit.

The included software

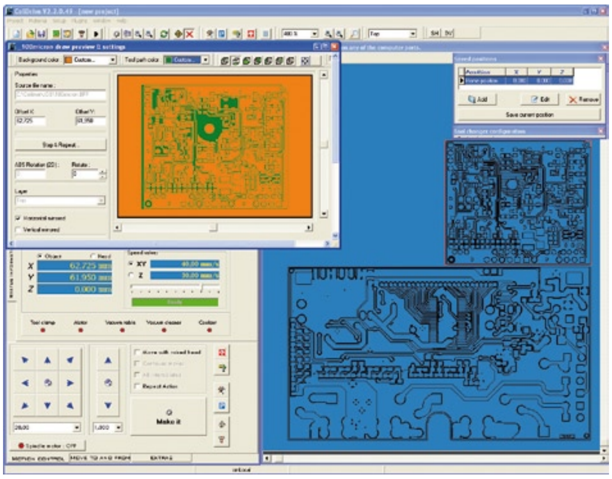
Two software packages are included with the Profiler as standard: ColiDrive [1] and ColiLiner. Both of them are derived from professional programs that have more to offer in terms of options and performance. The supplied versions are so specifically aligned to the needs of typical Profile users that every desirable function is available if the user has a bit of skill. You can import drawings for milling shapes and generate contours for milling prototype circuit boards. This works quite well, as can be seen on many user websites.

However, the customer support department of Colinbus received many questions, especially about the ColiLiner conversion program, which converts Gerber files into contours for the Profiler. The problems here had less to do with the supplied software than with the complexity of the Gerber standard. This format has a vast number of options and variants. Besides using the prescribed apertures, makers of PCB design packages can also use forms they create themselves, and they can work with different units at the same time. Given this situation, producing software that provides the right conversion at the press of button under all conditions is practically impossible. The problem files that Profile users sent to the support department were read in using a variety of Gerber viewers. Where one file might work perfectly with viewers X and Y but not with A and B, another file would work OK with A and B but not with X and Y. However, most of the viewers and ColiLiner had one thing in common: after a few minor adjustments to the settings, the right PCB always appeared on the screen. Unfortunately, adjustments of this sort require a certain amount of knowledge of the Gerber format or suitable patience. Once you have found the right settings for your CAD software, all subsequent files can be imported without any problems.

As the name suggests, ColiDrive is the software that you use to drive the machine. Unlike what some people mistakenly understood, it is not a CAM package with integrated control functions. As with most CNC machines, the idea is that ColiDrive receives machine code from a CAM package (ColiLiner is an example of a CAM package, but as already mentioned it is primarily designed for use in the electronics sector). Incidentally, with many CNC machines the users must write their own code, and this is also possible with ColiDrive.

As the number of delivered Profiler kits increased, it became clear that there was a strong need for direct data import capability. In hindsight, this is not surprising. Up until then, ColiDrive had only been supplied to the professional sector. In this sector, a machine is purchased for a particular purpose, and buying CAM software specifically made for this market is taken for granted. This is not the case with the Profiler. For this reason, a few weeks after the launch we decided to add an HPGL import function. As just about all commercial CAD packages can export in this format, with the inclusion of the import function it became possible to engrave or mill any desired shape without having to use a special CAM package.

Of course, you can do a lot more with real CAM software. A lot professional CAM packages have a postprocessor for ColiDrive. If you do not have this, it is very easy to write one yourself. The ColiDrive data structure is described in the document available at the following link: www.colinbus.com/profiler/commandset.pdf.



1

How to improve your Profiler

The spindle motor

When the Profiler was launched, the primary consideration was to supply a sound machine. To ensure that its owner could use also use it right away, the kit was completed with a simple spindle motor and an MDF base plate. This is a

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good solution for experimental use or simple milling work. Depending on the objective, you can continue using the machine with this configuration or acquire more professional tools

The spindle motor included with the kit is suitable for milling materials such as balsa wood and relatively soft plastics. If you want to machine harder materials or do more precise work, it is certainly worthwhile to invest in a better motor. The fact that quite a few people were nevertheless satisfied with the performance of the machine was a matter of pure luck, since some of the motors had 0.01 mm of play, while others had 0.5 mm. But as many people remarked on the Elektor forum, the price/performance ratio was reasonable.

If you want something better, you must first ask yourself what sort of work you want to use it for. Do you want to do very nice, fine engraving, do you want a powerful motor for milling hard metals, or do you want both? A truly professional spindle motor is expensive – as much as several times the price of the Profiler. It is thus questionable whether such an investment is sensible.

Practical experience shows that an AC spindle rated at around 500 watts is the most suitable. More powerful motors are generally to large and too heavy for the Profiler.

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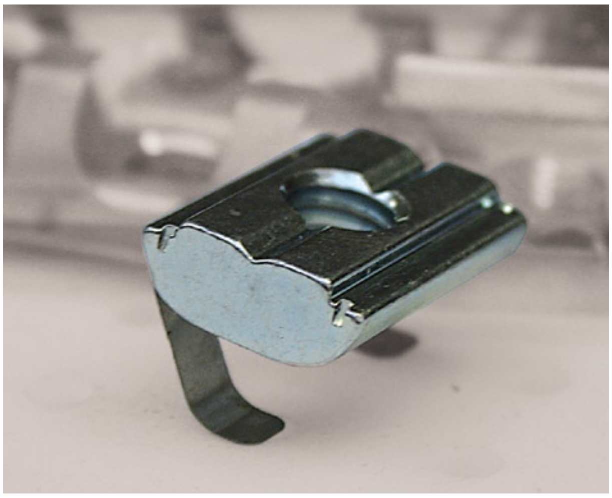

Unlike most DC motors, AC motors of this sort are also affordable. When looking for a motor, remember that it must be designed for machine mounting. You can see this from the steel mounting ring, which is used to attach the motor to the machine, and which also usually houses the bearings. The bearings must be suitable for machining use. Kress has a suitable motor, which is actually a bit too heavy for the Profiler, but the price is attractive. Colinbus can supply the IAC-500, which is ideal in terms of weight and precision, but it is it considerably more expensive. A variety of similar products are available under various brand names, and we recommend comparing them and carefully weighing their pros and cons. For Profile users with deep pockets, there is also the Jäger brand. These motors are very powerful and highly precise, and they are very lightweight. The only problem here is the price.

The base plate

A relatively thin MDF board is supplied with the Profiler for use as the base plate. If you want something more robust, pick up a piece of board at a builder's merchant with a thickness of 20 mm (it hardly costs anything), which will provide the basis for an inexpensive but stable support surface. If you want to invest a bit more, you can of course buy a plate with slots for T-nuts or a vacuum table. Each of these options has its own specific advantages, depending on what kind of work you want to do.

A vacuum table is ideal for machining flat material and films or for securing material without subjecting it to excessively strong forces. A vacuum table is particularly suitable for jobs with repeat parts. You can simply place the workpiece against a stop on the table, switch on the vacuum, and start machining. With a few accessories, you can also have the vacuum table or dust extraction system switch on automatically.

A T-slot table (see the lead photo) is ideal for clamping relative bulky workpieces. Nuts with a built-in spring can be slid into the slots and used with screws to secure clamps and blocks. The spring nuts can be shifted in the slots, which makes it very easy to clamp workpieces with different dimensions.

Naturally, you can also use the Profiler to make your own T-slot or vacuum table. However, you should bear in mind that making a decent T-slot table is relatively expensive and takes a lot of work. By contrast, making a vacuum table is relatively easy.

Milling 2D, text and PCBs

Beside learning how to operate machine tools, programming in G code and studying the properties of materials, professional milling machinists in training spend a year learning machining techniques. Naturally, the average Profiler user does not have this knowledge.

Thanks to the user-friendly interface of the Profiler and modern CAD/CAM packages, relatively inexperienced users can also produce very nice results with CNC machines. However, this does not mean that there is no longer any need for some knowledge of machining techniques. Although the user can usually have the machine do what he wants, the machine does not always do what it is supposed to do. In fact, it often doesn't. Poor milling results are usually not the fault of the machine or the software, but instead almost always a consequence of incorrect settings. Nevertheless, hundreds of users have shown that splendid results can be obtained with a bit of patience and experimenting. If you do something wrong and the Profiler gets stuck, there's no need to panic. It may complain, but it won't break. The message here is: try to find the best settings for each machining operation.

Milling 2D shapes and engraving text

The Profiler is primarily constructed for milling all sorts of 2D shapes. Many users draw the shapes in ColiLiner, generate the milling paths, and leave the rest of the work to ColiDrive. ColiLiner is not a real drawing package, but can still do quite a lot. For instance, you can use all standard text fonts, and most drawings work out nicely. However, if you want to use your own drawing package, simply export the drawing as an HPGL file and import it directly into ColiDrive.

Milling 3D shapes

The Profiler is not actually designed for 3D work. Nevertheless, it can be used to make very nice 3D shapes. This statement on our part drew a certain amount of criticism from users, and some explanation is in fact necessary. With a real 3D machine, the three axes are interpolated simultaneously. This is not the case with the Profiler. Only two axes can be interpolated at the same time, so the third one al-

ways comes afterward. It is thus possible to mill 3D shapes, but the end result not as nice and it takes much longer. For this reason, may people who like to make 3D forms first mill the shape and then finish the piece by hand (sanding). The final result looks surprisingly good.
Additional CAM software is necessary for 3D milling; it is not included with the Profiler. For example, Colinbus can supply DeskProto as an affordable solution. This package is not especially suitable for 2D milling, but it is a very powerful tool for making 3D models.

Milling PCBs

The Profiler is supplied with ColiLiner Lite (especially for *Elektor* readers who would like to mill the occasional PCB). The software supports reading in a Gerber or Excellon file and then milling channels around tracks and pads. This isn't as easy as it sounds. As far as we know, there are only a few software packages on the global market that can handle this, and they are either very expensive or are only supplied together with expensive milling machines.
The fact that the Profiler is supplied with this software does not really mean that the Profiler is a true PCB milling machine. This was already clearly stated in the first article. However, the many links and photos that users sent us clearly show that it is possible to mill good PCBs with this machine. As we have received a lot of questions on this subject, we want to address it here in somewhat more detail.
Milling PCBs is becoming increasingly popular. This is not because it is better than etching, but instead because it is faster and more environmentally friendly for one-off boards. With a true PCB milling machine, you can easily mill five tracks between the pins of an IC, which is more than good enough for modern circuitry. If you want to get acceptable results with the Profiler, it's only logical to have a look at how the pros do it: what tools do they use, and how do they achieve such amazing results?
Fitting the PCB is an important factor. The best way to do this is to use two small pins, since this way you can also make double-sided boards (even with the Profiler). ColiDrive is certainly not an obstacle here, since it is specifically made for this and shows an imaginary mirror line on the screen.
In practice, you start by drilling a hole with a diameter of 2.95 mm, located approximately in the middle of the X axis and at the start of the Y axis. Press the first reference pin in this hole [4]. Use a 3-mm dowel pin and ensure that it protrudes by approximately 4 mm. Now drive the machine bridge straight backward and drill a second hole approximately 20 cm away from the first one. Press the second reference pin in this hole. Store the location data in ColiDrive so the software knows the position of the reference line.
If you use a T-slot table, you can drill the holes in small plastic blocks. You can then use all different sizes of PCB material by sliding these blocks to different positions. To avoid any misunderstanding, note that the idea here is to mount PCB material on the machine and then mill one or more PCBs in the material.
As you also have to drill holes in the PCB, you have to use underlay material. Use a small board with a thickness of 2 mm for this – preferably a material that stays nice and flat, such as MDF. In this material, drill two 3-mm holes with exactly the same spacing as the on the reference board, and then place it over the two reference pins. Do the same thing with the PCB material. **Note:** single-sided PCB material may be slightly bowed, and if it is, it must be held flat with clamps or tape.
Now you have the material on the machine, and you can start making the PCB. Drill the holes first, as otherwise thin drills may break or thick drills may chew up the pads. There's not much that can go wrong during this process, since ColiDrive always asks you to fit the right drill in the holder. After all the holes are drilled, you can use small conical milling cutters to the tracks. End mills are too fragile for this work because the insulating channels are very thin, and they also wear much to quickly. To ensure that no residual copper is left, it is necessary to mill a little way into the tough epoxy material, and this dramatically reduces the life of the cutters.
Using conical cutters also has some disadvantages. In particular, the milling depth must be controlled precisely, as otherwise the width of the milled channel will vary, which creates problems with fine circuit board tracks. Most Profiler users solve this problem by first milling the base plate perfectly flat. If the PCB material is then fastened securely and held flat, the milling depth remains constant.
A better alternative is to use a floating cutter head. With this arrangement, the spindle motor is mounted in a holder that can move freely along the Z axis. The bottom ring slides over the surface of the PCB and ensures that the cutter – which is always at a fixed distance from the ring – maintains a constant cutting depth in the copper. If you use this arrangement, it doesn't matter whether the material is flat

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or bowed (within certain limits, of course) – the milled channels will always have a constant width. As floating cutter heads are usually adapted to the spindle motor that is used, they are difficult to find as commercial products. However, it's fairly easy to make one yourself once you understand the principle..
After the PCB has been completed, it can be milled out of the base material. This is usually done with a 2-mm roughing cutter. Do this at a very low feed rate, such as 5 mm/s, since otherwise too much heat will be generated and the tool will break.
A manual for using the Profiler to make PCBs is available on the Colinbus website at www.colinbus.com. For instance, it describes how you can make double-sided PCBs, despite the limitations of ColiLiner Lite. Be sure to download it – it's certainly worthwhile.

Handy milling tips

If you read milling tips on the Web or consult professional literature, you often obtain information about using large milling machines to machine materials. The Profiler is not

a large milling machine, and it must be used in a different manner.
In the first place, you use smaller tools with the Profiler. Unless you are working with very soft material, a 6-mm cutter is already quite large. Given that you are working with relatively small tools, it is often advisable to use a fairly high feed rate (the rate of travel for milling) and restrict the cutting depth. It is thus better to mill somewhat faster but not too deep. If you follow the suggestions listed below, your milling work will look a lot better.

How to mill: As we just mentioned, keep the cutting depth fairly shallow – the quality degrades quickly with increasing depth. Mill clockwise on inside curves and anticlockwise on outside curves. This yields the best appearance on the final product.

Which cutters: Cutters are available with one, two, three, or four flutes. This refers to the number of cutting edges around the circumference of the cutter. Each type has its own properties. Single- and double-flute cutters are used for most jobs with the Profiler. Triple- and quad-flute cutters are primarily used for hard alloys, and the Profiler is not suitable for these materials.

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Single-flute cutters are primarily used with wood and plastics, but nowadays they are also used with aluminium, due to the use of stronger cutter materials. Single-flute cutters enter the material better and have better chip removal than double-flute cutters.
Double-flute cutters are the best choice for milling plastics and non-ferrous metals. They produce a smoother finish and wear less quickly. They are also often used for a final polishing round.

Cooling: Cooling is almost always necessary [5]. The type of cooling depends on the material to be machined. As it is not possible to use liquid-stream cooling with the Profiler, the following tips can be helpful.
Copper, bronze, brass and aluminium can be cooled quite well with methylated spirits. Thin oil is also good for cooling aluminium. You can use a small brush or plant sprayer to apply the liquid. A couple of handy youngsters remodelled a paintbrush and fitted it to the machine.

Spindle speed: With plastics, the result is strongly dependent on the feed rate and spindle speed. A high spindle speed can be used for milling metals, but this is often inadvisable with plastics. With a high spindle speed, the plastic melts and sticks to the tool, and everything gets stuck.
Although many people may not believe it, the feed rate is often too low. A lot of heat is generated if the cutter moves slowly through the material, and this causes problems. If nothing else works, try cooling with compressed air.
Solid-core board (such as Trespa) can be milled very nicely, but it causes a high rate of tool wear. Always enter the material very slowly, because the highest rate of cutter wear occurs during plunge cutting.
Always use single-flute cutters for milling polystyrene and foams. Cooling is rarely a problem with the correct machining speeds. If cooling is necessary, you can only use air.

Securing the tool and workpiece: Always insert the tool as far as possible into the holder. Tools that extend a long way create troublesome vibrations. The work table must be flat and stable. The T-slot table (optional accessory) is very suitable for this purpose. The workpiece must be held firmly so no vibrations can occur and it cannot slip (which is much worse). Use clamps to secure the workpiece firmly in place. Spray-on glue and double-sided tape are good options for thin or light materials.

Applications

Many enthusiastic users have sent photos, drawings, and stories about the various applications they have found for the Profiler. Many of them came from departments of large companies that use the Profiler as a platform for experiments, but they also came from many hobbyists and self-employed persons. Some examples:

- A large cosmetics company used two Profilers to fill more than 800,000 bottles.
- Several users drill hundreds of PCBs every day with the machines.
- A builder of architectural models created a model of an entire neighbourhood in a month.
- A user in the diamond business uses three Profilers to measure and check diamonds.
- A lot of users employ the Profiler for potting and dispensing…
- …or for ultrasonic cutting of plastics.
- A toy manufacturer uses it to produce all of its new models.
- And of course, there are hundreds of hobbyists who make incredibly nice things, such as lifelike cockpits (hi Hessel), miniature cars, microscopic components, splendid jewellery, clocks, and very fine printed circuit boards.

As you can see, everything is possible with this milling machine if you just put some time and effort into it. Check the Profiler forum on the Elektor website for even more ideas, tips and reports on user experience.

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The Profiler kit can still be ordered on the Elektor website. Colinbus presently has around 100 kits in stock in the warehouse. If you order now, the kit can thus be delivered quickly (as long as stocks last).


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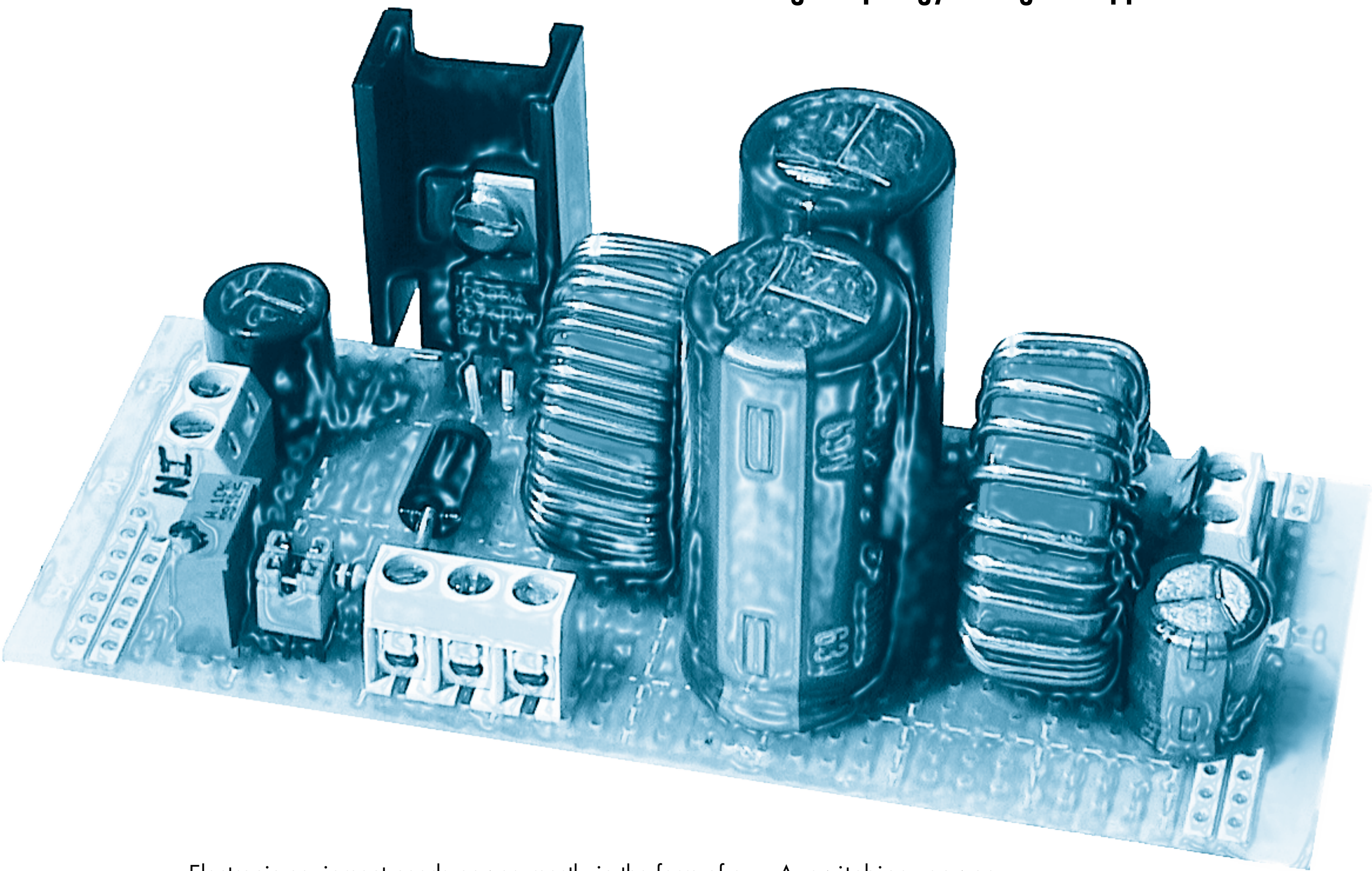
Cool Power

Switch mode power supplies: an introduction

Sergio Sánchez Moreno

Switch Mode Power Supply Units (SMPSUs) are often too quickly put aside because of their complexity. This article presents an overview to SMPSU technology and a brief description of the most widely used topologies, but in a practical way, trying to demystify the topic and encourage the electronics entusiasts to start developing his or her own 'switchers', or at least know how to choose the right topology for a given application.



Electronic equipment needs power, mostly in the form of a static voltage (DC). The national grid delivers an alternating voltage (AC), so most electronic devices have a dedicated power supply (PSU) to convert this alternating voltage to the voltage that is needed by the circuitry. This conversion is never 100% efficient.

Generally, we have two types of power supplies: linear and switching. A linear power supply uses a pass element such as a transistor that dissipates the excess energy. This, of course results in energy loss due to the simultaneous voltage drop and current flowing through the component.

A switching power supply delivers its power in pulses or periodic 'packets' (at typically 10 kHz to 1 MHz rate) that are averaged to provide a smooth output. The power is transferred to the load (circuit) by means of non-dissipative components (at least theoretically), such as switches that operate only in two states, ON and OFF, inductors, capacitors and transformers. A theoretical switch doesn't dissipate power, ($P=V\times I$) because when it is open, no current flows through it, and when it is closed, it becomes a short-circuit (the voltage drop across it is 0). Of course there will be some losses in practice, but for sure we start from a better point than with linear regulators in terms of energy usage!

Why choose SMPSU?

Efficiency: one of the key advantages of SMPS (switch-mode power supplies) is that power can be converted in a useful way to the load and still keep losses very low, typically below 20% of the useful power. Generally this is way better than a linear PSU.
Size: despite a generally higher parts count, when all things are considered (the heat sink that may be required for this one, for example), a 'switcher's' size can be considerably smaller than a linear PSU. When transformers are involved, such as in AC/DC converters, the reduction is drastic, because switching transformers operate at much higher frequencies (10 kHz-1MHz) so their size can be greatly reduced.
Flexibility: switching regulators easily provide multiple voltages from a single input source, even higher in value or polarity-inverted. This is more difficult and costly to do with linear PSUs.

Disadvantages of SMPS

Noise and interference: the fast transitions occurring in a switching regulator can produce a lot of harmonics that are easily radiated. If not properly controlled, this may cause interference with nearby equipment or with the load itself. This noise can also be conducted in the forms of spurious noise or ripple. Fortunately, a lot of effort has been put into this issue and now it is possible to have very quiet SMPSUs even at high power levels.
Complexity/Reliability: the higher number of parts in a typical SMPSU, including the control circuit, has an impact in reliability; the more parts, the more possible failures. Among them, power semiconductors are the most prone to failure, although with careful design and thanks to the outstanding evolution of semiconductors, very high reliability can be obtained now.
Design difficulty: the design of a switching power supply is totally different and generally more complicated than an equivalent linear PSU, and the designer must know a lot of fields (power electronics, magnetics, EMI/RFI, feedback theory, etc).

Buck converter

The most basic switching converter is the buck converter. It takes a DC input and converts it to a lower DC output. The basic architecture can be seen in **Figure 1**.
The buck converter comprises a switch, a diode (that acts like a second switch), an inductor, and a smoothing capacitor. There are two possible status for the switch, ON and OFF, that are determined by a controller, whose main function is to get the output voltage to the desired value regardless of the input or load variations. When the switch is ON (closed), the diode is open as it is directly connected to the input and becomes reverse biased,. Then, $V_{in}=V_L+V_o$, so $V_L=V_i-V_o$. The basic equation of an inductor is $V_L=L dI_L/dt$, then

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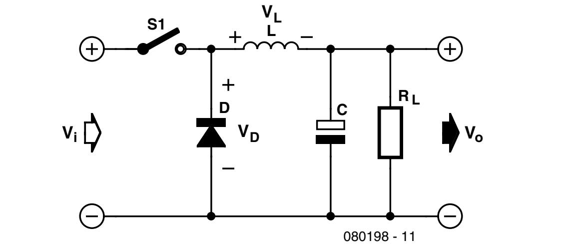

$$I_L = \int_0^{t_{on}} \frac{Vi - Vo}{L} dt$$

As $-(V_i-V_o)/L$ doesn't depend on time, the increment of the current is constant and it becomes:

$$\Delta I_{L(on)} = \frac{Vi - Vo}{L} t_{on}$$

(i.e. inductor current increases linearly during the ON phase).

When the switch is OFF (open), the input voltage source gets disconnected from the circuit, and the diode gets forward biased, providing a patch for the current to flow. $V_L=-V_o$. So, similarly, we obtain

$$\Delta I_{L(off)} = \frac{-Vo}{L} t_{off}$$

These are only increment rates, not absolute values. The average value of the current, I_{avg}, depends on the load resistance, and will be the mean value of max. and min. currents.

Continuous vs. discontinuous operation

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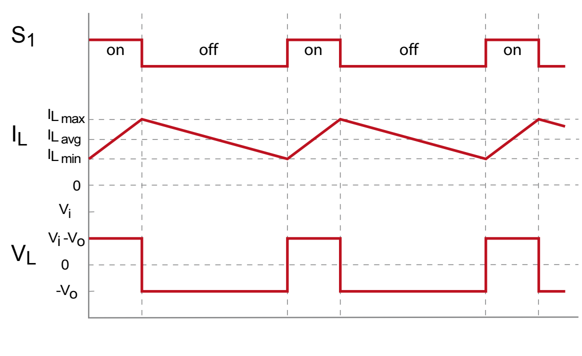


In **Figure 2** you can see the aspect of the inductor current, that is a triangle centered in the average current, rising and falling linearly when the switch is ON and OFF, respectively.

We assume that I_L never drops to zero. We will call this mode *"Continuous Conduction Mode (CCM)"*. Then in steady state it is clear that I_L at the start of the cycle ($t=0$) must be the same as I_L at the end of the cycle ($t=T$), because if not, the average current would indefinitely increase or decrease. Thus, the increments $\Delta I_{L(on)}$ and $\Delta I_{L(off)}$ must be equal but of opposite sign. That means that $\Delta I_{L(on)} = -\Delta I_{L(off)}$, so

$$\frac{Vi - Vo}{L} t_{on} = \frac{Vo}{L} t_{off}$$

If we assign D (duty cycle) to the portion of the period T ($=1/F_s$, switching frequency) that the switch is on, $D=t_{on}/T$, then $t_{on}=DT$, so the rest of the time the switch is off: $t_{off}=T(1-D)$. Substituting,

$$\frac{Vi - Vo}{L} DT = \frac{Vo}{L}(1-D)T$$

or, simplified:

$$\frac{Vo}{Vi} = D$$

D will be always less than or equal to 1, so V_o will always be less than or equal to than V_i. That's why the Buck converter is also called 'step down converter'.
Note that, in CCM, V_o only depends on the duty cycle and V_i. For example, if we want 5 V from a 12 V input, the controller will have to turn the switch on during 5/12=0.4166 (41.66%) of the time, regardless of the load, leaving it off the rest of the cycle.

If the current drawn by the load is not large enough, the former current waveform will evolve as shown in **Figure 3**, eventually reaching zero when the switch is OFF. This mode of operation is called Discontinuous Conduction Mode (DCM). In DCM we can't apply the above equation that the increments $\Delta I_{L(on)}$ and $\Delta I_{L(off)}$ have the same magnitude, and the math become more complicated. In this case the relation between V_o and V_i is not as simple as in CCM. For reference, the output voltage can be calculated then as:

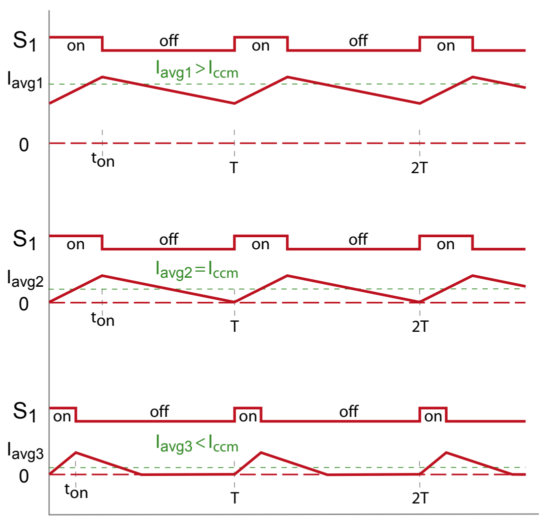
$$Vo = \frac{Vi}{\frac{2L \cdot Iavg}{D^2 \cdot Vi \cdot T} + 1}$$

As you can see, now it also depends on the switching period (T), the value of the inductor and the input voltage itself.
The minimal average current that guarantees that the inductor current doesn't drop to zero (so we keep the converter in CCM), is:

$$I_{avg(CCM)} \geq \frac{Vi(1-D)DT}{2L}$$

If one wants to keep control of a buck converter simple, a minimal load must be provided so it remains in CCM. There is no cause that impedes us running a buck regulator in DCM mode, although in this case it is sometimes better to use the variation of the switching frequency as the control parameter, instead of the duty cycle, (FM, frequency modulation instead of PWM, pulse width modulation).

3



Boost converter

4

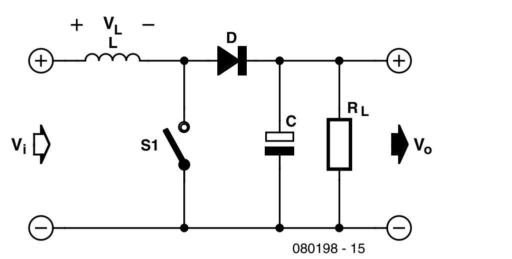


Figure 4 shows the basic architecture of a boost converter. The analysis is very similar to the buck converter, the main equations being $V_L = V_i$ (ON state), so:

$$\Delta I_{L(on)} = \frac{Vi}{L} t_{on}$$

Note that, during the ON state, the current to the load is supplied by the storage capacitor, thus the output voltage is smooth if it is large enough.

For the OFF state $V_L=V_i-V_o$, so:

$$\Delta I_{L(off)} = \frac{Vi - Vo}{L} t_{off}$$

Now we find that:

$$\frac{Vo}{Vi} = \frac{1}{1-D}$$

D will always be less than or equal to 1, so V_o will always be equal or greater than V_i. That's why the Boost converter is also called 'Step up converter'.

In CCM, output voltage only depends on the duty cycle and input voltage. For example, if we want 12 V from a 5 V input, the controller will have to turn the switch on during 58.3% of the time, regardless of the load, leaving it off the rest of the cycle.

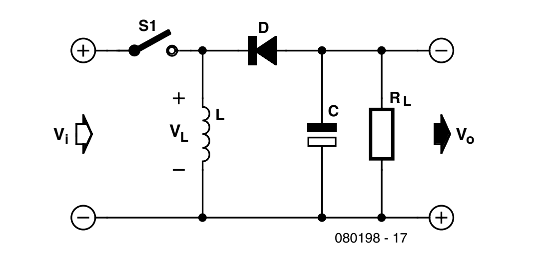
However, as opposed to buck regulators, boost ones are more commonly used in DCM for stability reasons. The expression for the output voltage becomes:

$$\frac{Vo}{Vi} = 1 + \frac{V_i D^2 T}{2LI_{avg}}$$

In order to allow for core flux reset and avoid saturation, D is usually limited to around 0.8.

Buck-boost or inverting converter

5



The inverting converter is used to obtain negative voltages from a positive source. **Figure 5** shows the basic schematic. The analysis is very similar to the boost converter. The main equations for the ON state are V_L=V_i, so:

$$\Delta I_{L(on)} = \frac{Vi}{L} t_{on}$$

For the OFF state V_L=–V_o, so

$$\Delta I_{L(off)} = \frac{-Vo}{L} t_{off}$$

Being in parallel with the inductor, the capacitor gets charged to a negative voltage during OFF phase, and then provides current to the load when the switch goes ON again, allowing for assumedly constant output. The following relationship between V_o and V_i exists:

$$\frac{Vo}{Vi} = \frac{-D}{1-D}$$

So the buck-boost converter can provide a voltage from theoretically 0 to theoretically minus infinity from a positive input voltage. Of course, this converter can also operate in DCM if the load current I_{avg} is not large enough. In this case, analyzing the storage of energy in the coil, we can demonstrate that the V_o/V_i relation becomes:

$$\frac{Vo}{Vi} = -\frac{V_i D^2 T}{2LI_{avg}}$$

There are of course countless variations of these basic topologies, such as the "Cuk" converter, that provides the same V_o/V_i relationship as the Inverter topology but using two inductors.

NOTE: There is another topology also called 'Buck-boost', consisting of a buck converter followed by a boost converter, with the additional difference that it doesn't invert polarity.

Isolated converters

When the input or output voltage is high enough to be dangerous, an isolated topology must be used, where the separation between input and output is not accomplished only by a semiconductor, but by a physical dielectric barrier. The circuit is then split in two parts: the *primary* (that gets power directly from the source) and the *secondary* (where the output(s) are connected). International regulation dictates some norms about the required distances (named clearance and creepage) between both parts in order to ensure safety. These norms must be had in mind when designing an isolated converter.

The typical application of isolated converters (although not the only one) is AC/DC (mains input) PSUs, also called "offline converters". There are several topologies, some of them directly derived from the basic regulators explained before, while others are a bit more complicated and appeared in order to provide higher power levels.

Flyback converter

The basic schematic can be seen in **Figure 6**. It is clearly derived from the buck-boost (inverting) converter: the input inductor has been substituted by a transformer, with the diode and capacitor connected in its secondary. The dots and diode polarity have been rearranged so the output voltage is positive. Finally, the connection between primary and secondary has been removed to provide galvanic isolation.

When S1 turns ON, the transformer current starts to ramp up linearly at a rate $t \times V_i/L_{pri}$, where L_{pri} is the primary inductance. As primary and secondary have opposite polarity due to the different position of the dots, the secondary voltage is multiplied by the turns ratio N_2/N_1 and inverted in polarity, so the diode gets reverse biased. The load is

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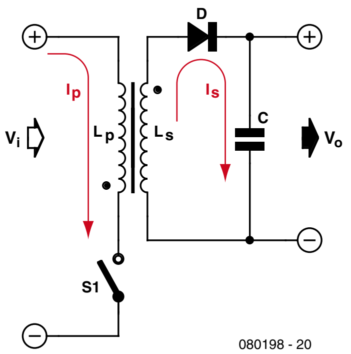

supplied current by the capacitor alone, that we assume previously charged.

When S1 turns OFF, there is no primary current, but the polarity reverses, and so does the secondary voltage: the diode gets now forward biased and hence the core energy can be discharged through the secondary (see **Figure 7**), at a linear rate of $-t \times V_o / L_{sec}$. During this time, the load receives current, and so does the capacitor, that replenishes its charge for the next ON time.

During OFF time, the secondary voltage is reflected back ("flies back") to the primary, multiplied by the turns ratio, so the rating of S1 must be at least $V_{in} + V_o \times N_1 / N_2$ plus some margin.

Unlike in other types of isolated converters, the flyback transformer stores energy itself (as well as the capacitor that supplies the load during the first part of the cycle), and is usually constructed with ferrite materials, with a 'gap' or separation between the core halves that increases energy storage capacity.

Using the expression of the energy stored in an inductor during the ON time, and assuming that it fully discharges during the OFF time (discontinuous mode), the expression for the output voltage is:

$$\frac{Vo}{Vi} = D \cdot \sqrt{\frac{T \cdot V_o}{2 I_{avg} L_{pri}}}$$

The controller can adjust the output voltage by means of the duty cycle *D*.

Note that the voltage at the primary is always positive, so only one quadrant of the transformer *B/H* curve is used, leading to inefficient core use. Other topologies such as

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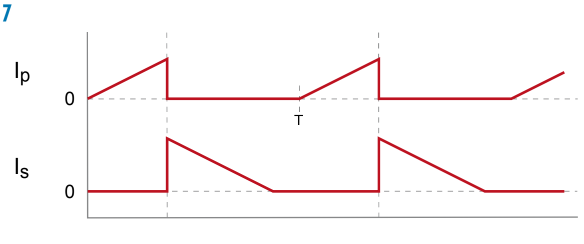
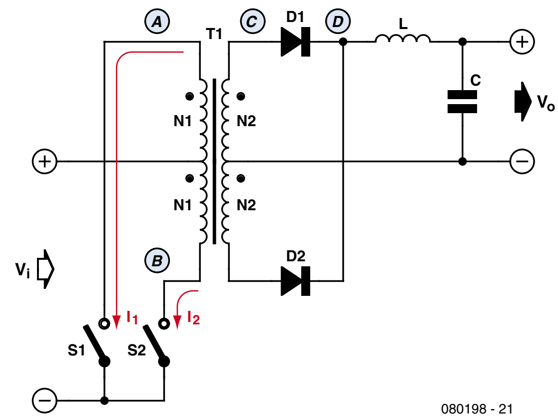


push-pull or half/full-bridges can get at least double the power from the same core volume. But even when a flyback is useful only for <200 W typically, it has lower cost (doesn't need output inductors, uses a single primary switch and secondary diode, etc), and that's one of the main reasons for its popularity. Flyback converters can be found in every TV set, monitors, laptop chargers, small adapters, etc.

The flyback can be constructed with many output voltages with the only addition of separate secondaries. Cross-regulation (regulation of each output when the load of another output changes) is particularly good in this topology, that's another reason of its success.

8



Push-Pull converter

When higher power is needed, better transformer utilization is required, and hence a topology that uses two quadrants of the *B-H* curve (provides positive and negative voltage swing to the primary). The push-pull is one of these topologies, see **Figure 8**.

The transformer has a centre-tap in the primary, connected to the input source V_i, so it really has two identical primaries in series, each having N_1 turns. The same happens in the secondary, there are two in series each one having N_2 turns.
Both switches are activated by a control voltage with duty cycle varying between 0 and 50%. Both switches can never be ON at the same time. **Figure 9** shows the basic waveforms of this converter.

When S1 or S2 turns ON, its corresponding primary is set to almost 0V, so it primary 'sees' V_i. The total primary voltage then swings from $-V_i$ to $+V_i$. The current of each primary ramps up linearly during the corresponding ON time due to the primary inductance. The primary voltage is multiplied by N_2/N_1 and applied to the secondary. The corresponding diode gets forward biased, so when any of both switches is on, there is current in one of the secondaries, so the inductor current, that supplies the load (and capacitor) ramps up.
When both switches S1 and S2 are OFF, the diodes block and the only current to the load is provided from the output inductor (and the smoothing capacitor), that starts ramping down at a rate $-t \times L_1 \times V_o$. The expression for the output voltage is

$$\frac{Vo}{Vi} = 2D \cdot \frac{N_2}{N_1}$$

The controller can adjust the output voltage by means of the duty cycle. Note that we can get an output voltage that is lower or higher than the input, depending on the transformer construction.

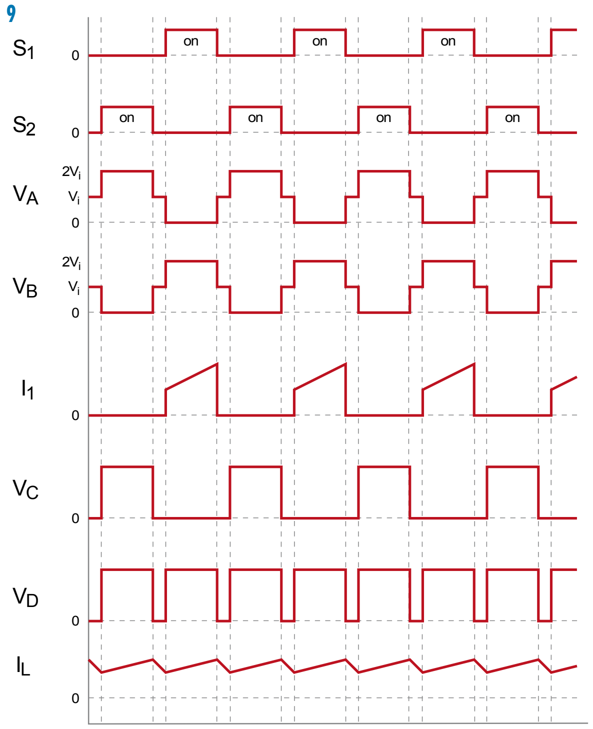
There is a potential problem with push-pull converters that has limited their use: if the flux swing magnitude is not exactly the same for both half-primaries, the core will eventually 'walk' into saturation. Its inductance drops drastically, behaving nearly as a short-circuit, so the switches will be destroyed. This can be detected because the current waveforms of the switches don't have the same amplitude, and when the situation is really critical, one of the waveforms can start to curve upwards at the end of its ON time.
This is less of a problem with MOSFETs, that provide some auto-correction due to their negative temperature coefficient ($R_{ds(on)}$ increases with current, so primary voltage drops due to the higher $V_{ds(on)}$).

Note that the voltage each switch withstands is twice the input voltage, so they are not very suitable for high power off-line converters (each switch would have to be rated at nearly 1KV and also high current, being expensive). This kind of converter is preferred for lower $V_{i.}$
A typical application of push-pull converters are step-up inverters for powering audio amplifiers from car batteries, up to 1KW. The primary currents are huge, but the voltage rating of the MOSFETs is only 30-60 V, so there are many high-current devices readily available.

Half-bridge and Full-bridge converters

For 230 VAC off-line converters, the voltage in the push-pull MOSFETs may become unpractical. Half-bridge and full-bridge converters, on the other hand, allow for a more relaxed rating of the switches, while still providing high output power and good use of the transformer. The schematic of the simpler of both, the half bridge, can be seen in **Figure 10**.

9



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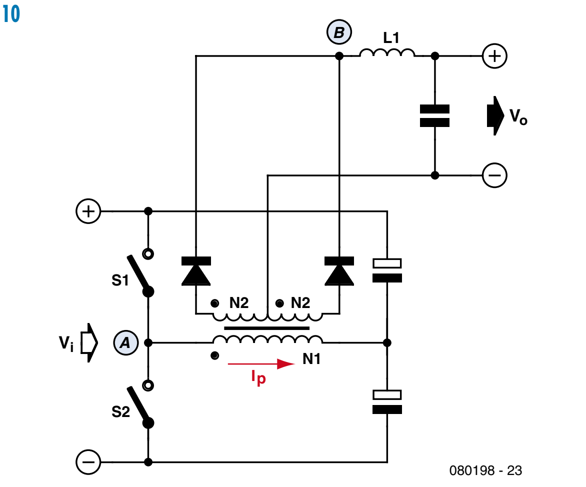
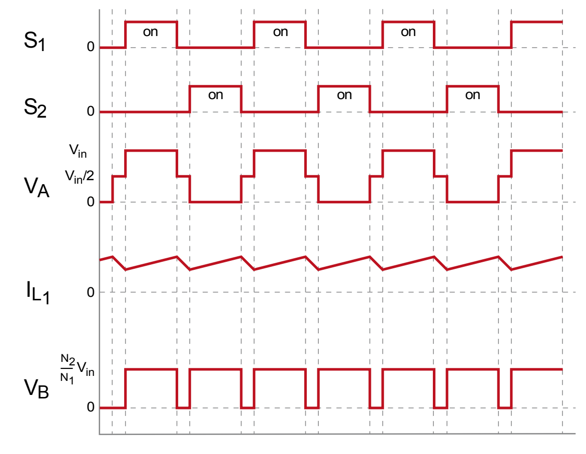


This topology also uses two switches, two rectifier diodes and 1 output inductor. The transformer has a single primary with N_1 turns, and two center-tapped secondaries, each one having N_2 turns. Note that the other transformer primary leg is connected to $V_i/2$, built with a capacitive voltage divider.

Both switches are activated by a control voltage with duty cycle varying between 0 and 50%. Both switches can never be ON at the same time. **Figure 11** shows the basic waveforms of this converter.

When S1 or S2 turns ON, the transformer leg that is connected between them is switched either to V_i or 0V, and as the other leg is fixed at $V_i/2$, the total voltage in the primary swings from $-V_i/2$ to $+Vi/2$. The current of the primary ramps up (in magnitude) linearly during the ON times. The primary voltage is multiplied by N_2/N_1 and applied to the secondary. The corresponding diode gets forward biased, so when any of both switches is on, there is current in one of the secondaries and hence one of the diodes is forward-biased, so the inductor current that supplies the load (and

11



capacitor) ramps up.
When both switches S1 and S2 are OFF, the diodes block and the only current to the load is provided by the output inductor (and the smoothing capacitor), that starts ramping down at a rate $-t \times L_1 \times V_o$.
The expression for the output voltage is similar to the push-pull topology, but as the voltage swing of the transformer is halved:

$$\frac{Vo}{Vi} = D \cdot \frac{N_2}{N_1}$$

The controller can thus adjust the output voltage by means of the duty cycle. Note that we can also get an output voltage that is lower or higher than the input.
The full bridge is very similar, but the transformer primary is connected between two sets of switches, for a total of 4. The left side top turns ON simultaneously with the right side bottom, and conversely. The capacitor voltage divider doesn't exist, and the voltage swing in the transformer primary is doubled (and hence its use is fuller). The output/input relationship becomes:

$$\frac{Vo}{Vi} = 2D \cdot \frac{N_2}{N_1}$$

Sometimes, a coupling capacitor C_c is added in series with the primary, in order to remove any DC in the transformer windings and avoid saturation. C_c must have a value large enough so that it doesn't produce significant (<5%) voltage "droop" on the top of the transformer primary voltage waveform. A high voltage polypropylene of good quality ceramic cap should be used. The voltage-divider capacitors in half-bridge must also be properly dimensioned, with a high-valued (20-100 k) resistor in parallel with each one to ensure proper balancing at $V_{bus}/2$.
Half-bridge converters are commonly used for medium-power (250 W-1 KW) offline applications, the main one being PC PSUs. Another example of this kind of PSUs can be found in the **SAPS-400 Audio SMPSU** described elsewhere in this issue. This one has two symmetric outputs with coupled inductors for good cross-regulation, as well as a couple of auxiliary windings.
Although full-bridges have four switches, the control circuit is the same as for half-bridge or push-pull, as the MOSFETs turn on in pairs so only two signals have to be provided. However, isolation is required for each gate-source voltage, as the sources of each MOSFET are not common.
Full-bridges are more costly, so they are reserved for powers above >1 KW.

Losses in the converters

Although the equations obtained above don't show this, there are of course some losses during the conversion in all this kind of converters, that have two main components:
Conduction losses occur when the switch is ON, due to its ON resistance, $R_{ds(on)}$ in MOSFETs. In formula:

$P_{cond} = I^2_{switch} \times R_{ds(on)} \times D$

(the switch is only closed during a part of the cycle D)
Switching losses: real switches don't change instantaneously from ON to OFF, there are rise and fall times (t_r and t_f). During these times both current and voltage drop is developed at the switch simultaneously, producing power dissipation. These losses can be approximated by:

$$P_{switching} = \frac{V_{switch} I_{switch}}{2} (t_r + t_f) f$$

There are other kinds of losses, such as the gate driver losses, the losses associated to the diodes "recovery time", losses in the wire and core of the magnetic components, etc., but they are usually smaller.
A typical simple converter can quite easily reach efficiencies of around 90%. As a comparative example, if one needs 5 V from a 12 V input, with 2 A load current (P_{out}=10 W), a linear regulator will dissipate (12–5)×2=14 W. A buck converter would do the job dissipating only around 1.2 W.

What topology to choose?

On the Elektor website we present a table and a flowchart for free downloading. With it you can easily choose a topology that's best suited to the application. Topics as safety, input/output voltage, output power and costs will be covered also.

(080198-I)

Web Links (reference & tutorials)

www.smps.com

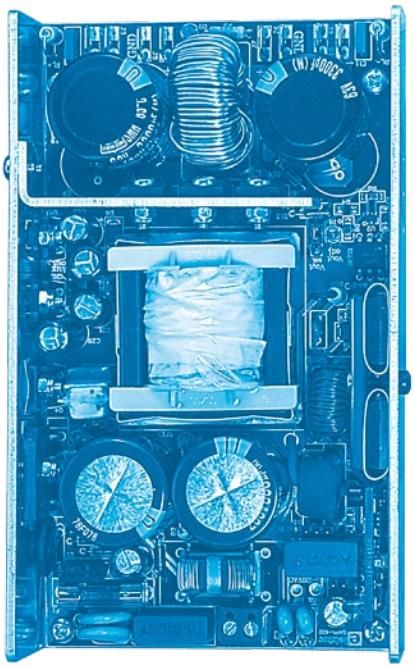
www.smps.us

www.onsemi.com/pub_link/Collateral/SMPSRM-D.PDF

http://sound.westhost.com/project89.htm

http://schmidt-walter.eit.h-da.de/smps_e/smps_e.html

http://members.tripod.com/valveaudio/Membuatsendiri.htm



USB-to-TTL Serial Cable

A new item in the Elektor shop

Jan Buiting & Antoine Authier

Many 'legacy' peripherals, microcontroller projects and older boards are left abandoned because they have no USB connectivity and therefore look terminally cut off from the modern PC (which, as many of you have painfully discovered) has no RS232 anymore. Customers today want plug & play behaviour from their electronic equipment and none of the old fumbling around with RS232 connectors and cables, let alone juggling with wires and sub-D connectors. No USB? Useless old grot.

Elektor readers are different. To them, USB is just another step on in the evolution of connectivity in general. Also, they think it's a pity to waste all that fine I/O equipment and microcontroller stuff built over the past 10 years or so just because it doesn't have USB. Conversions and adaptations are in order and that's where electronics comes in.

The 5-V version of the USB-TTL cable is available from the Elektor Shop.

Mention 'USB to serial conversion' and you can't go round Future Technology Devices International (FTDI), a.k.a 'FTDIchip' headed by the amiable Fred Dart.

At Embedded World 2008, Fred's assistant Daniel McCaffrey gave us a handful of cables, boards and bits of heatshrink sleeving. It was not after the show and with the help of some colleagues that we realized this stuff could be extremely useful for Elektor readers.

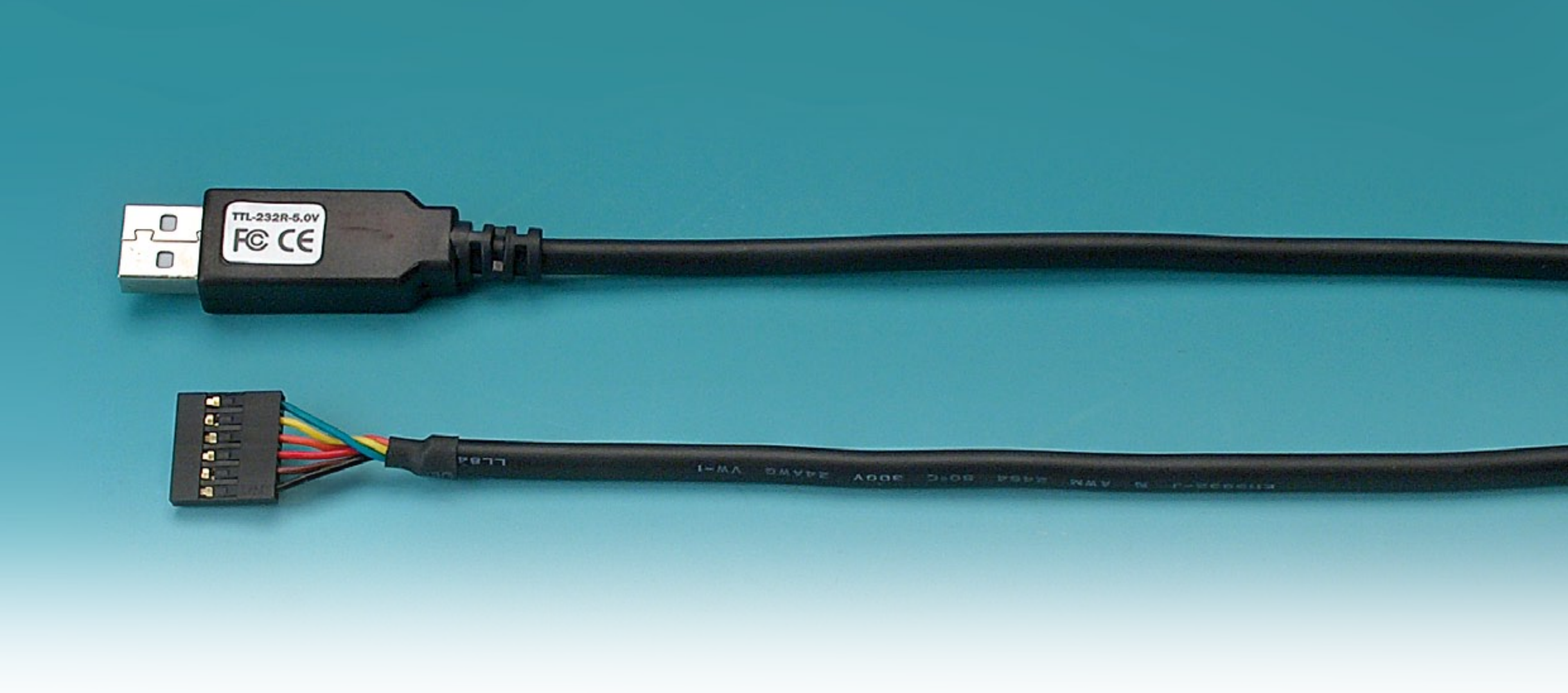
What's in the plug

What looks like a 1.8-m long cable with different connectors at either end, is actually an electronic circuit [1]. All parts except the 6-way receptacle are contained in the moulded USB-A plug. The circuit diagram is given in **Figure 1**. No surprise an FT232RQ IC is found. The circuit can be set for 3V3 or 5 V I/O voltage level using a wire link but that's not accessible to the user. Hence two versions of the cable exist: 5.0 V and 3.3 V. Elektor only supplies the 5 V version. The TTL level signals CTS\, TXD, RXD and RTS\ are carried on the cable together with GND and VCC. At the other end of the cable is a 6-pin SIL receptacle you can plug onto a mating pinheader.
The conversion circuit is powered by the USB host.

Software

All drivers for the cable are available from the FTDI website www.ftdichip.com. They come in two two classes:

- Royalty-free COM PORT (VCP);
- Royalty-free D2XX *Direct* Drivers
  (USB drivers + DLL s/w interface).



Either class covers:

- Windows 98, 98SE, ME, 2000, Server 2003, XP;
- Windows Vista / Longhorn;
- Windows XP 64-bit;
- Windows XP Embedded;
- Windows CE.NET 4.2 & 5.0;
- MAC OS 8 / 9, OS-X;
- Linux 2.4 and greater.

Besides these, 'third party' drivers also exist.
Driver installation is simply a case of plugging the device in and following on-screen prompts. All instructions on FTDI driver installation are at [2].

A different use

FTDI also supply the same USB-TTL converter hardware without the moulding around the board/USB plug, and the cable attached (**Figure 2**). The miniature PCB comes with three pieces of heat-shrink sleeving you should apply yourself using a heatgun.

The bare plug and board make a nice security dongle!

All is revealed at [3]. Use is made of the ChipID technology of the FT232R in combination with the D2XX driver [4]. An ActiveX component called SafeGuard-IT is provided to help set this feature up [5]. It employs an 'asymmetric public-private key encryption scheme'.

(080213-I)

The 5-V version of the USB-TTL cable is available from the Elektor Shop as item # 080213-71.

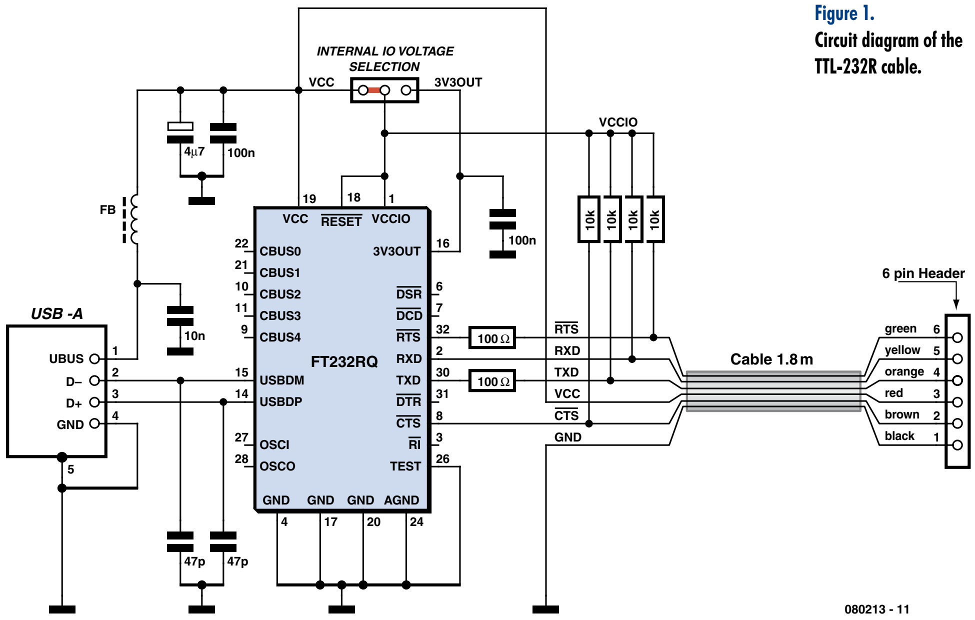


Figure 1.
Circuit diagram of the TTL-232R cable.

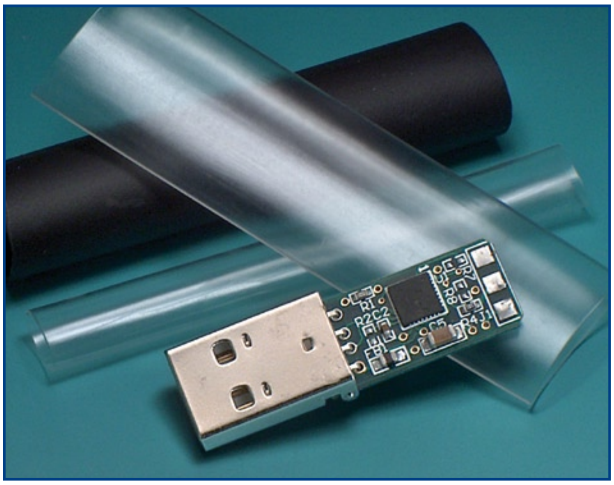


Figure 2.
The USB converter without the cable makes a very low cost security dongle for a PC.

Web Links

[1] TTL-232R cable datasheet:
www.ftdichip.com/Documents/DataSheets/Modules/DS_TTL232R.pdf

[2] www.ftdichip.com/Documents/InstallGuides/Windows_XP_Installation_Guide.pdf

[3] www.ftdichip.com/ttl232r-pcbex.htm

[4] D2XX driver page:
www.ftdichip.com/Drivers/D2XX.htm

[5] www.ftdichip.com/Projects/SafeGuard-IT.htm

Other uses for EIR

Much more than just a radio: a powerful development card for ARM7

Antoine Authier & Harald Kipp

This article explains how to use the Elektor Internet Radio board for developing your own extensions and realizing your own projects around this amazing piece of condensed technology.

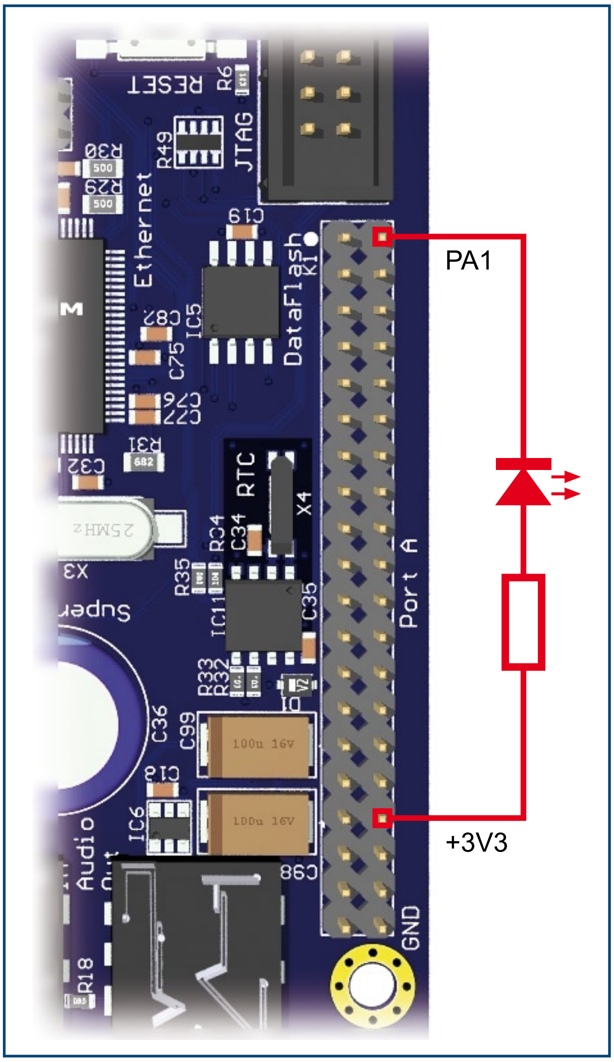


Figure 1. Connect the LED cathode to pin 2 (PA1) and the resistor to pin 34 of connector K1.

In the first part, we're going to describe the tools needed and how to use them; in the second, we'll be developing a concrete example around an LED.

Development environment

Let's start by installing the working environment. In this article, we've chosen to present the development tools available for Microsoft's Windows operating system.

Installation under Linux is possible (see the procedure described on the CD-ROM). We used Windows XP SP2 on a Pentium 4 and Windows 2000 on a Pentium 3.

Let's start by recovering the files required from the CD-ROM supplied with your kit: they are available on the 'Tools' page. When you insert the CD-ROM into your computer, a menu is displayed in your browser; click on the link named: *Tools required to develop for the EIR*.
(If this menu fails to display automatically, double click on the `index.html` file in the CD-ROM root directory)

Then in the Windows section, copy the following programs:

- `Install AT91-ISP v1.10.exe`
- `yagarto-bu-2.18_gcc(…).exe`

The others are not required for the purposes of this article.

AVR91-ISP lets you program the microprocessor at the heart of the EIR's ARM7TDMI.

Yagarto is a software suite that includes *gcc*, the C cross-compiler for ARM, and Eclipse, the programming environment.

Now let's install these applications. We've chosen to install them in a special directory for this project `d:\EIR\software` in order to illustrate our example clearly.

Nut/O.S. firmware

Now we're going to deploy the sources of the firmware. The files needed are also on the CD-ROM. Click on the *firmware* link, from the top left menu.
Nut/O.S. has to be installed first. Copy the sources by clicking the link *On your Windows PC* in the *development* section; then *ethernut-4.5.2.exe* on the next page. Run this program. We've chosen to install it in `d:\EIR\ethernut-4.5.2`.
At the end of installation, check the option *Start Nut/OS Configurator* — while we're about it, we'll set these parameters.

The configurator asks us to choose a hardware descriptor file; select the one corresponding to the EIR, called `eir10b.conf`.
Then go into the Settings page from the Edit menu *Edit>Settings* or press [Ctrl+T]. Under the tab *Build*, enter the pathname for the Nut/O.S. sources (*Source Directory*) — `d:\EIR\ethernut-4.5.2\nut` in our example.
Select the *arm-gcc* platform then configure the paths for the compilation and library installation directories, *Build directory* and *Install directory*. The install directory must be called *lib* and must be within the compilation directory, which itself must be a sub-directory of Nut/O.S. So we've chosen `d:\EIR\ethernut-4.5.2\nut\build` and `d:\EIR\ethernut-4.5.2\nut\build\lib` (see screenshot in Figure 4).
Under the third *Tools* tab you'll need to enter two paths separated by a colon. The first points to the Nut/O.S. tools `d:\EIR\ethernut-4.5.2\nut\tools\win32` and the second to those of the compilation chain installed with Yagarto, i.e. in our case `d:\EIR\software\yagarto\bin`.
Under the fourth and last tab, enter the root path for the directory that is going to contain your applications; here we've chosen `d:\EIR\ethernut-4.5.2\application` (**attention**: whatever you do, don't choose the Nut/O.S. sources' sub-directory *app*). Lastly, choose the *arm-jom* programmer, and then click OK.
Once the configuration is finished, you need to compile the Nut/O.S. libraries. This step may take a few minutes; click on *Build Nut/OS* from the *Build* menu. In the event of an error, re-check your configuration. If everything has worked properly, you can now close this program.

Our first application

Now create a sub-directory in `application` to develop our example — let's call this `blink`. Download the **080199-11.zip** archive from the article page, and unzip it to this location.
You'll note that the source code is simple (almost self-explanatory, if you've read Chapter 34, *PIO: Parallel Input Output Controller*, of the AT91SAM7SE512 documentation, downloadable from the ATMEL website [2]).
The `PIOx_PER` register allows us to enable each pin of port x of a PIO controller and disables the function of any internal peripheral that might be associated with it. As you can see here, we are configuring pin PA1 as a generic input/output.
The `PIOx_OER` register allows us to configure each pin of port `x` as an output. Here we're configuring pin PA1 as an output.
Then comes the infinite loop where the LED is alternately lit and extinguished. This action is provided by two further registers.
First off, `PIOx_CODR` which allows us to force each pin of

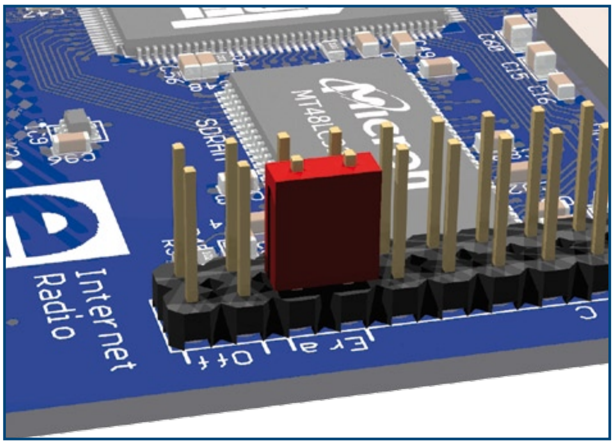


Figure 2.
The jumper for erasing the microprocessor's internal memory is fitted between pins 34 and 36 of connector K3.

port `x` to logic 0. In this situation, there is a potential drop across the LED terminals, and it lights up.
And then `PIOx_SODR` which allows us to force each pin of port `x` to logic 1; in this situation there is no longer any potential drop across the LED terminals, so it goes out.
`NutSleep` is a timer provided by the Nut/O.S. libraries, which needs to be provided with a duration in milliseconds, defined in the file `sys/timer.h`.

Now we're going to work with the Windows command interpreter in order to compile this source code. Before starting, read the box about `PATH` configuration.
So open a command interpreter `cmd.exe` and go to your application directory — `cd d:\EIR\ethernut-4.5.2\ap-`

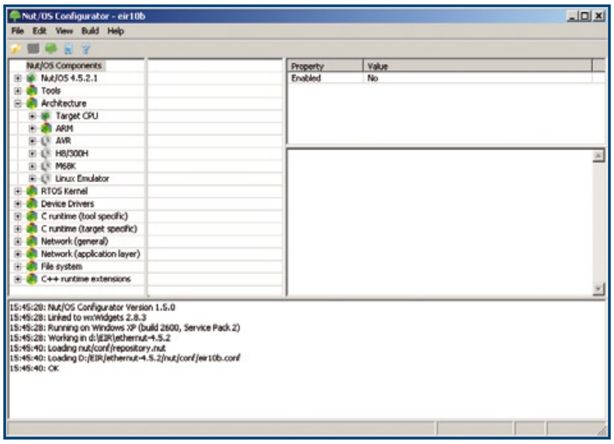


Figure 3.
Have fun with navigating the EIR hardware parameters. Do not change anything!

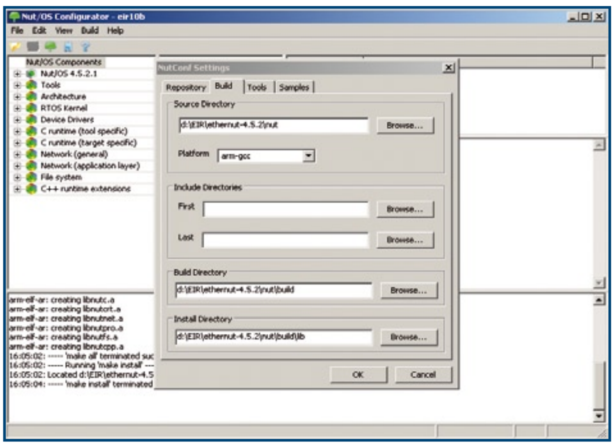


Figure 4.
For all configuration operations it is essential to fetch the absolute paths of the subdirectories.

`plication\blink` here.
Then all you have to do is type `make clean` to purge previous compilations, then `make` to build the binary file. If everything has gone OK, you'll see the file `blink.bin` appear.

A bit of hardware

With the aid of a female connector, connect the resistor and LED to Port A as per the circuit in **Figure 1**.

Binary programming on the microprocessor

Now we're going to use the `SAM-BA` tool to program the microprocessor.

Connect the USB cable between the EIR and your computer. First of all, you need to erase the microprocessor's Flash memory and restart it so it will go into USB programming mode by loading the appropriate program from its ROM. To do this, connect the jumper provided between pins 34 and 36 of connector K3 (alongside the legend `Era`, see **Figure 2**); then press the `reset` button. Remove the jumper.

Windows ought then to find and install a new hardware peripheral. Installation ought to be automatic, if `AVR91-ISP` has been installed correctly.
Run the application `SAM-BA` and select `\usb\ARM0` as the means of connection and AT91SAM7SE512-EK as target, then click on *Connect*.

Check that the tab *Flash* is displayed and select the file for programming by clicking on the *Open* icon on the *Send File Name* line. Find and select your `blink.bin` binary. Click on *Send File*. Once this operation is over, the software asks you if you want to block some regions of memory; answer *No*. You can also re-check that everything has gone OK by clicking on *Compare send file with memory*.

Important: Now run the script *Boot from Flash (GPNVM2)* by selecting it from the list and clicking *Execute*. You can close the application. Then press the *reset* button on the EIR: the LED should flash.

A second example

We also provide you with the archive **080199-12.zip** (downloadable free from www.elektor.com/EIR) with another example that let's us make the LED pulse, thanks to the microprocessor's PWM peripheral.
You'll note that the archive contains two directories in its root. The version of Nut/O.S. supplied on the CD-ROM does not contain the description of the PWM peripheral for the AT91SAM7SE. So you need to update your source tree and extract the files `at91_pwmc.h` and `at91sam7se.h` to `d:\EIR\ethernut-4.5.2\nut\include\arch\arm` (the second file already exists, you'll need to overwrite it).
Then create a sub-directory `pulse` in your `application` subdirectry and unzip the corresponding source code.
The procedure for compiling and programming remains the same, see above.

The source code describes a simple application for the microprocessor's PWM module; refer to Chapters 34 & 37 (*Pulse Width Modulation Controller*) of the microprocessor documentation.

Getting back to the basic firmware: the radio

In the directory `firmware` of the CD-ROM you'll find the archive `webradio-1.2.1.zip`. Then all you need do in order to listen to the radio is unzip this into your application folder, compile it, and program your EIR with the `webradio.bin` binary generated.
Don't use version 1.2.0, it doesn't compile.

Enjoy your development. And if you have produced an interesting application, don't hesitate to tell us all about it!

Equipment required

– EIR kit
– USB cable type A male – type B male
– stabilized 12 V power supply
– red LED
– 180 Ω resistor
– 2×20 pin female socket strip for headers.

(080199-I)

Source code and applications

The information published here is based on the use of the source files and applications contained on the kit CD-ROM.

Under Windows, take care that the compiler and tools executed by the command interpreter are indeed the Yagarto ones. To reduce the risk of confusion following the installation of multiple compilation chains, always make sure you specify absolute access paths for the tool executables, and during the configuration stages, enclose them in quotes — e.g., "c:\program files\yagarto\bin".

Setting the PATH

We recommend you create a batch file to contain the update command for your (environment variable) PATH so that Windows will go there to find the Nut/O.S. and Yagarto tools.

You need to store this script in your `PATH` default paths list; call it for example `seteirenv.bat`.

In our example, it will contain the line `set PATH=d:\EIR\ethernut-4.5.2\nut\tools\win32;d:\EIR\software\yagarto\bin;%PATH%`.

Run this before invoking the Nut/O.S. or Yagarto tools.

Bibliography and web links

[1] www.ethernut.de/en/hardware/eir

[2] www.atmel.com/

elektor/intel 'unplugged': results revealed

Elektor readers rise to the Intel Challenge

Wisse Hettinga

In our November 2007 edition we posed you the question, how can one power a notebook computer for half an hour without batteries or a mains supply? Actually the original challenge came from Intel, when the firm first raised this issue with a number of European universities. This gave our international editorial board an idea: why not get our readers involved as well? *Elektor* is now read in ten languages by an army of electronics experts nearly a million strong. And if this contest didn't arouse some reaction, what on earth would?

No worries — the reactions came in by the shed load, including some absolutely way-out ideas. What's more, this contest was a fantastic opportunity for researchers in 'blue skies' domains such as 'free energy' and other 'alternative' approaches. Here was their moment to demonstrate what their theories were truly worth. We might have expected, for instance, some means of exploiting 'earth currents' or perhaps finding a way to harvest RF energy from a 2 km long antenna, then transform this into something usable. But nothing of the sort! A fact even more remarkable was that readers also scorned the 'obvious' starting places such as solar or wind energy…

It was apparent that the greatest appeal of mains and battery-free power was to our German readers. By a significant factor this was the group that produced the greatest number of creative solutions. Take for instance the contribution from Lothar Miller. On a visit to a Christmas market he and a friend came up with the wild idea, why not simply recycle the awesome sound energy of pealing church bells?

No waiting, job done. He constructed a kind of 'proof of concept' demonstration from two air-coupled loudspeakers and demonstrated clearly that the electrical output from a reverse-connected speaker was sufficient to illuminate a lamp bulb. Achieving the same result in the field, from actual church bell sound energy, was clearly going to need a little more development work. So for now his ingenious set-up remains unfortunately just the preliminary stage of a working prototype.

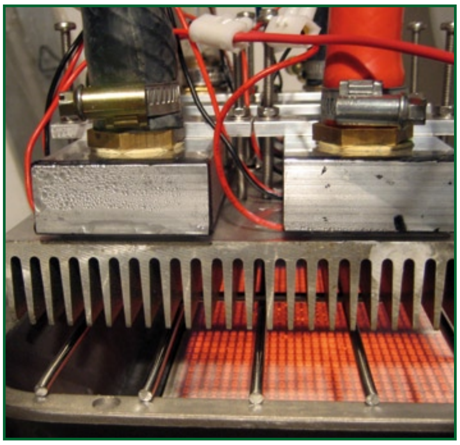
Alexander Westhoff sought a simpler solution, based around existing technology. This *Elektor* reader opted for using the brand new HydroPak (a carry-pack housing a water-activated fuel cell device). The underlying idea, albeit not entirely a new one, is to turn hydrogen into electricity, a process that will not be launched onto the commercial marketplace until later this year. So it's understandable that Mr Westhoff is not quite ready yet to grant us a demonstration…

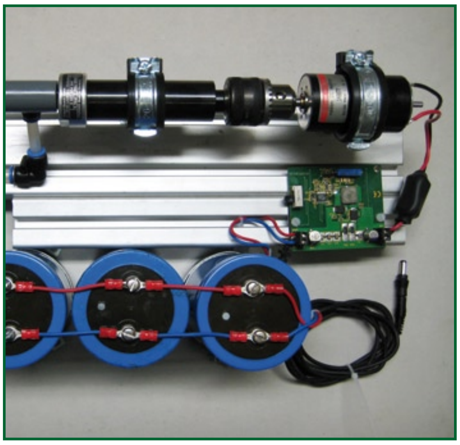
A somewhat greater amount of original engineering input went into the offering from Michael Rösseler and Matthias Mikysek — to produce electricity out of thin air! A motor driven by compressed air operates a dynamo, the output of which is groomed by a DC-DC converter to produce sufficient voltage for a notebook. Convincing evidence that this works in practice can be seen in a video that the pair have uploaded to YouTube (check out 'Elektor' and 'Perpetuum Calculum').

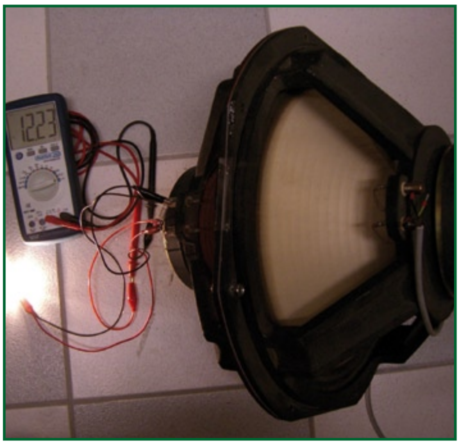
Zany indeed but probably the wackiest idea came from Jürgen Depke — at least in terms of practicality. He rejected simple solutions like bicycle dynamos and instead clicked on eBay to order some Peltier elements from far-off China. Then he set them up in reverse, as a current generator in fact, and it all worked! This has got to be pure genius…

Now comes the agonising part, to choose the absolute winner out of so much creativity. Even getting the jury to agree on the top-ranking solutions was not easy, as all of the contributions had their own particular strong points. Nevertheless the unconventional process chosen by Jürgen Depke for producing electrical energy immediately earned him the reward of a brand new laptop. You've probably guessed which idea came second — yes, the compressed air gizmo. Michael Rösseler and Matthias Mikysek will be getting a visit from the postman — to deliver a Rangeman Next wireless router by Netgear. Lothar Miller earns a special prize for originality and wins a router too. And if Alexander Westhoff can demonstrate even just a single prototype of a fuel cell-driven laptop, industry will be beating a path to his door.

(080067)







Air Power, Sound

Winning themes of our Notebook

Dr. Thomas Scherer

In November 2007 this magazine launched a competition under the title 'The Challenge'. The task was to power a laptop in an unconventional way. The cream of the contributions proves there is almost no limit to our readers' creativity.

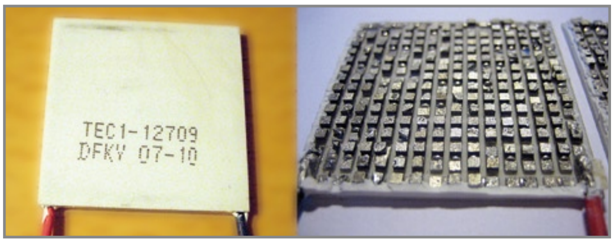


Figure 1. Internal and external views of the type of Peltier element used by Jürgen Depke. Note the multiple sub-elements connected electrically in series and thermally in parallel.

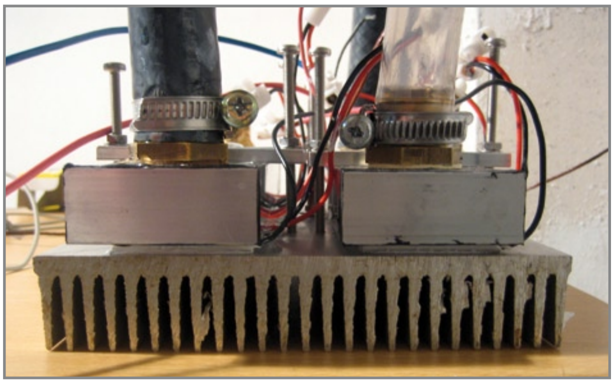


Figure 2. The Peltier elements are fixed between two water-filled square channels (above) and a substantial aluminium heatsink (below).

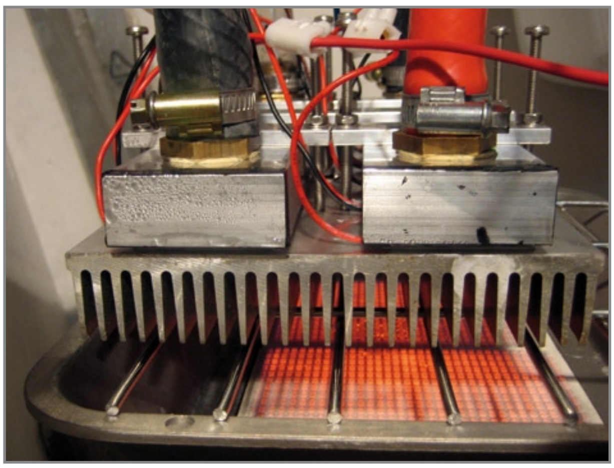


Figure 3. Depke's power generator under test: a gas burner heats from below while cold mineral water flows through the pipe system above. Water condensation results from the coldness and burnt gas.

As mentioned earlier, our contestants disregarded conventional low-hanging fruit (such as solar, wind and water power) in favour of exploring genuinely new territory. It's time now to go over to the winners' podium and pay tribute to the top three contributions.

First Prize: Heat

Jürgen Depke astonished us in the stylish yet practical way he deployed a physical principle [1] little exploited outside the field of space flight. As is generally known, with Peltier elements [2] an electrical current flow leads to heat transfer. It also works in reverse, so that a temperature difference will cause electric current to flow. Before we all get too excited it must be said that the efficiency of a Peltier element is not very high and prize winners should be aiming not at a few milliwatts but something around 30 W! Assignments like this call for some serious head scratching—or else the singleness of purpose that Jürgen Depke has. Observing the maxim 'biggest is best' and blessed with plenty of confidence he ordered from a Chinese supplier ten of the largest Peltier elements that he could find (see **Figure 1**). Each of these elements was supposed to be rated at 136 W of electrical energy. The burning question was whether they would work in reverse mode.

Eventually the eagerly awaited consignment arrived, along with a major disappointment: one of the ten elements was defective. Anxiously Jürgen worried whether the remaining nine elements would deliver enough power...
One thing was clear—to produce maximum electrical output the temperature difference had to be as large as possible. Our champion reckoned cold water would be just the job for the cool pole of the element, whilst a gas burner would make an ideal energy source for the hot side.
The water issue seemed straightforward enough but was heating components as delicate as Peltier elements with a gas burner such a good idea?

Fortunately Depke is accomplished not only in physics and electronics; his competence extends to metal-bashing as well, as **Figure 2** proves. The construction is a kind of

& Heat
competition

sandwich composition—the lower component is a large, thick aluminium heatsink with ribs or fins, which subsequently will be heated with a gas fire panel. Above this lie two well-sealed pipes or channels of square cross section. Fitted at either end of the upper sides of these pipes are the input and output water connections. Mounted between them are the cherished Peltier elements, all smeared with plenty of heat transfer compound (heat conductive paste). Note the loving attention to detail: the water flow in the two pipes doubles back on itself so there is not the minutest chance that the aluminium heatsink might heat up unevenly!

Figure 3 indicates at last how the set-up operates in practice. Depke arranges for bottled mineral water with a temperature of 6 °C to flow through the pipes. It works out that the burning gas raises the temperature of the heatsink such that 110 °C is measured on the upper side. The temperatures observed are within supportable limits for Peltier elements and the temperature difference was entirely acceptable at more than 100 °C. Using a load of two 12 V halogen lamps each rated 20 W, Depke was able to measure a constant nominal voltage of 20.12 V at a nominal current of 1.53 A. In simple arithmetic his unconventional power source thus manages to deliver just over 30 W. As far as voltage is concerned, we are sure that a brand new gas canister would run a laptop for well over half an hour. You can admire his handiwork in all its glory in the photos on his website at [3].
In our opinion Jürgen Depke has won his new laptop most deservedly — and in an extremely interesting way. Our warmest congratulations!

Second Prize: Air power

There's nothing airy-fairy about this contribution. Right now serious consideration is being given to harnessing renewable energy on a large scale and storing it in underground caverns (for instance as compressed air pumped into disused salt mines). Afterwards suitable motors and generators can turn energy of this kind into electricity as and when required. A similar notion must have gone though the minds of Michael Rösseler and Matthias Mikysek last year when they decided to devote the winter to meeting the Elektor challenge. Their goal was to convert (compressed) air into (electrical) energy. What's more, they succeeded!
After they had fiddled about, tested and finalised a functioning prototype, they sent us a PDF file of documentation. From this we extracted **Figure 4**, which is a kind of block diagram of their 'energy transposer'. A compressed air reservoir provides air, via a pressure reducer, to a drive a pneumatic motor. The pressure reducer provides a regula-

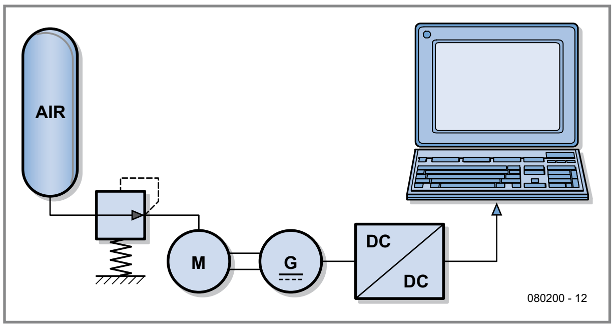


Figure 4.
'Schematic' of an air-to-electricity converter by Michael Rösseler and Matthias Mikysek.

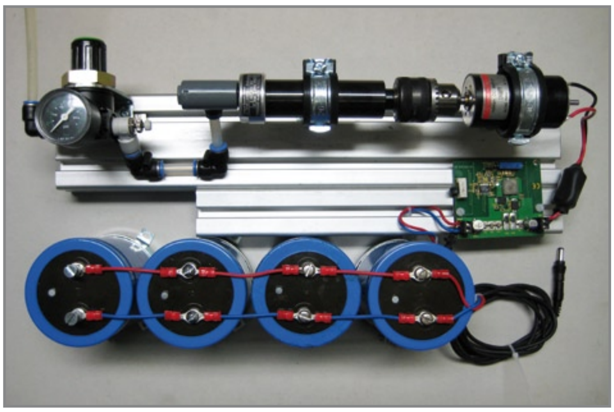


Figure 5.
Construction of an air-to-electricity converter: pressure reducer (upper left), compressed air motor (upper centre), generator (upper right), DC-DC converter (centre right) and a smoothing buffer of electrolytic capacitors (below).

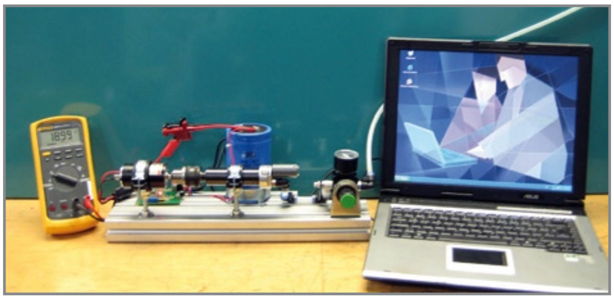


Figure 6.
Air operation of a laptop in action: the photo shows an earlier prototype, which although equipped with only a single buffer capacitor still managed to deliver stable power to the laptop when not under heavy load.

ted drive pressure to the motor (in this case 6 bar), regardless of variations in the input pressure delivered to the reservoir. The motor is naturally mechanical and coupled to a generator; with the electrical energy produced going to a DC-DC converter to produce the correct voltage for a laptop computer.
So far, so theoretical. It's perfectly obvious that a proposition of this kind *ought* to work but the question is whether the theory would hold out in practice. But it certainly does and the pair turned the plan seen in **Figure 4** into the practical set-up of **Figure 5**, which contains everything apart from the compressed air reservoir and the laptop. To assure the voltage required by the notebook, buffer electrolytics with a total capacity of a mighty 22.4 mF are fitted at the output of the DC-DC converter.
According to Rösseler's und Mikysek's calculations on the basis of a generously rated 120 W motor an industry standard 50 litre compressed air canister and a filling pressure of 200 bar should provide 37 minutes of operation. If anyone is desperate to see the exact calculation, here it is. According to Boyle-Marriott [4] 50 litres at 200 bar correspond exactly to 10,000 litres of uncompressed air; the motor with a nominal power rating of 120 W requires nominally 4.5 l/s (litres per second). That means the contest requirements were in fact exceeded by seven minutes!
To make sure the impartial Elektor scrutineers could see that the set-up worked genuinely, honestly and actually, Michael Rösseler and Matthias Mikysek sent in not just a photo (**Figure 6**) but also uploaded a video to YouTube [5]. We are totally convinced, finding their handiwork very attractive and fully deserving of the second place in our contest!

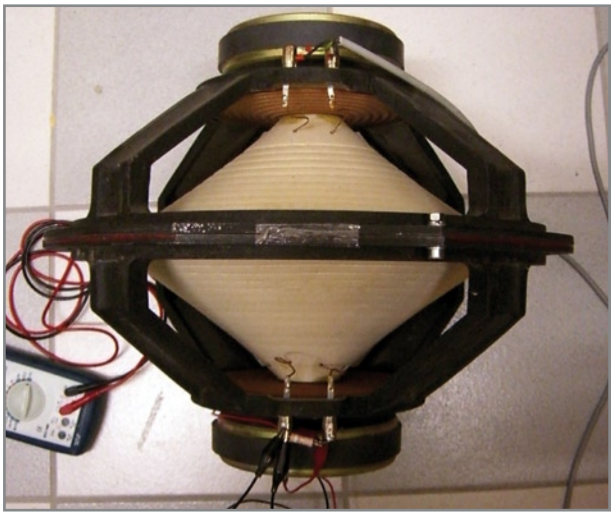


Figure 7.
Construction of a noise recycler: Noise generator (above) and directly connected (acoustically coupled) noise-to-electricity converter of the same kind (below).

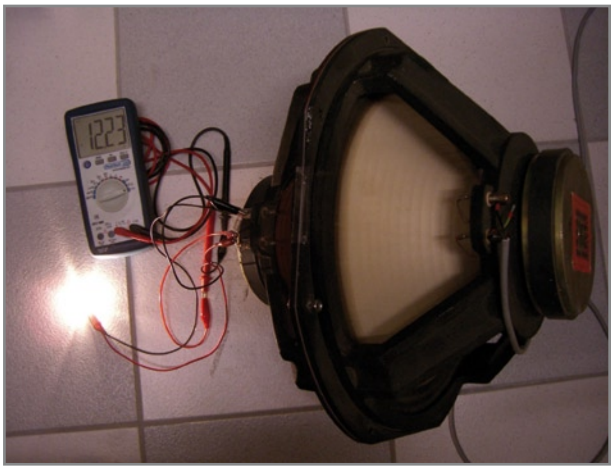


Figure 8.
Proof of concept: the sound wave generator drives a noise recycler. The 20-W halogen lamp bulb is burning too bright for comfort!

Third Prize: Sound

We also received some contributions that tended closer to theory than practice, making it rather difficult to demonstrate how they would boot up a laptop, let alone power it for a whole thirty minutes. In some cases we had more than a little doubt. Now and again we were also obliged to raise an eyebrow at the unconventional techniques people were proposing. This was precisely the case with Lothar Miller's contribution, differentiated by its amazing 'noise recycling' strategy.
Miller described his visit to a traditional market last Christmas, where he noticed how the booming reverberation of the church bells completely masked all conversation and reduce just about all other sounds to nothing. This set him wondering whether the energy in those deafening chimes could somehow be turned into enough electricity to power a laptop. Well, somebody had to think of this!
No sooner thought than done. Lacking a peal of actual church bells in his workshop, Lothar made do with a 40-cm bass loudspeaker by the respected firm Visaton and (mis) used this as a church bell simulator. To produce a decent audio level the loudspeaker was fed with sinewave tones sourced from a function generator (a Voltcraft MXG-0802 from Conrad Electronics) and amplified substantially by a power mixer (MXH300 by Behringer). A second loudspeaker of the identical type served as sound-to-current converter. Anyone interested in reproducing the set-up should take a look at the construction photo in **Figure 7**.
Two bass loudspeakers screwed tightly against one another—is this going to work? Lothar Miller is not short of proof and has furnished a photo (**Figure 8**) of a 20 W halogen bulb driven by a sound wave converter producing just over 12 V. Which is plenty enough energy for surfing the Net with a notebook.

Whilst this solution fails to demonstrate a practical means of coupling sound wave converters to church bells, we'll overlook that omission and concentrate on Lothar's wildly imaginative approach. On that basis his 'Proof of Concept' is certainly worthy of the Third Prize, don't you agree?

(080200-1)

Web Links

[1] http://en.wikipedia.org/wiki/Thermocouple

[2] http://en.wikipedia.org/wiki/Thermoelectric_cooling

[3] www.depke.info/html/elektor_.html (in German)

[4] http://en.wikipedia.org/wiki/Ideal_gas_law and http://en.wikipedia.org/wiki/Boyle%27s_law

[5] www.youtube.com/watch?v=tJbHUccJBYc

Thermo-Snake

a 128-channel USB'ed datalogger
for a 1-wire thermal monitoring network

Carlo Tauraso

It's often necessary to monitor the temperature of different rooms. For example in a green-house with various kinds of plant, in a wine cellar, on a motor surface or simply in your home. There are commercial dataloggers designed for this but they come at a price. Here's a DIY alternative with real-time monitoring and recording capabilities.

Commercial temperature loggers typically have a limited number of channels. Normally, every channel is self-reliant so you have to install a communication line for each one. With Thermo-Snake you can connect from 1 up to 128 digital thermometers like the Dallas DS18B20 directly on a single two-wire cable. All temperature values are recorded on your PC through a USB port without memory space limitation. Using the software manager developed for the project you can monitor the temperature in real time and set an alarm threshold value for each individual thermometer. All temperature values are recorded with date and time stamps in a text file that you can simply export to other applications for graphic diagrams and statistical analysis. If a temperature exceeds the alarm threshold value the PC beeps and the relevant cell on the data grid becomes red. This project is inexpensive — we reckon it will set you back less than £ 15 for a minimal 4-channel datalogger configuration, and it is very simple to make.

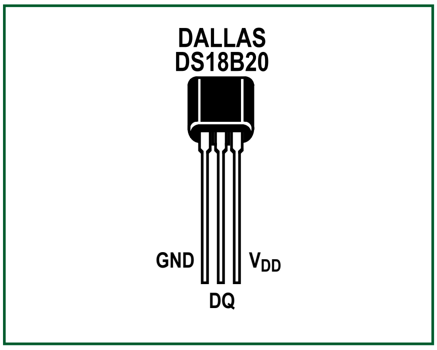


Figure 1. DS18B20 appearance and pinout.

Thermo Network with the DS18B20

The DS18B20 Digital Thermometer from Maxim ICs (formerly Maxim/Dallas) provides 12-bit centigrade temperature measurements. The device, illustrated in **Figure 1**, communicates over the '1-

Wire' bus that by definition requires only one data line and GND (ground) for communication with a microprocessor. It has an operating temperature range of –55 °C to +125 °C and is accurate to ±0.5 °C over the range of –10 °C to +85 °C. A very interesting thing about the DS18B20 is its ability to take its supply power directly from the data line ('parasite power' Maxim calls it), eliminating the need for an external power supply. Also, each DS18B20 has a unique 64-bit serial code, which allows multiple DS18B20s to function on the same bus. So, it is simple to use one PIC18F2550 microcontroller to control many DS18B20s distributed over a large area. With these features you are able to make a real thermometer network.
The DS18B20 pinning goes like this:

Pin	Description
1	Ground
DQ	Data In/Out. Open-drain 1-Wire interface pin. It needs a pull-up resistor (4.7 kΩ) to VDD. In parasite power mode it also provides power to the device.
VDD	Power supply voltage (+5 V nominal)

In 'parasite power' mode, VDD must be grounded, i.e. VDD and GND connected together, so the PIC uses only two wires (DQ + GND) to communicate with the DS18B20. This mode is very useful for applications that require remote temperature sensing. There is only a little problem to solve. When the DS18B20 is performing temperature conversions, the operating current can be as high as 1.5 mA. For small networks, the PIC18F2550 digital output and a resistor pull-up on DQ are sufficient. In other cases, to avoid an unacceptable voltage drop across the resistor, it is necessary to provide a strong pull-up on the DQ line whenever temperature conversions are taking place. The image in **Figure 2** shows a typical configuration with a MOSFET pull-up to ensure that the DS18B20 has sufficient supply current.
Each DS18B20 contains a unique 64-bit code stored in ROM. So, the PIC can directly interrogate each sensor on the Thermo-Snake. You can create your personal network through a software phase called 'Device Learning'. On the board there is a three-pin strip connector. Insert the DS18B20 and then 'learn' it by a click. The software records the 64-bit code and you can associate different information to it: position, mnemonic description, alarm temperature threshold. As illustrated in **Figure 3**, the least significant eight bits of the ROM code contain the DS18B20's 1-Wire family code: 28h. The next 48 bits contain a unique serial number. The most significant eight bits contain a cyclic redundancy check (CRC) byte that is calculated from the first 56 bits of the ROM code.

Figure 4 shows the software during "Device Learning". Simply insert the device pins into the 3-way receptacle on the board, click on the 'Find' button and you will see the 64-bit serial number.

Caution. The Thermo-Snake two-wire cable with the DS18B20 devices on it must not be installed in the vicinity of high-voltage or mains wiring, or fed through mains conduit. The connection of each DS18B20 sensor to the cable must be fully isolated with heat-shrink sleeving.

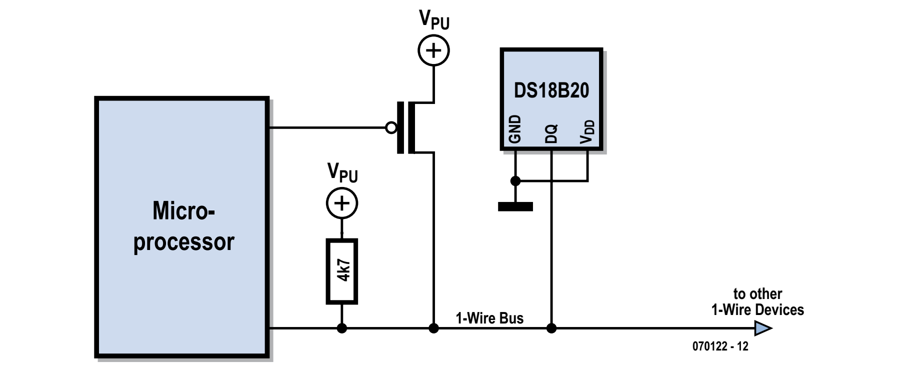


Figure 2. Connecting the DS18B20 temperature sensor on to a 1-Wire network. (courtesy Maxim IC)

8-BIT CRC		48-BIT SERIAL NUMBER		8-BIT FAMILY CODE (28h)	
MSB	LSB	MSB	LSB	MSB	LSB

Figure 3. The format a DS18B20 will use to send messages over the 1-Wire bus.

Circuit diagram

The design whose surprisingly simple schematic is shown in **Figure 5** is based the 'lowest' USB-savvy PIC micro, the PIC18F2550. The 1-Wire Bus is connected to pin RA1. The 4.7 kΩ pull-up resistor in position R2 is essential for correct communication and the 'parasite power' supply. PORTA pins are all digital I/O (you know, ADCON0 = 0x00 and ADCON1=0x0F). On the 3-way socket strip, K3, pin 1 (GND) is linked to pin 3 (VDD) allowing you to insert the DS18B20 device either way around as long as pin 2 (DQ) remains in the middle.
For the 1-Wire bus we use a simple two-way pinheader, K2. If you want to

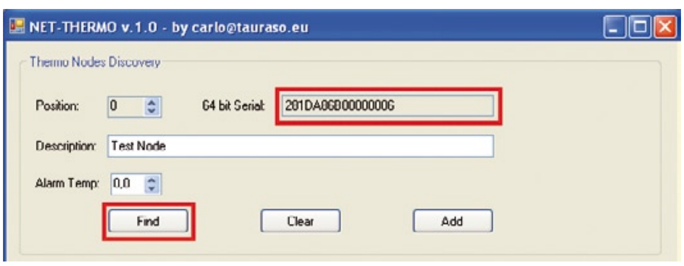


Figure 4. Device Learning phase.

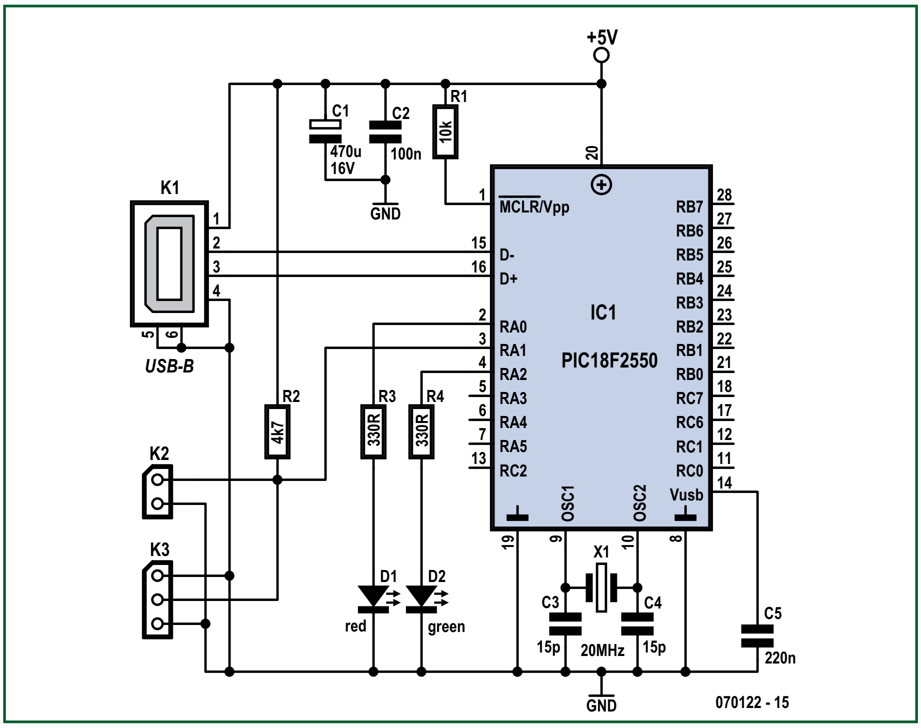


Figure 5. Circuit diagram of the Thermo-Snake central control unit.
The string of DS18B20 sensors (up to 128!) is connected to K2. K3 is for learning.

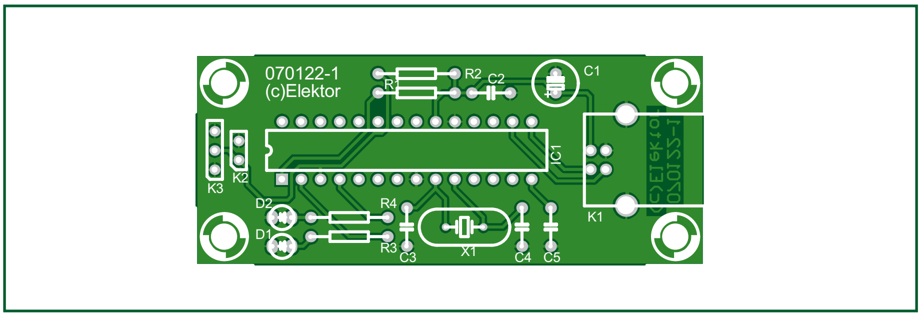


Figure 6. Component mounting plan of the PCB designed for Thermo-Snake. The copper track layout is a free pdf download.

box up the board, wire K2 to a cheap 3.5-mm jack socket.
For USB applications there exist several different sets of power configurations. In this project we use the 'Bus Power Only Mode', so all power (5 V) is drawn from the USB host.
A 20-MHz quartz crystal, X1, is used to generate the system clock. For Full Speed operation, the clock source must be 48 MHz. The 18F2550 device includes a Phase Locked Loop (PLL) multiplier circuit designed to produce a fixed 96 MHz reference clock from a fixed 4 MHz input. Here we use the prescaler (PLLDIV2, DIV1, DIV0) to divide the 20 MHz xtal frequency by 5. The resulting 4 MHz goes to the PLL and after up-conversion the 96 MHz output is divided by 2 using CPUDIV1 and CPUDIV0 to generate the required clock for the MCU core and USB module. Capacitors C3 and C4 are dimensioned according to the Microchip datasheet.

LEDs D1 and D2 communicate the state of the circuit to the user. When D2 (Green) is on, the USB device is 'enumerated' correctly. D1 (Red) indicates a temperature conversion so it blinks during monitoring. R3 and R4 limit the current flowing through the LEDs.
PIC port pins RC5 and RC4 are directly connected to the D+ and D–USB data lines. There are two fundamental bus speeds: Full (pull-up on D+) and Low (pull-up on D–). An internal pull-up is used on D+ to specify full-speed mode, scrapping another discrete component from the BOM.

Construction

The printed circuit board designed for the Thermo-Snake control board is shown in **Figure 6**. Ready-made boards can be ordered from www.thepcbshop.com a.s.a.p. after this publication.
There are no critical parts and you should be able to find them in any electronics shop. Use 3-mm LEDs, ceramic capacitors (except C1), 0.25-watt resistors and a socket for the PIC micro. You have to be careful with the USB connector as an error can cause a short or break on the USB port of your PC. On the prototype a type B USB connector was used for easy connection to a standard A-B USB cable. The final prototype is shown in the introductory photograph.

Software

There are two pieces of software for this project: PIC and PC. The PIC software comes as a commented source code listing and is contained in archive file **070122-11.zip** you can download for free from the Elektor website. The PIC firmware was developed using the MikroC compiler from MikroElektronika

COMPONENTS LIST

Resistors
R1 = 10kΩ
R2 = 4kΩ7
R3,R4 = 330Ω

Capacitors
C1 = 470µF 25V
C2 = 100nF
C3,C4 = 15pF
C5 = 220nF

Semiconductors
D1, D2 = LED, 3mm, low current
IC1 = PIC18F2550, programmed, Elektor SHOP # **070122-41**.
X1 = 20MHz quartz crystal
DS18B20 temperature sensor, quantity as required (max. 128).

Miscellaneous
K1 = USB-B connector
K2 = 2-way SIL pinheader, lead pitch 2.54 mm
K3 = 3-way SIL socket, lead pitch 2.54 mm
PCB, ref. **070122-I** from www.thepcbshop.com
PCB artwork file, free download # **070122-1** from www.elektor.com
Project software: PIC hex and source files, PC executable. Free download # **070122-11.zip** from www.elektor.com

which seems to take the embedded world by storm.
If you wish to program your own microcontroller and/or make changes to the firmware code, be sure to set up the PIC programming parameters correctly (they're sometimes called fuses or fuse bits). These may differ between programmers!
USB-wise, Thermo-Snake is a HID (Human Interface Device) so the installation is very simple: connect it to a free USB port! All Microsoft operating systems from Win 98SE onwards will recognise the device immediately and drivers are integrated into the O.S. After that, click on the NET-THERMO icon to configure and monitor your network.

NET-THERMO is a dot-NET 2.0 project so *ho-hum* it is ready for Windows Vista. This software has three principal functions: thermal network configuration, real-time monitor and temperature recorder. The first permits to add, modify and delete network nodes.

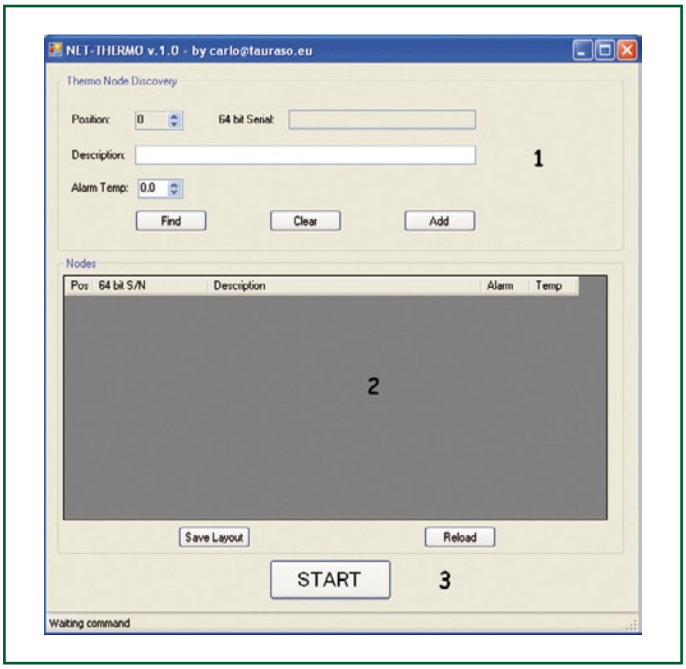


Figure 7. Main screen presented by the Thermo-Snake PC software.

Click on the icon and you will see the main form in **Figure 7**. You first have to pass the 'learning phase'. Look at the area marked '1'. Insert the node (DS18B20) you want to add into the 3-way receptacle on the Thermo-Snake board. Then click on the Find button. In the '64-bit Serial' field you will see the 64-bit unique code needed for each node identification. This is the primary key of your network database. You can integrate this code with other information like the physical position, a mnemonic description, and a temperature value threshold. When you have finished, click on the Add button. All information will be added to grid position 2. Repeat these two steps for all nodes you want to add to your network, making sure you do not mix up the 18B20 devices. When you want to clear the fields, click on the Clear button. **Figure 8** shows a three-node network example.

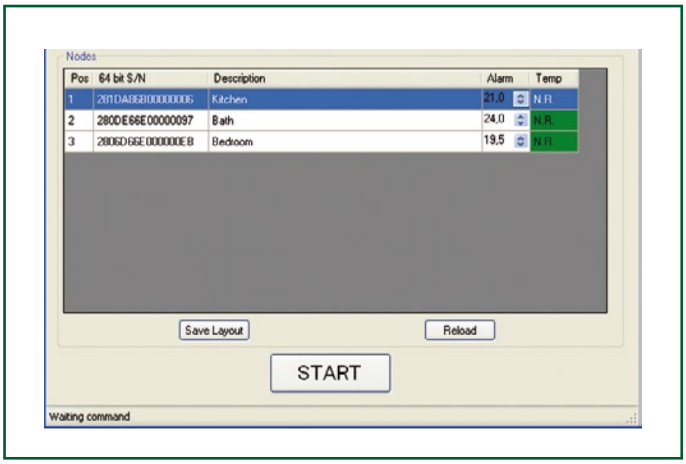


Figure 8. Here, Thermo-Snake has three thermal sensing points installed in the home.

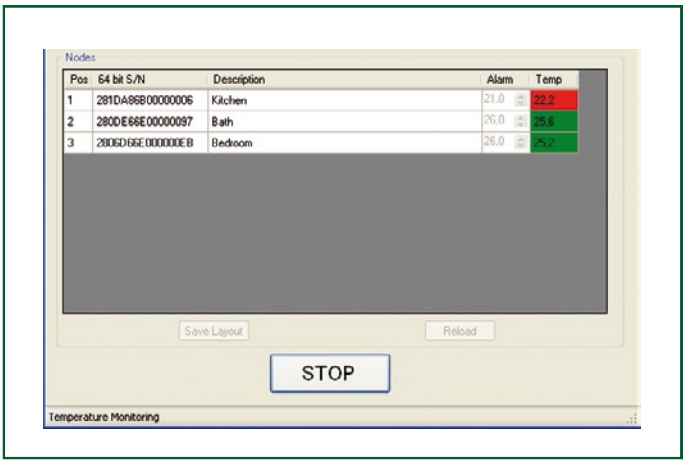


Figure 9. Alarm! The temperature in the kitchen has exceeded the user-defined threshold.

You can modify: position, description and alarm threshold directly by selecting the relative cell and pushing the F2 button. Naturally, the 64-bit code is read only. When you have finished, to configure the network you can save it with a click on the Save Layout button. This software saves all configuration information in an XML structure called rete.xml. You can delete a node simply by selecting the relative row and pushing the CANC button. If you make a mistake you can reload the configuration saved in the XML structure clicking on the Reload button. You can sort all records by position, by description, by 64-bit ID, pushing on the relative column headers.

When you are ready to start monitoring, click on the Start button (the button label changes to 'Stop'). During monitoring all controls are disabled, you can only stop the recording process by clicking on the Stop button again. The temperature values ('Temp' column) will be updated in real time. When a DS18B20 does not respond, the label 'N.R.' will appear. When a temperature value exceeds the Alarm threshold, the relative cell colour changes from green to red. **Figure 9** shows a temperature alarm on the first node.

Finally, click on the Stop button. Browse the program directory and you will see a text file. The file name format is:

```
T day-month-year-hhmmss
```

Table 1. File format for time stamp

Field1	Field2	Field3	Field4
DATE	TIME	NODE ID	TEMPERATURE

It represents the date and time when software monitoring started, see **Figure 10**.
The file format is very simple as shown in **Table 1** and **Figure 11**.
You can export data to different kinds of applications for drawing diagrams.

The (long) cable

When you build the Thermo-Snake you can use a simple two-wire cable, soldering each DS18B20 directly on to it and providing electrical isolation, of course. Alternatively, you can use commercial cables like the WRDOWY17 from Crystalfontz [1].

In private homes, distributed temperature monitoring can help you discover 'wasters' and cut down on heating costs. In the industry, it allows you to have a single overview of what's happening at many temperature measuring points along the production line. Have fun with Thermo-Snake.

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Web Link

[1] www.crystalfontz.com/products/cables/WRDOWY17_images.html

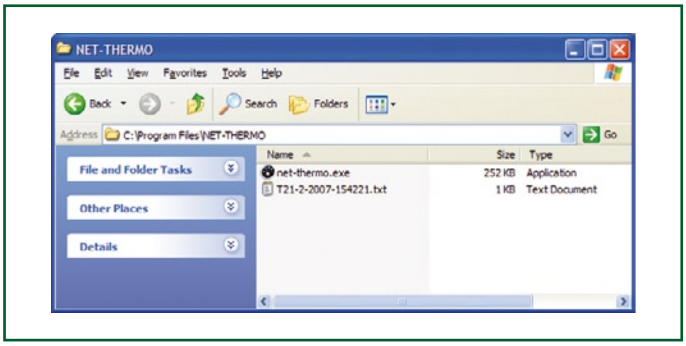


Figure 10. Showing the location and format of the log file containing the measured temperatures.

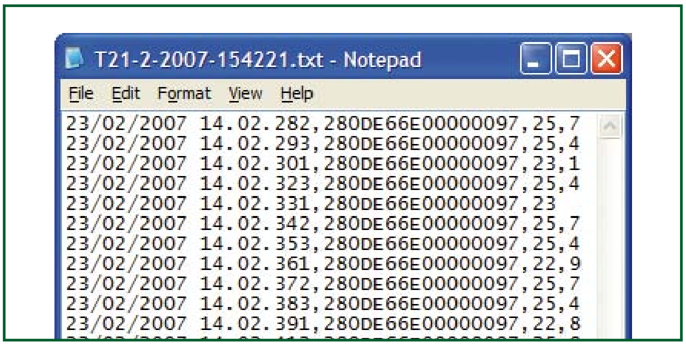


Figure 11. Temperature information measured and logged by Thermo-Snake is Time & Date stamped and can be exported to statistics programs or spreadsheets to make nice graphs.

Mains Adapters

The case of the treacherous LED...

Dr. Thomas Scherer

I notice on the cover of an old copy of Elektor in large print it states: 'Equipment is only as good as its power supply'. Even though that particular edition is now more than thirty years old the statement is as true today as it was then.

Relations

Fourteen days ago I took a call from my wife's cousin Tina; she was having trouble connecting to the internet. I pictured their network setup which I had installed a few years ago: an internet router with Ethernet connection to an access point providing WLAN coverage for all the family's laptops. It appeared that none of the lights were lit on the access point. The usual suspects had already been ruled out: the mains adapter had not been accidentally pulled out and power was definitely available at the wall socket. On the face of it this was almost certainly a hardware failure, either a mains adapter or one of the pieces of equipment or maybe both; it was difficult to be more specific over the phone.

The next time they visited they had the access point and mains adapter with them so I was able to run some tests. Firstly plug in the mains adapter, check the output voltage… nothing; this was going to be easier than I had thought. A rummage through my drawers did not produce a suitable replacement adapter capable of supplying 5 V at 2 A so for testing I rigged up a bench supply with the output set accordingly. The access point sprang into life and I could connect to it using my laptop. The diagnosis was clear; access point OK, mains adapter dead (makes a change, it's usually the expensive part that breaks first!). This adapter was totally encapsulated so it could not be fixed. I identified several suitable replacements advertised on the website of a local electronics store; this was the quickest and cheapest solution to the problem. It was now only necessary to carry out an on-site reconnection of the equipment with the new adapter before harmony (and internet access) could again be restored to the family.

Two weeks later

It's 10 pm on a Sunday evening and after a busy weekend it's usually a good time to sit down, check my inbox and look for any interesting new posts in the forum on the Elektor website. To the left of the screen next to the list of E-mail accounts I notice an unwelcome icon indicating that the last attempt to access the mail server was unsuccessful. A click on 'receive' does not clear the problem and while attempting to surf, the browser confirms that there is indeed no internet connection.

Watson, Bring my spy glass

What's going on? Maybe the router had somehow reset to its factory settings? Using the browser to access the router's setup page indicates that the problem is more serious; it is not possible to view this page.

I looked behind the monitor where my eight-way Gbit-hub is hidden and see that the power LED is lit but all of the other port LEDs are off.

Perhaps the hub firmware has crashed? Disconnect the mains plug, wait a few minutes then plug in again… still only the power LED was lit.

It was time to disconnect the equipment and take a closer look on the bench. It didn't look as if we had the same problem as Tina, the power LED indicated clearly that the adapter was supplying power.

Just to be sure I measured the output voltage and although slightly low (7.39 instead of 7.5 V) it was certainly in the ball park and should not be the source of the problem. As a test I switched the adapter output to 9 V and tried again but still only the power LED lit up.

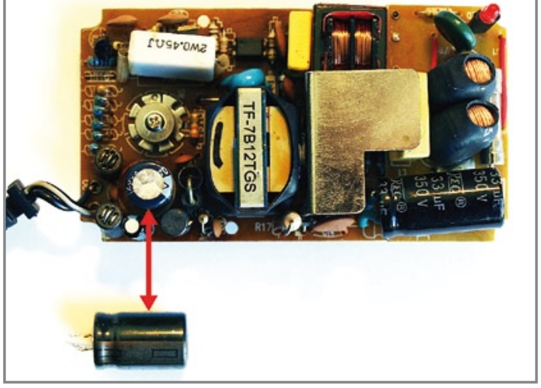
It was fairly easy to identify two step-down regulators on the hub's circuit board, one of them was producing 3.32 V which is a fairly typical supply value for modern LSI devices while the other had an output of only 1.18 V. This value seemed way too low to power the chips on the PCB.

With the finger of suspicion now pointing back at the mains adapter it was time to break out the bench supply again, this time set to 7.5 V with a 1 A current limit. Bingo, the hub booted up and all the LEDs lit up as if Christmas had come. It seems that the mains adapter had not been delivering the goods despite the power LED indicator.

Mains adapter

With the adapter safely disconnected from the mains and its cover off I had a closer look inside to see if anything was obviously amiss. This unit had performed flawlessly for the last three years and seemed in good condition but my eye was drawn to an electrolytic output capacitor which had a 'lightly toasted' appearance. More disturbing were the bulges in its aluminium casing and swelling of the rubber gasket around the leads, this device had at some point obviously sustained a high internal pressure and over-temperature event.

The picture shows the PCB with a new capacitor fitted; the red arrow points to the old one. It was a little curious, the power LED had indicated that the supply was OK and the no-load output voltage was almost correct but the hub did not function correctly. Markings printed on the case indicated that it was a 1000 µF capacitor but measurement with a component tester yielded a value of just 65.4 µF. A loss of 93.46 % of its capacitance would produce abysmal supply regulation especially under load. The truth is an LED is not at all fussy about the quality of its dc supply but the same cannot be said for the high tech chips found in modern equipment.



So the lesson here is don't be fooled by the reassuring glow of an LED and while it may be true that the equipment is only as good as its power supply, in this case the power supply is only as good as its capacitors…

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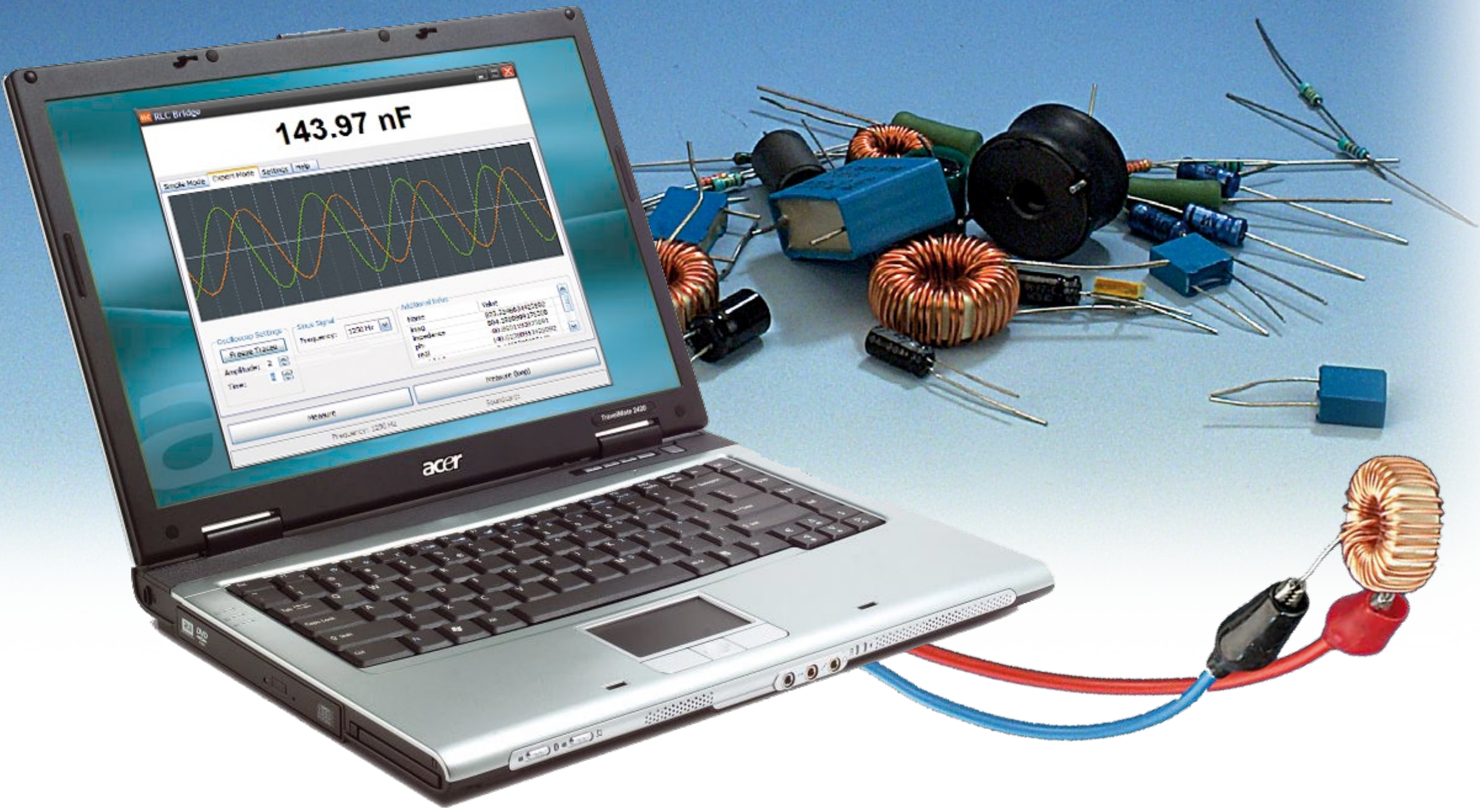
2-Pound RLC Meter

impedance measurement using a sound card



Martin Klaper and Heinz Mathis

Is it possible to make an RLC meter for less than two pounds? In this article the authors answer this question with a resounding 'yes' in the form of a simple and compact circuit that will enable you to make RLC measurements rapidly, accurately, and, above all, cheaply.

For many years the two authors have used a Marconi RLC bridge. To use this device two controls are adjusted until a meter reads 'null', and then the value of the connected resistor, capacitor or inductor can be read from the settings of the controls. It is also possible to use the instrument to measure the loss factor tan δ and the Q (quality) factor.

Not every household is lucky enough to own such an instrument or an expensive RLC meter; PCs and sound cards, however, are ubiquitous. And it turns out that these can be used to make excellent measuring instruments, as one of the authors has already described in *Elektor* [1]. There we described how to make an ECG (electrocardiogram) recorder using a sound card, and it is a relatively small step from that to the idea of measuring impedance using a sound card.

In outline, this is how it works: using the two input channels of a stereo sound card we can measure two voltages simultaneously. A resistor in series with the device under test (R, L or C) is used to convert the current flowing through it into a voltage. If an alternating voltage is applied to the device under test and the resulting current is measured, we can calculate its (complex) impedance. The alternating test voltage can be provided by an output of the sound card. Could we implement all of this on a PC? After a little contemplation, soldering and programming, the answer turned out to be yes.

Almost any PC can be used for this project, even a dusty old 500 MHz machine. There is even no need to open it up, as we only need access to the external connections of the sound card. Of course, we cannot guarantee that every PC will work, but we have tried a range of machines, desktop and laptop, running Windows XP and Vista,

and all have worked perfectly.
Besides the PC very little is required: build the tiny circuit described below, connect it to the PC, and run the software provided.
The hardware consists of just two resistors and a dual operational amplifier: total cost well under two pounds. The circuit can conveniently be built on perforated board or on a breadboard, and then, low-cost impedance meter in hand, you can test inductors, capacitors and resistors to your heart's content. The circuit gives astonishingly good accuracy: its results have been checked against a much more expensive RLC meter on the authors' bench.

Impedance

Impedance (from the Latin 'impedire', to hinder, hence 'impediment' etc.) is essentially the degree of opposition to current flow. It is a complex quantity, that is, it has real and imaginary parts. The impedance of a pure resistor has zero imaginary part, although the impedance of a practical resistor (and in particular a wirewound resistor) will have a small imaginary part. Ideal inductors and capacitors have a purely imaginary impedance, but again real inductors and capacitors have a small real part to their impedance along with a (hopefully dominant) imaginary part. This deviation from the ideal gives rise to power dissipation or losses in the component. For this project we imagine a real component to comprise an ideal component in series with a pure resistance, the latter representing the losses. At a specified frequency an impedance can be expressed in polar coordinates or in Cartesian coordinates:

$Z = |Z|\angle\theta = R + jX$
where $|Z| = \sqrt{(R^2 + X^2)}$ and $\theta = \arctan(X/R)$

Here Z is the (complex) impedance, measured in ohms, $|Z|$ is the magnitude of Z, and θ is the argument of Z. Z has real part R and imaginary part jX (see also the formulae in the accompanying box).
Below we will describe two ways of measuring impedance, which (although both inspired by the previous article in *Elektor* mentioned above) have been developed independently of one another. Method A is an adaptive linear combiner using a least-squares method which makes a measurement at constant frequency, calculating phase lag and loss factor. Method B goes by the delightful name of 'approximation of the characteristic curve using a variable test frequency and the method of least squares'.
And now to the gory details.

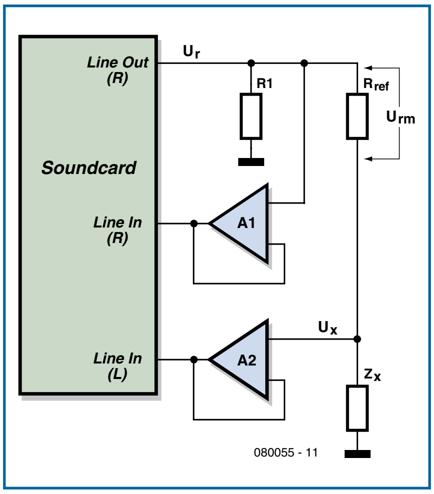


Figure 1. Block diagram for method A.

Method A

One of the two output channels of the sound card drives a voltage divider, consisting of a reference resistor R_{ref} and the device under test Z_x, with a sine wave (**Figure 1**). The second output of the sound card is unused. It could be used in an enhanced version of the meter to allow for switching ranges automatically (in the current version the range has to be changed manually). The two input channels measure the two voltages on the voltage divider, which allows the ratio between these two quantities to be measured at any instant. In principle it would be possible to assume that the voltage applied to R_{ref} is simply proportional to the voltage that has been output by the program to the sound card. In practice, however, sound cards have a certain latency which means that there is a delay between the program sending a signal to the sound card output and its actually appearing there (see our test of sound cards elsewhere in this issue). Using two inputs on the sound card gets around this problem in an elegant way.
R1 references the output of the sound card to ground. The two operational amplifiers, each with a gain of one, act as buffers with a high input impedance and a low output impedance. The sinusoidal voltage U_r (from 'line out'), which is applied to the test circuit, is measured on the right input channel. The voltage across the device under test, Z_x, is measured using the left input channel. The operational amplifier used is a type LM358, although any similar device would do equally well. The supply voltage for the opamp is relatively low at ±3 V, in order to protect the sound card input from damage in the event of something going wrong.
The accuracy of the measurements made depends on the accuracy of reference resistor R_{ref}. It is therefore very important to know the value of this resistor as accurately as possible. R_{ref} can be changed to change the measurement range: for best results the value of R_{ref} should be comparable to the impedance of the device under test. For added convenience it would be possible to provide for automatic range switching using the spare output channel of the sound card.

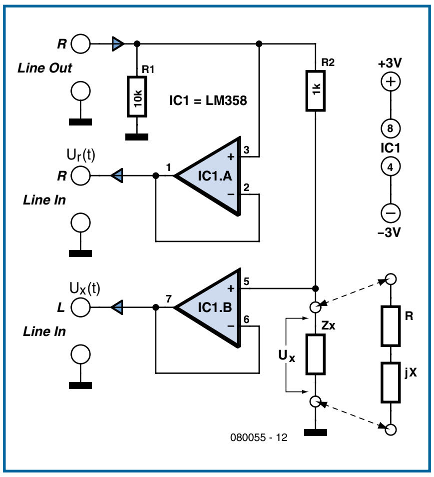


Figure 2. The hardware for method A consists of just a dual opamp and two resistors.

The concept

The ratio between the amplitudes of the voltages dropped across the reference resistor and the device under test, and the phase angle between these voltages, are the keys to computing the impedance of the device. The series combination of the reference resistor and the device under test is driven by the signal U_r, which is one output of the sound card; a voltage is dropped across the device under test whose amplitude and voltage depend on its impedance. Our first approach works as follows: we measure using a constant-frequency stimulus voltage (1250 Hz for example) and take the measured signal at U_r into an adaptive linear combiner implemented in software. The combiner employs two vari-

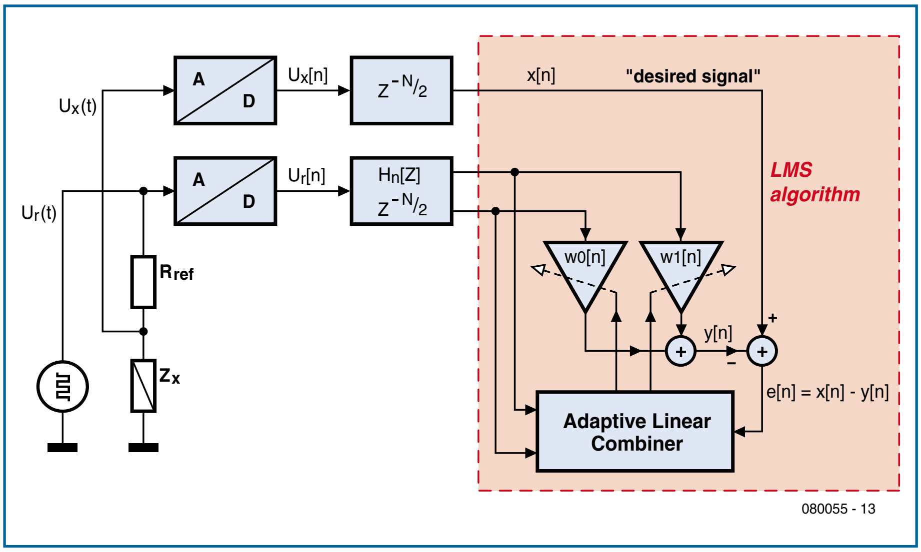


Figure 3. Functional diagram for method A.

able weights, w_0 and w_1, which can be thought of as equivalent to the potentiometers in an analogue RLC bridge. The program adjusts the weights until the voltage at the output of the combiner matches that across the device under test as accurately as possible in amplitude and in phase. By 'as accurately as possible' we mean that we try to minimise the mean squared difference between the two signals. The complex impedance of the device under test can then be determined from the weight values w_0 and w_1.

The system thus works in a very similar fashion to the authors' trusty Marconi bridge, with the adjustment of the (virtual) potentiometers under software control.

The algorithm

We use the so-called LMS (least mean squares) algorithm, which is an iterative approach to finding the optimal values of the weights w_0 and w_1. At each time step it adjusts the weights and then recomputes the real and imaginary parts of the resulting signal and thence the resulting error. The adjustment is a small step in the direction which reduces the error as quickly as possible (the 'method of gradient descent'), seeking the minimum of the error function like a skier who always chooses the steepest downhill route with the aim of reaching the lowest point of a valley.

When the error e(n) falls below a preset threshold the execution of the algorithm terminates, and the weight values are taken as correct. Now we can use them to compute the impedance we are trying to measure.

From the block diagram in Figure 1 we have:

$$U_x = I_{Rref} \times Z_x = U_{rm} / R_{ref} \times Z_x$$

where $U_{rm} = U_r - U_x$.

Now let $U_{rm} = A \times \sin(\omega t)$ and $U_x = A \times \sin(\omega t + \varphi)$, and we can write $U_x = w_0 A \times \sin(\omega t) + w_1 A \times \cos(\omega t)$.

Figure 3 shows the adaptive linear combiner. U_r (from 'line out') is modified using the weights w_0 and w_1 so that it is as close as possible to the desired signal U_x; e(n) is the computed error.

The impedance of the device under test is then given by

$$Z = R_{ref} w_0 + jR_{ref} w_1.$$

Software

The program that generates the sinewave signals, reads back the signals on the line-in input, and calculates the impedance of the device under test is written in Java.

The user interface shows the measured values as well as a display of the voltages across the reference resistor R_{ref} and the device under test Z_x. The LMS algorithm can be replaced by a different algorithm (see under the 'Settings' tab). The algorithm must be derived from the class Alg and implement the determine() method (see **Figure 4**). This allows a variety of different approaches to be compared: for example, a second approach, which uses a variable frequency, is described below. It would also be possible to implement the classic three-voltmeter method.

The software architecture is illustrated in **Figure 5**.

The sound card

The sound card samples the incoming signals 44100 times per second, and we allow a choice of test frequency from 1000 Hz, 1250 Hz and 2200 Hz. The sound card must have a stereo

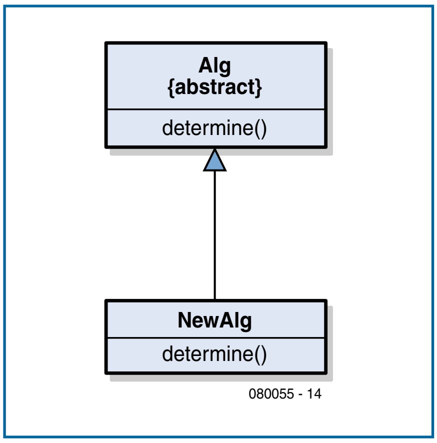


Figure 4. Deriving a new algorithm.

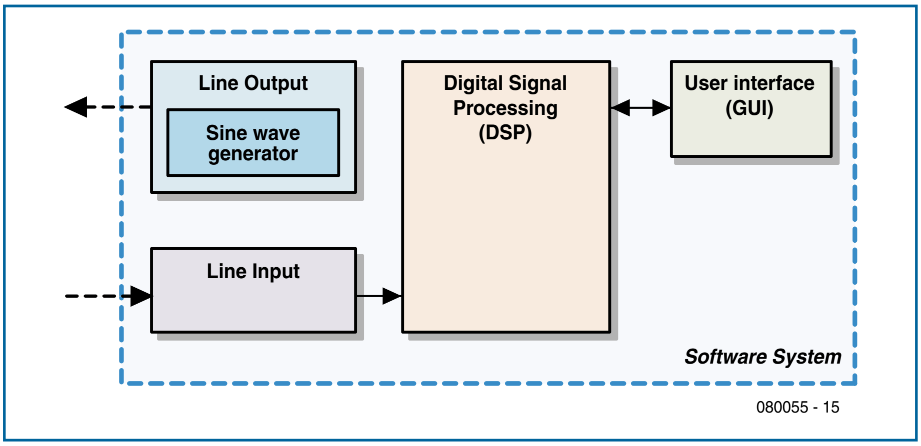


Figure 5. Block diagram of the software.

About the authors

Martin Klaper studied Electronic Engineering at the Swiss Federal Institute of Technology in Zurich, graduating in 1977. He then worked in development for 20 years at Crypto AG. From 2000 to 2005 he lectured in computing and telecommunications at the Solothurn University of Applied Sciences, and currently he lectures at the School of Engineering and Architecture in Horw, near Lucerne. He is also a keen radio amateur (call sign HB9ARK) and is particularly interested in the ideas behind software-defined radio.

Heinz Mathis studied Electronic Engineering at the Swiss Federal Institute of Technology in Zurich, graduating in 1993. After several years working as a development engineer in industry at various companies in Switzerland and in Britain, in 1997 he returned to the Swiss Federal Institute of Technology to become a research assistant. He received his doctorate in the field of signal processing in 2001 and went on to work for u-blox AG developing GPS receivers. Since 2002 he has lectured on mobile communications at Rapperswil University of Applied Sciences. His main interests are in the fields of high-frequency engineering and digital signal processing for mobile radio and GPS applications.

input (watch out: some laptops only have a single input channel).

There are two important points to note: if U_r has a very high amplitude, it may distort. Although the actual amplitude of U_r does not enter into the final calculation, it must nevertheless be a pure sinewave. It is also possible to overdrive the input amplifiers on the sound card, which will also lead to distortion.

The program is able to display the input waveforms to allow the user to check for distortion. The relevant levels can be adjusted using the PC's audio mixer settings. For a more precise measurement of the degree of distortion, connect an oscilloscope (or, even better, an audio spectrum analyser). It is also essential to ensure that the balance between left and right channels is set exactly in the centre.

The software oscilloscope display gives a good demonstration of the time relationship between the voltage across a capacitor or inductor and the current flowing through it.

Installation and operation

The RLC meter software can be downloaded from the *Elektor* website [3]. It is also necessary to have the Java runtime environment [2] installed. Then it is a simple matter of unpacking the software and running it. The Java program consists of three parts, (rlc.jar, swt.jar and swt-win32-3236.dll) which must be kept in the same directory. The program is run by double-clicking on rlc.jar.

Figure 6 shows the graphical user interface. Clicking on the relevant tabs switches between a simple meter mode and an expert mode. In simple mode the program just displays the measurement result in large characters so that it can easily be read from

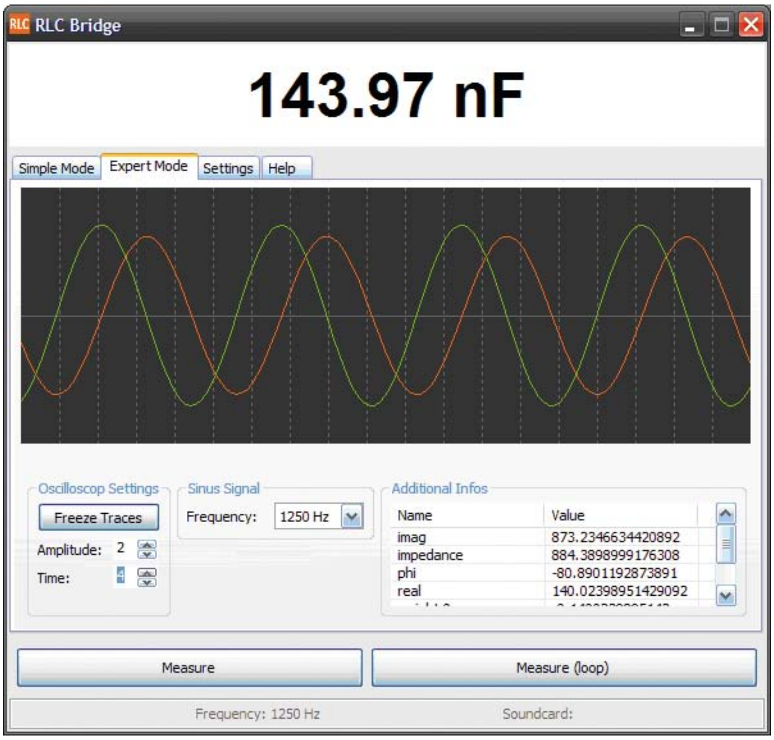


Figure 6. How the software displays its results on the screen.

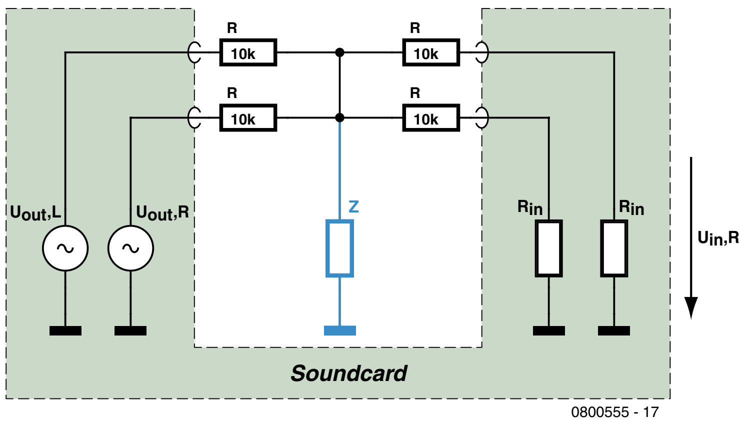


Figure 7. The hardware for method B consists of just four resistors.

Phase shift φ:

$$\varphi = \arctan\left(\frac{\omega_1}{|\omega_0|}\right)$$

Component characterisation:

φ = 0: pure resistance

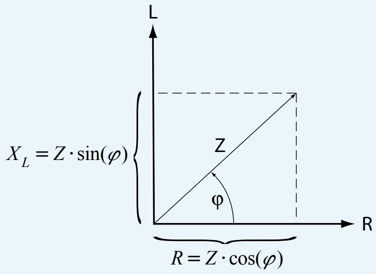
φ < 0: capacitor

φ > 0: inductor

Impedance Z:

$$Z = \sqrt{(\omega_0 \cdot R_{ref})^2 + (\omega_1 \cdot R_{ref})^2}$$

Real (R) and imaginary (X_L or X_C) parts:



Resistor: R = Z

Inductor:

$$L = \frac{X_L}{2\pi f}$$

Capacitor:

$$C = \frac{1}{2\pi f \cdot Z}$$

a distance. The series equivalent circuit is also shown graphically. In the case of a resistor the ohmic value is also displayed as the corresponding colour code.

It is possible to make single measurements or continuous measurements: the latter is particularly useful when tuning components such as coils.

In expert mode the display shows the input signals oscilloscope-fashion on the display, along with some interesting intermediate values computed by the LMS algorithm. Three different measurement frequencies are available. The 'Settings' menu allows the selection of a different sound card if more than one is present, and it is also possible to switch to a different measurement algorithm (if one has been implemented) for comparison purposes.

As mentioned above it is important to know the value of the reference resistor R_{ref} accurately, as the accuracy of the whole measurement depends on it. Ideally we should aim for an accuracy of 1 % or better, and if possible it is worth measuring the value of the resistor before use with a precision bridge. It is also important to use a film resistor for R_{ref} rather than a wirewound type, as the latter will have significant inductance. Accurate measurements of reactance from 0.01 R_{ref} to 100 R_{ref} are possible. It is a good idea to arrange the circuit so that different resistors can easily be substituted for R_{ref} to extend the range of the instrument.

Method B

An even simpler approach, suitable for measuring an unknown impedance Z using a sound card, is to use only the voltage divider part from the above circuit using a series resistor R. If we construct a symmetrical T-network it has the advantage that the circuit is symmetric with respect to the inputs and outputs of the sound card. This method also has the advantage that it can be used with single-channel sound cards, although using two channels helps to reduce the noise in the measurement a little. We thus end up with the simple resistor network shown in **Figure 7**.

R_{in} is the input impedance of the sound card, which can be determined from the datasheets of the devices used. The details of the derivation of the formulae for calculating the unknown impedance are available in a supplementary document that can be downloaded from the *Elektor* website.

The task for the software in the meter is now to measure the amplitude of the signal levels at the inputs to the sound card. The measurement is carried out at a range of different audio frequencies. If the unknown impedance is purely resistive the amplitude will exhibit no frequency dependence, whereas for an inductive or capacitive load the amplitude will increase or decrease (respectively) with increasing frequency.

For each of the three quantities R, L and C the software calculates a nominal value which minimises the squared error over the set of test frequencies used. The corresponding residuals (i.e., the normalised distances between the measured amplitudes and the theoretical amplitudes for the calculated component value) are also computed. The value which leads to the smallest residual is taken as the correct one and is displayed as the result, along with its corresponding unit.

(080055-I)

References and Internet links

[1] Martin Klaper, 'ECG using a Sound Card', Elektor October 2006.

http://www.elektor.com/magazines/2006/october/ecg-using-a-sound-card.58566.lynkx

[2] Java compiler and development environment (JRE and JDK): the Java Runtime Environment (JRE), version 5.0, is required to run the program, and the J2SE development kit (JDK), version 5.0, is required to modify and compile the program.

http://java.sun.com/javase/downloads/index.jsp

[3] Software download: www.elektor.com; month of publication

In all mains-operated equipment certain important safety requirements must be met. The relevant standard for most sound equipment is Safety of Information Technology Equipment, including Electrical Business Equipment (European Harmonized British Standard BS EN 60950:1992). Electrical safety under this standard relates to protection from

- a hazardous voltage, that is, a voltage greater than 42.4 V peak or 60 V d.c.;
- a hazardous energy level, which is defined as a stored energy level of 20 Joules or more or an available continuous power level of 240 VA or more at a potential of 2 V or more;
- a single insulation fault which would cause a conductive part to become hazardous;
- the source of a hazardous voltage or energy level from primary power;
- secondary power (derived from internal circuitry which is supplied and isolated from any power source, including d.c.)

Protection against electric shock is achieved by two classes of equipment.

Class I equipment uses basic insulation ; its conductive parts, which may become hazardous if this insulation fails, must be connected to the supply protective earth.

Class II equipment uses double or reinforced insulation for use where there is no provision for supply protective earth (rare in electronics – mainly applicable to power tools).

The use of a a Class II insulated transformer is preferred, but note that when this is fitted in a Class I equipment, this does not, by itself, confer Class II status on the equipment.

Electrically conductive enclosures that are used to isolate and protect a hazardous supply voltage or energy level from user access must be protectively earthed regardless of whether the mains transformer is Class I or Class II.

Always keep the distance between mains-carrying parts and other parts as large as possible, but never less than required.

If at all possible, use an approved mains entry with integrated fuse holder and on/off switch. If this is not available, use a strain relief (Figure, note 2) on the mains cable at the point of entry. In this case, the mains fuse should be placed after the double-pole on/off switch unless it is a Touchproof® type or similar. Close to each and every fuse must be affixed a label stating the fuse rating and type.

The separate on/off switch (Figure, note 4), which is really a 'disconnect device', should be an approved double-pole type (to switch the phase and neutral conductors of a single-phase mains supply). In case of a three-phase supply, all phases and neutral (where used) must be switched simultaneously. A pluggable mains cable may be considered as a disconnect device. In an approved switch, the contact gap in the off position is not smaller than 3 mm.

The on/off switch must be fitted by as short a cable as possible to the mains entry point. All components in the primary transformer circuit, including a separate mains fuse and separate mains filtering components, must be placed in the switched section of the primary circuit. Placing them before the on/off switch will leave them at a hazardous voltage level when the equipment is switched off.

If the equipment uses an open-construction power supply which is not separately protected by an earthed metal screen or insulated enclosure or otherwise guarded, all the conductive parts of the enclosure must be protectively earthed using green/yellow wire (green with a narrow yellow stripe – do not use yellow wire with a green stripe). The earth wire must not be daisy-chained from one part of the enclosure to another. Each conductive part must be protectively earthed by direct and separate wiring to the primary earth point which should be as close as possible to the mains connector or mains cable entry. This ensures that removal of the protective earth from a conductive part does not also remove the protective earth from other conductive parts.

Pay particular attention to the metal spindles of switches and potentiometers: if touchable, these must be protectively earthed. Note, however, that such components fitted with metal spindles and/or levers constructed to the relevant British Standard fully meet all insulation requirements.

The temperature of touchable parts must not be so high as to cause injury or to create a fire risk.

Most risks can be eliminated by the use of correct fuses, a sufficiently firm construction, correct choice and use of insulating materials and adequate cooling through heat sinks and by extractor fans.

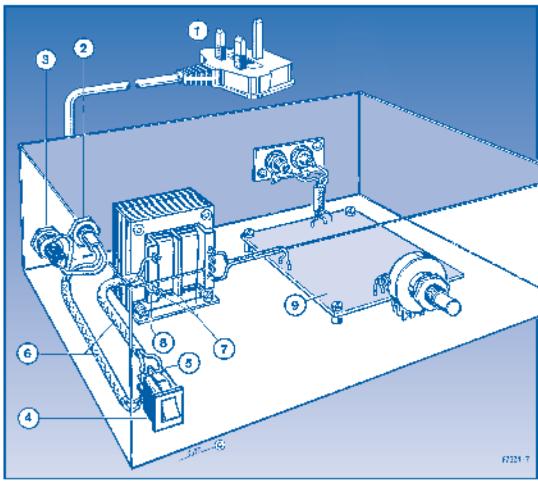
The equipment must be sturdy: repeatedly dropping it on to a hard surface from a height of 50 mm must not cause damage. Greater impacts must not loosen the mains transformer, electrolytic capacitors and other important components.

Do not use dubious or flammable materials that emit poisonous gases.

Shorten screws that come too close to other components.

Keep mains-carrying parts and wires well away from ventilation holes, so that an intruding screwdriver or inward falling metal object cannot touch such parts.

As soon as you open an equipment, there are many potential dangers. Most of these can be eliminated by disconnecting the equipment from the mains before the unit is opened. But, since testing requires that it is plugged in again, it is good practice (and safe) to fit a residual current device (RCD)*, rated at not more than 30 mA to the mains system (sometimes it is possible to fit this inside the mains outlet box or multiple socket).



1. *Use a mains cable with moulded-on plug.*
2. *Use a strain relief on the mains cable.*
3. *Affix a label at the outside of the enclosure near the mains entry stating the equipment type, the mains voltage or voltage range, the frequency or frequency range, and the current drain or curent drain range.*
4. *Use an approved double-pole on/off switch, which is effectively the 'disconnect device'.*
5. *Push wires through eyelets before soldering them in place.*
6. *Use insulating sleeves for extra protection.*
7. *The distance between transformer terminals and core and other parts must be ≥6 mm.*
8. *Use the correct type, size and current-carrying capacity of cables and wires – see shaded table below.*
9. *A printed-circuit board like all other parts should be well secured. All joints and connections should be well made and soldered neatly so that they are mechanically and electrically sound. Never solder mains-carrying wires directly to the board: use solder tags. The use of crimp-on tags is also good practice.*
10. *Even when a Class II transformer is used, it remains the on/off switch whose function it is to isolate a hazardous voltage (i.e., mains input) from the primary circuit in the equipment. The primary-to-secondary isolation of the transformer does not and can not perform this function.*

* Sometimes called residual current breaker – RCB – or residual circuit current breaker –RCCB.

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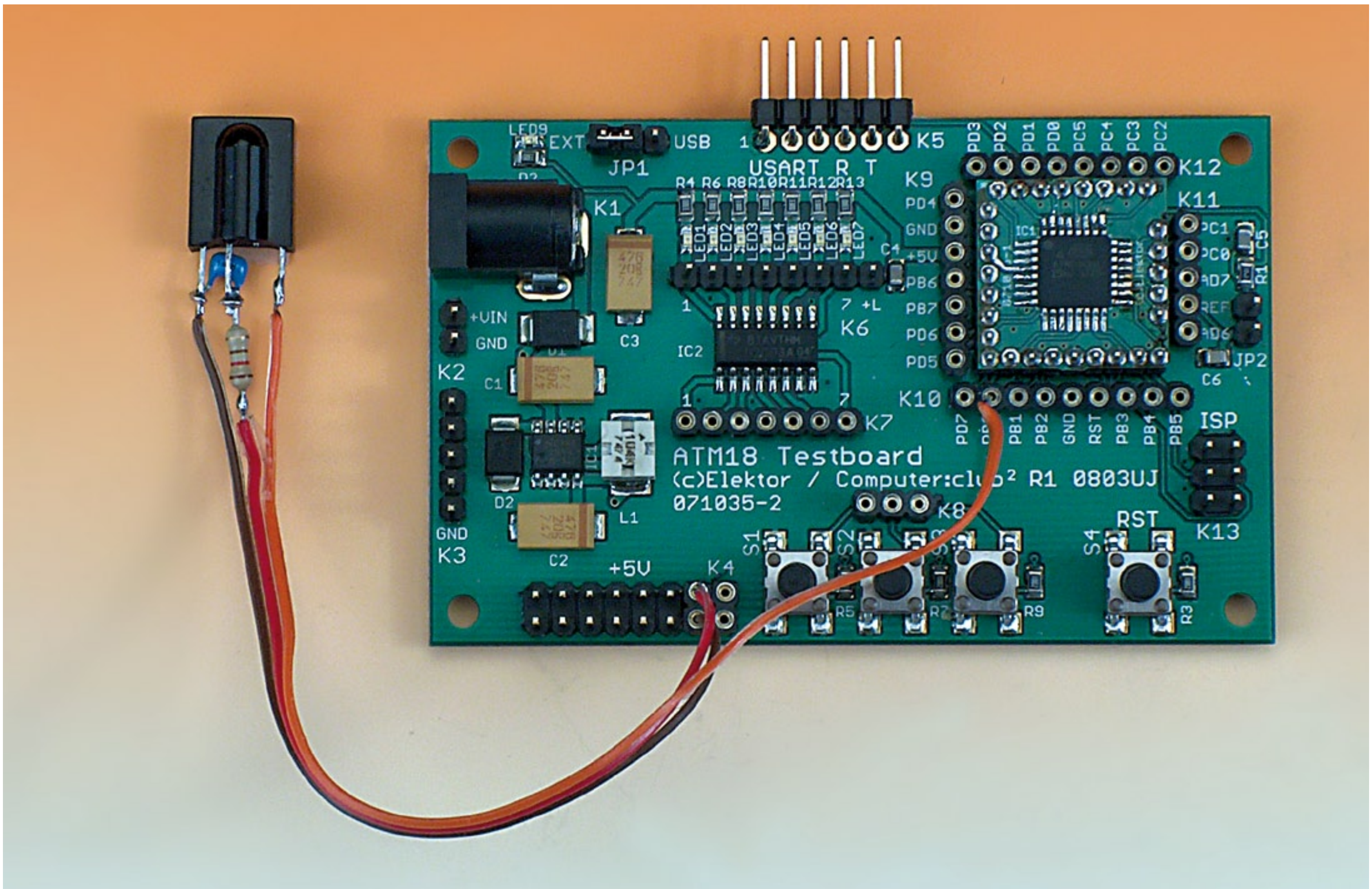
3-core mains cable to BS6500 1990 with three stranded conductors in thick PVC sheath			
Max current	**3 A**	**6 A**	**13 A**
conductor size	**16/0.2 mm**	**24/0.2 mm**	**40/0.2 mm**
Nom cond area	**0.5 mm²**	**0.75 mm²**	**1.25 mm²**
overall cable dia.	**5.6 mm**	**6.9 mm**	**7.5 mm**
Insulated hook-up wire to DEF61-12			
Max current	**1.4 A**	**3 A**	**6 A**
Max working voltage	**1000 V rms**	**1000 V rms**	**1000 V rms**
PVC sheath thickness	**0.3 mm**	**0.3 mm**	**0.45 mm**
conductor size	**7/0.2 mm**	**16/0.2 mm**	**24/0.2 mm**
Nom cond area	**0.22 mm²**	**0.5 mm²**	**0.95 mm²**
overall wire dia	**1.2 mm**	**1.6 mm**	**2.05 mm**
3-flat-pin mains plug to BS 1363A			

Invisible Commands

ATmega88 decodes infrared control commands

Udo Jürss and Wolfgang Rudolph



In the previous instalment in this series we connected an LCD panel to the ATM18 test board, allowing the microcontroller to speak to the outside world. Now we look at how to interface to an ordinary remote control using the RC-5 code, as found in any household. We display the received data on the LCD panel.

We shall turn the ATM18 board becomes an analyser that can display the commands sent by an infrared remote control. The infrared signals are invisible to the naked eye, and in any case are too quick for a human to be able to read the code. Nevertheless, it is possible to see the output of a remote control indirectly, as many digital cameras have sensors that respond to infrared. Hold the remote control up to the camera and press a button on it, and the infrared LED should be visible in the camera's electronic viewfinder.

The actual pattern of pulses emitted

by the remote control can be inspected using a photodiode and an oscilloscope (**Figure 1**). In our circuit we use an integrated infrared receiver instead of a photodiode.

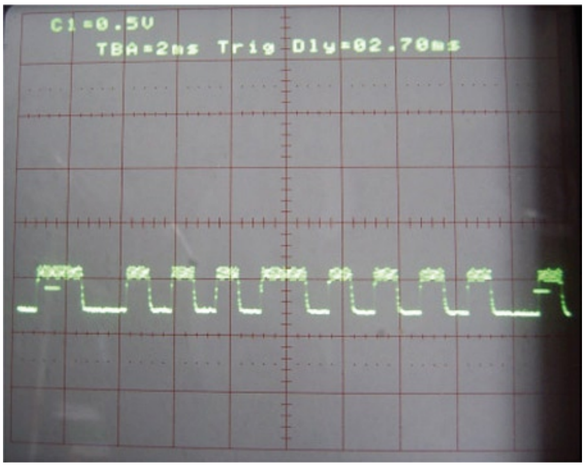


Figure 1. Oscilloscope trace of an RC-5 signal.

Infrared receiver

The device we have selected is the TSOP1736 made by Vishay (formerly Vishay Telefunken) (**Figure 2**). As can be seen from the block diagram (**Figure 3**) the device includes a photodiode whose output signal is amplified, filtered and finally demodulated. At the output is a digital signal like that shown in Figure 1. The TSOP device is available in various versions which differ only in the centre frequency of the integrated band-pass filter. We use the 36 kHz version as this is compatible with most remote controls. Other versions cover frequencies between 30 kHz and 40 kHz. The exact frequency is in any case not particularly critical as the pass band of the internal filter is relatively wide. The receiver will thus work at frequencies other than its nominal centre frequency, but its sensitivity will be somewhat reduced.

The TSOP device is simply connected to the power supply and to a suitable port pin on the ATM18 module: we chose port pin PB0. Power to the device (GND and V_S) is provided via a low-pass filter consisting of a 100 Ω resistor and a 100 nF capacitor to ensure that the supply voltage is clean. **Figure 4** shows the connections.

It is convenient to make up a flexible cable consisting of three wires, using red and blue or red and black for power and a third colour for the signal wire (**Figure 5**). A two-way pin header can be soldered to the end, and this can be connected to connector K4 (external 5 V power supply) on the test board. Observe correct polarity: the ground pins of the connector are nearest to the edge of the printed circuit board. The output signal can also be terminated in a pin to fit the socket on the test board.

On the TSOP1736 infrared sensor the pin spaced apart from the others is the signal output (V_O, pin 3). In the middle is the positive supply voltage (V_S, pin 2), and at the other end from the signal output is the ground connection (GND, pin 1): see Figure 2.

Signals

Many infrared remote controls for televisions, video recorders and other items of consumer electronics use the RC-5 standard originally defined by Philips. This modulates the infrared signal at a frequency between 30 kHz and around 50 kHz. The remote control transmits bursts of this carrier, with each burst having a length of 0.888 ms or 1.776 ms. With a modulation frequency of 36 kHz this means that each short burst consists of 32 individual pulses, and each long burst 64. The data packet lasts around 25 ms overall and is repeated every 100 ms for as long as the button on the remote control is held down.

The protocol uses a bi-phase signal, with each bit having a duration of 1.776 ms. Half of this time is active, the other half inactive. When the 36 kHz signal is present in the first half of the bit time, a logic zero is being sent; when the signal is present in the second half of the bit time, a logic one is being sent.

The signal always starts with the same fixed pattern, and then three data fields follow. **Figure 6** shows the sig-

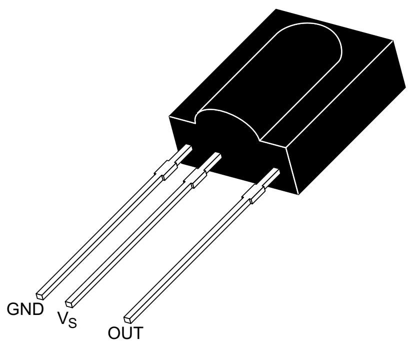


Figure 2. Package and pinout of the TSOP1736.

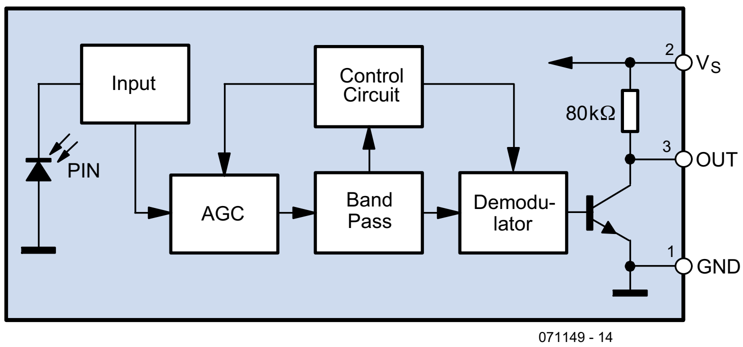


Figure 3. Block diagram of the infrared receiver.

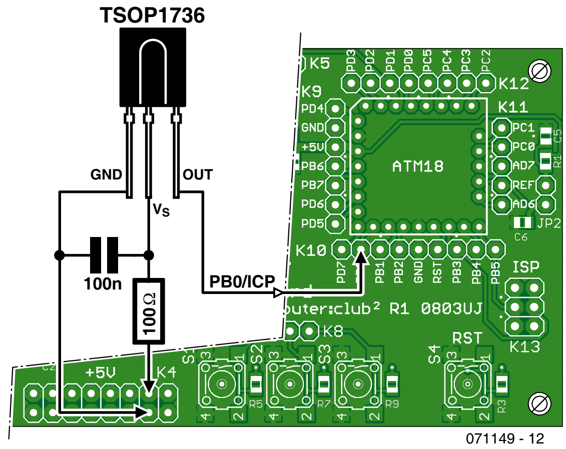


Figure 4. Making the connections to the infrared receiver.

Figure 5. TSOP with RC (resistor-capacitor) filter and connecting wires.

nal received from a remote control as seen at the output of the TSOP1736.

- The control bit (Ctl) toggles between 0 and 1 each time a button is pressed. This allows the receiver to detect the difference between a button that is held down and a button that is pressed repeatedly.

- The device address (Address) contains five bits, sent with the most significant bit first. Standard device addresses include 0 for televisions and 5 for video recorders. This field allows several remote controls to be used in the same room.

- The data field (Data) contains six bits, corresponding to one of up to 64 different buttons. Codes from 0 to 9 are assigned to buttons marked with those digits. Again, this field is sent with the most significant bit first.

Other light sources can often interfere with infrared remote controls. Fluorescent tubes are a particular problem, producing regular pulses of interference. The RC-5 decoder software checks that the start sequence of the received signal is as expected: if not, it is likely that the signal arose from some kind of interference.

Example application using CodeVisionAVR

A ready-made application example using CodeVisionAVR is available for download from the Elektor website. A free version of this C compiler, specially produced to accompany this series of articles, is also available for download. This means that anyone is free to examine the code in detail and make their own modifications and extensions. C neophytes may prefer to work with the BASCOM example described in the next section.

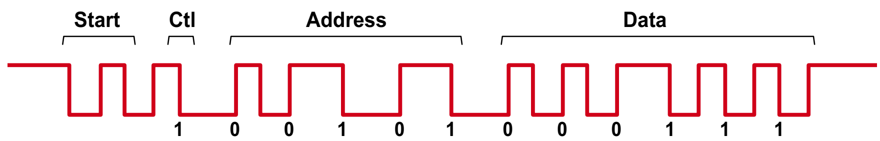


Figure 6. Example RC-5 signal with address 5 and command 7.

Trying out the program is a simple matter of uploading the hex file provided. The following connections need to be made:

- LED1 to LED6 should be connected to PC0 to PC5;

- connect the LCD expansion described in the previous article in the series (optional);

- connect the serial interface (optional) using either an FTDI USB-to-serial converter cable or a level shifter.

Reset the board and the program will greet you by flashing the LEDs three times. It then waits for a command from the RC-5 remote control. Buttons 1 to 6 are recognised and toggle the corresponding LEDs on and off. Button 0 turns off all the LEDs. The output drivers on the test board can be used to switch external devices: the open collector outputs of the ULN2003 can sink a maximum current of 500 mA and can withstand voltages of up to 50 V.

If an LCD or a serial interface is connected it is possible to see all the commands sent by the remote control. For example, a terminal program might show a received command as follows:

```
Bits: 0,1111100000000001,
Ctrl:1, Addr: 0, Cmd: 1, Err:0
```

The device address was 0 (corresponding to a TV set) and button 1 was pressed. We now have a way of determining whether a given remote control does indeed use the RC-5 code and what device address it uses. This could form the basis of a very flexible RC-5 tester.

How is it done? The source code reveals all. Timer 1 on the ATmega88, which is 16 bits long, is used to decode the signals from the infrared receiver module. With each rising or falling edge on PB0 triggers an Input Capture Interrupt, and the value in Timer 1 at that moment is stored in Input Capture Register ICR1. The pulse length is measured, and interference is rejected by comparing the length against preset minimum and maximum values. The tolerance is defined in the include file 'application.h'. Each Input Capture Interrupt initiates a timeout (implemented using an Output Compare Interrupt). When the timeout expires (after five times RC3_DOUBLE_TIME) the Output Compare Interrupt is triggered and the 'rc5_ready' flag is set. Then, in function 'rc5_decode()' the number of received bits is determined and the signal timing is checked. If too many or too few bits have been received, or if the signal timing is in error, the 'rc5_error' flag is set. These two flags can be tested by the main control program. The received data, along with the error flag, are shown on the LCD panel: this should help give some idea as to how the program works and make it easier to see how to modify the program for a particular application.

BASCOM-AVR example program

Processing the RC-5 signals in BASCOM is very straightforward because the relevant commands are already provided. **Listing 1** shows a small example, where data are received on input PB0 and transferred to the outputs on port C. Using the same connections as for the C example above the bit pattern of the received command is displayed directly on the LEDs. Device address 0 is used, which is compatible with a remote control for a television. This program allows three or four devices to be controlled very simply using the number buttons: pressing 0 switches all devices off, 1 switches just the first device on, 2 switches just the second device on, 3 switches on both of these devices, and so on.

The main command in Listing 1 is Getrc5(address, command). This must be preceded by a CONFIG RC5 command to specify the input pin that is being used (here PB0). Byte variables 'address' and 'command' must be already declared, and the interrupt must be available. RC-5 reception happens in the background under interrupt control using Timer 0. Each call to Getrc5() returns the most recently received data. If no signal has been received the returned values for 'address' and 'command' are both 255, and so whether a signal has been received can be tested by inspecting the value of 'address'. If 'address' is 0 then a command has been received without error and the device address is 0 (a television). If the remote control belongs to a video recorder, 'address' must be compared against 5. When the correct address is seen, the contents of the variable 'command' are valid. Bit 7 contains the toggle bit, which in this example we mask off. The other seven bits are output to port C.

BASCOM uses a routine from Application Note AVR410, which can be downloaded from the Atmel website. The RC-5 reception functions are implemented as an assembler subroutine running in the background.

It is possible to understand how Atmel's code works by working through it in detail. Of course, you can perfectly happily use the code in BASCOM without understanding its innermost secrets; Atmel have done the spadework, and you can concentrate on building your application. The functions provided allow you to control relatively complex processes in a straightforward way, as the RC-5 processing goes on transparently in the background.

(071149-I)

Listing 1

RC-5 reception using BASCOM

```
,RC5 receiver, input B.0
,Outputs port C

$regfile = "m88def.dat"
$crystal = 16000000

Dim Address As Byte , Command As Byte
Config Portc = Output
Config Rc5 = Pinb.0
Enable Interrupts

Do
  Getrc5(address , Command)
  If Address = 0 Then
    Command = Command And &B01111111
    Portc = Command
  End If
Loop

End
```

The ATM18 Project on Computer:club²

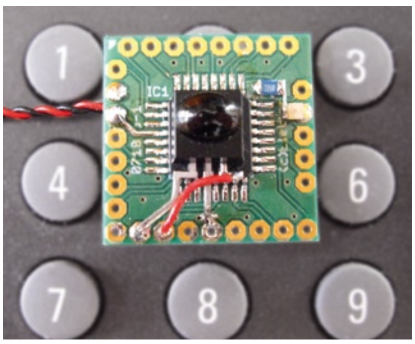
aTM18 was developed jointly by Elektor and Computer:club2 (www.cczwei.de) with contributions from Udo Jürss, the main developer of www.microdrones.de.

Each month, the latest developments and applications of the ATM18 system are presented by Wolfgang Rudolph of CC2-TV in a TV broadcast on the German NRW-TV network. The RC-5 decoding with the ATM18-AVR board can be seen in Broadcast # 11 of CC2-TV on 22 May 2008.

CC2-TV is also broadcast as a Livestream on the Internet at www.nrw.tv/home/cc2.

CC2-TV Podcasts are available from www.cczwei.de and — a few days later — from sevenload.de

A minimal application



It is possible to build a tiny stand-alone RC-5 receiver using the ATM18 microcontroller module. With just 3 components and weighing just 0.8 g this board can switch an LED on and off in response to the RC-5 commands it receives.

A tiny type TSOP4436 infrared receiver made by Vishay is located in the middle of the board above the processor. It is connected to PB0, PB1 and ground at the lower edge of the board. To the right there is a 390 Ω resistor with one end soldered to ground. An LED goes from the other end of the resistor to PC1_ADC1. The connections to the power supply are visible on the left.

Microcontroller with infrared module and LED

LED Tester

Check and compare intensity

Ton Giesberts

LEDs are used everywhere these days, not just as on/off indicators any more but now also as a source of light. Before you mount an LED in your circuit it would be nice if you could first check whether you have the right type and how much current it needs to have for it to be bright enough.

The simple circuit described here allows you to test LEDs quickly and make a distinction between low-current and high-efficiency types. Low-current LEDs give quite a bit of light with a current of only 1 to 2 mA, while high-efficiency LEDs produce a lot of light at a current of 10 mA or more (refer to the characteristics in **Figure 1**). Moreover, when you design a circuit in which multiple LEDs are going to be on at the same time, it is important that all these LEDs are equally bright at a particular current.

This can also be verified with this test circuit: two (or more) LEDs can be connected in series so that you can select them for equal brightness.

In this circuit we start with an adjustable current source. The current through the LED (or two in series connected LEDs) is adjustable from 0 up to 20 mA. Based on the brightness of the LED(s) while turning the potentiometer from 0 to maximum, you can determine which type of LED(s) you have. A low-current LED will quickly be quite bright at a small current and will not get much brighter when the potentiometer is turned further. On the other hand, a high-efficiency LED will slowly continue to increase in brightness.

If you would like to select LEDs for equal brightness then you can connect two, or even more than two, in series. Using red LEDs and a power supply voltage of 9 V you can even connect 4 in series, which makes the selection process significantly easier. If you like, you may increase the power supply voltage up to a maximum of 15 V (but not two 9-V batteries in series!). The maximum allowed power supply voltage for the opamp that is used here, a TLC271, is only 16 V. At this voltage you can compare 6 to 8 LEDs (red, yellow or green). The actual maximum number depends on the forward voltage drop of the LEDs under test. With

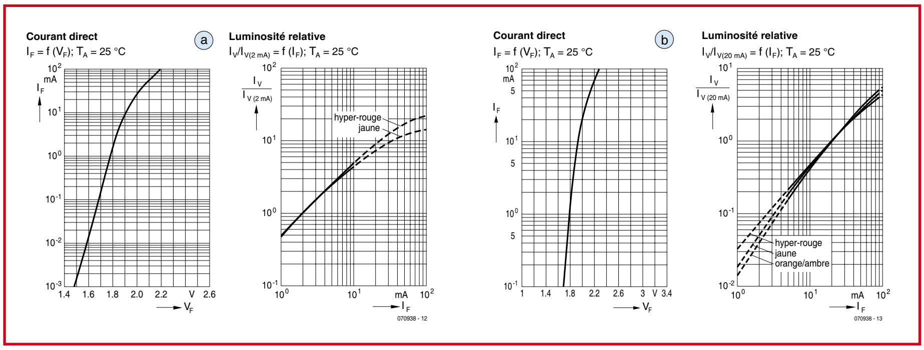
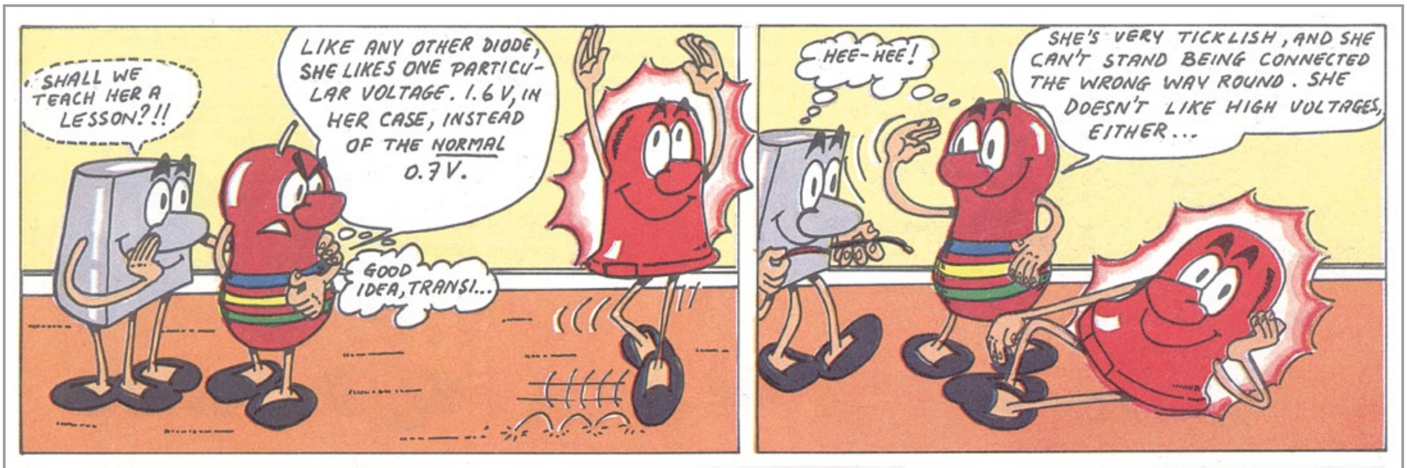
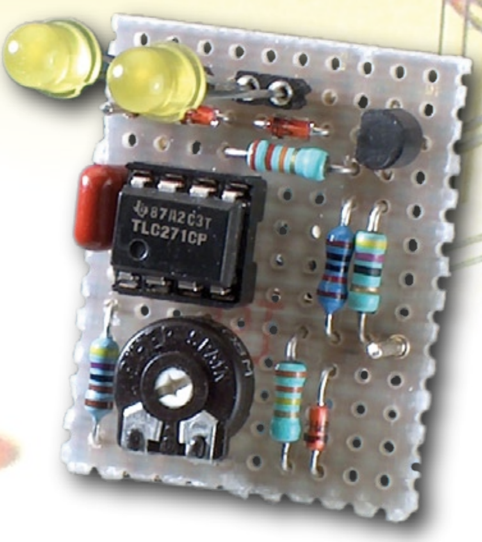


Figure 1. Forward voltage and intensity of a low-current LED (a) and a high-efficiency LED (b).
Source: Osram Opto Semiconductors.





white LEDs this voltage is about 3.6 V, so at a power supply voltage of 15 V you can only measure 3 at the same time.

Schematic

The circuit (**Figure 2**) consists of the classic current source made from a transistor and an opamp. The opamp compares the voltage drop across the emitter resistor R5 of T1 with the set-point voltage at the wiper of potentiometer P1. The base of T1 is driven via voltage divider R3/R4 by the output of the opamp. The values of this voltage divider have been chosen such that in a potential fault situation (for example when the output of IC1 is driven to the supply rail), the current through T1 can never become too high. This maximum is a little more that 20 mA. (But take note! If you increase the power supply voltage to the entire circuit, the maximum current through T1 in a fault condition will also increase!)

A zener diode (D1) is used to generate a reference voltage in a simple manner, which makes the voltage across P1 independent of the supply voltage. The current through D1 is set frugally at 1 mA and as a result the reference voltage is only 4.2 V, instead of the nominal 4.7 V. The value of R2 was selected so that the voltage across P1 is about 1 V.
Before you fit this resistor, note the actual value of the potentiometer you have. This type of potentiometer often has a tolerance of ±20%. If your potentiometer deviates more than 5% from the nominal value then you can adjust the value of R2 by the same proportion.
P1 is drawn as a preset in the schematic, but if you have a frequent need to select LEDs you can also use a normal potentiometer for P1 and maybe add a graduated scale as well.
A 4.7-V zener diode is connected in parallel with each LED (D2 and D3). The function of these zeners is twofold. On the one hand, when one LED is removed the current through the other LED continues to flow uninterrupted. On the other hand when an LED is connected the wrong way around the zener diode prevents the voltage across the LED from exceeding the maximum reverse blocking voltage. This is often 5 V, but is sometimes specified to be lower than that!

Construction

The best way to build the circuit is to use a small piece of prototyping circuit board. The few parts and the connections between them are easily fitted. To facilitate the quick insertion and removal of the LEDs, it is best if you use 2 times 2 connectors from a turned-pin IC socket.
The maximum current consumption of our prototype was just under 23 mA and the minimum current was 1 mA (the current through R1). The opamp is set to low-power mode by connecting pin 8 to the positive supply voltage; it now consumes mere microamps.

If you want to be able to safely test (many) more LEDs at the same time, you can use a separate, higher power supply voltage for the string of LEDs (but note the maximum ratings of the transistor). If necessary, at very high voltages you can use a power transistor for T1 (and fit a heatsink, if required). However, don't forget to connect a zener diode across each LED, this is much safer.

(070938-I)

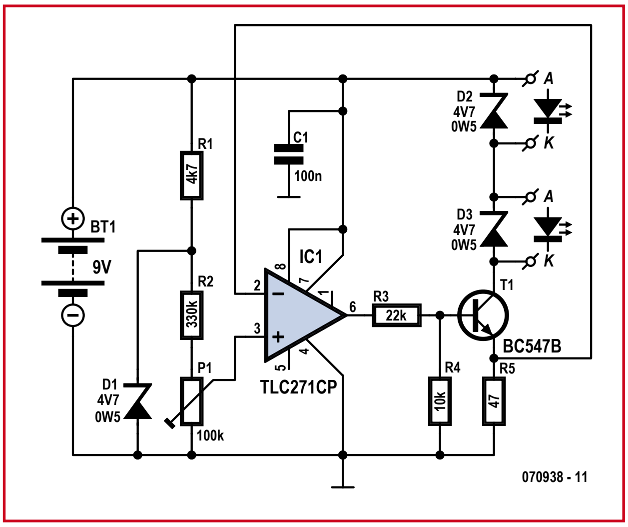


Figure 2. The LED-tester consists of an adjustable current source which can supply up to 20 mA at a power supply voltage of 9 V.

extrait de la bande dessinée "Resi & Transi – Échec aux Mystères", 1984

Hexadoku

Puzzle with an electronics touch

Here's the June 2008 instalment of Hexadoku, Elektor's brain teaser that looks here to stay on page 76! We never thought Hexadoku would become such a success and we thank the thousands of readers from all over the world who have participated so far. All correct entries received enter a prize draw.

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.

SOLVE HEXADOKU AND WIN!

Correct solutions received enter a prize draw for an

E-blocks Starter Kit Professional

worth **£248.55**

and three **Elektor SHOP Vouchers** worth £35.00 each.

We believe these prizes should encourage all our readers to participate!

The competition is not open to employees of Elektor International Media, its business partners and/or associated publishing houses.

PARTICIPATE!

Please send your solution (the numbers in the grey boxes) by email to:

editor@elektor.com - Subject: hexadoku 6-2008 (please copy exactly).

Include with your solution: **full name and street address.**

Alternatively, by fax or post to: **Elektor Hexadoku**
Regus Brentford - 1000 Great West Road - Brentford TW8 9HH
United Kingdom - Fax (+44) 208 2614447

The closing date is **1 July 2008.**

PRIZE WINNERS

The solution of the April 2008 puzzle is: **FA63E**.

The **E-blocks Starter Kit Professional** goes to:
Paul Martin (UK).

An **Elektor SHOP voucher worth £35.00** goes to:
Amir Omahic (CR); Odd-Arne Olsen (N);
Michael McGovern (IRL).

Congratulations everybody!

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

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

Neuwirth FUP1D PMR test unit (1973)

Jan Buiting

Until well into the 1990s, the repair and alignment of personal mobile radio (PMR) equipment was done not only by the official dealers or equipment retailers, but also by Fred of the local radio/TV shop. All you needed, it seemed, was the right crystals for the customer's allocated channel frequency, an alignment manual and a set of (coil) adjustment tools. However most PMR equipment works in frequency bands like 68-88 MHz or 146-174 MHz for which no RF equipment is available in the average RTV repair shack. Dummy loads, deviation and symmetry meters, who's ever heard of that?

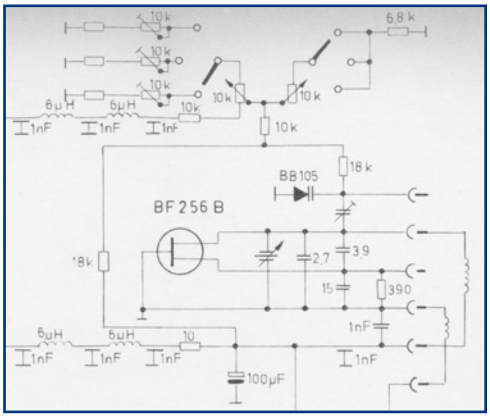
In the early 1970s a company with this ego boosting name: *Dipl.-Ing. Heinz-Günther Neuwirth Messgeräte der Hochfrequenztechnik Hannover-Westerfeld* recognised the market situation and packed everything you could possibly need to get a PMR on the air (again) into a single equipment. They called it: *Funküberprüfungsplatz* hence the type code 'FUP', or *Funkprüfgerat.* Both terms mean PMR checking station but the product became legendary as 'the Neuwirth FUP'. Shoptalk would go like this: "So *this Moto MC80 from the cabbies is as deaf as doornail, Fred, what does the FUP have to say about it?" "Dunno, d'ye know what channel it's on?"*

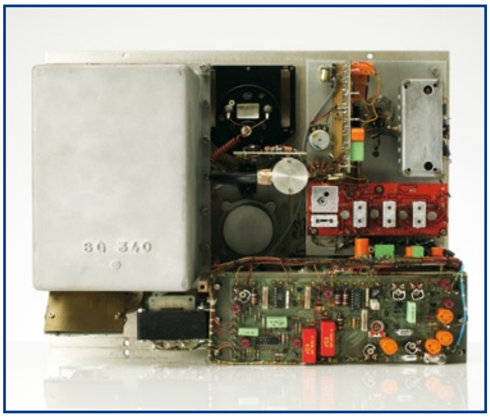
The FUP1A had four frequency ranges: 68-88 MHz; 80-95 MHz; 95-110 MHz and 140-175 MHz. The later FUP1D came with the 420-475 MHz UHF PMR band added. Still later the top notch FUP1DZ had an internal counter.

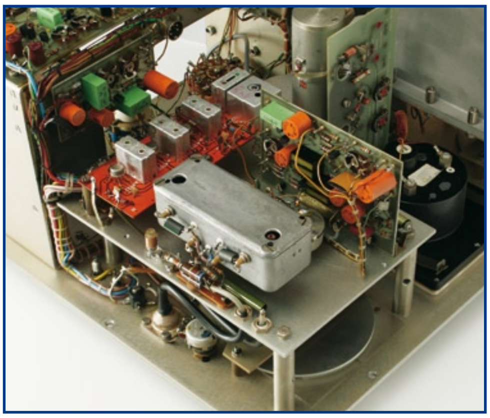
The FUP is truly a combined piece of test equipment. It contains: LF generator, LF voltmeter, RF signal generator with NBFM modulation, deviation meter, RF power meter, dummy load. The FUP can be mains powered or from its internal rechargeable battery pack.

The clever RF technician can combine and set up some of these sub-functions to do things like antenna SWR checking, deviation symmetry checks, S/N measurements, image rejection and spurious checking, not forgetting listening to local VHF FM stations in his workshop (simple: jack antenna into dev meter input, set to max. sensitivity and tune to 90 MHz or so).

The electronic design of these FUPs is extremely simple and conservative, and successfully so. PLL technology? None, a single FET is used. Yet the frequency stability of the equipment after about 15 minutes of warming up is almost uncanny. The reason for not including a PLL of any sort must have been: we do not want the extra complexity and the loop noise it brings along onto its output signal. The secret to the stability and amazing spectral cleanness of the RF output signal supplied by the FUP is not the BF256 FET in its totally classic oscillator circuit, nor the solid mechanical design of the output attenuator, but the use of NP0 ceramic and silver-mica capacitors in all the right places. The result: a +750 Hz drift from a target frequency of 145.000 MHz after 15 minutes of warming up, and never more than 200 Hz off the mark when the equipment remains on. More than adequate for those countless Motorola, Storno, Philips, Pye, Telefunken, SEL and GEC taxi radios of the 1970/80s, which were mostly simple xtal driven NBFM boxes. No PLL lock-up problems or digital whine and shot noise on the FM modulation.







I've seen at least one FUP on sale at radio rallies in Germany, Belgium or Holland. They're sometimes seen on German Ebay too. Most are battered after a lifetime of being hauled all over the country in thumping RTV service vans. Most have replaced knobs with badly chosen colours. Original manuals are rare; the copies — tatty.

Neuwirth's FUP1As and 1Ds were exported and widely rebranded for resale in various countries and regions. The one photographed here is Dutch labeled. The best looking FUPs are light blue and marked 'mi'. I suspect these are from Italy. If any reader is able to identify the company, please let me know.

I still use my own FUP1D for two purposes. One is aligning vintage 4 metre PMRs radios (68-88 MHz) and the other, to silence my neighbour's FM radio left playing at vol. 10 in the garden shed or in the teepee long after the kiddies lawnparty is over. I stick a telescopic rod antenna on the FUP's RF output, crank up the level to 10 mV (max.) and then tune the frequency dial from 88 to 105 MHz until the radio is silenced. Readjustment is never necessary, and I never feel tempted to switch on the 1-kHz AF test tone at the full ±25 kHz FM deviation. I've cable radio myself.

(080196-I)

Retronics is a monthly column covering vintage electronics including legendary Elektor designs. Contributions, suggestions and requests are welcomed; please send an email to editor@elektor.com

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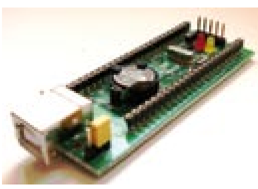

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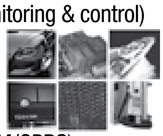

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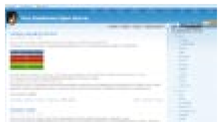

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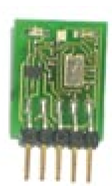

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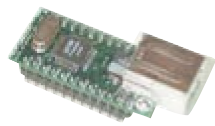

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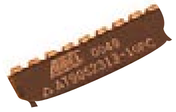

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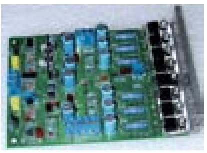

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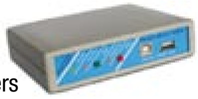

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Elektor Internet Radio

(April 2008)

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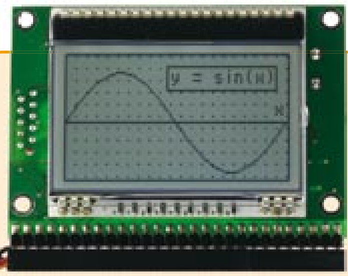

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(May 2008)

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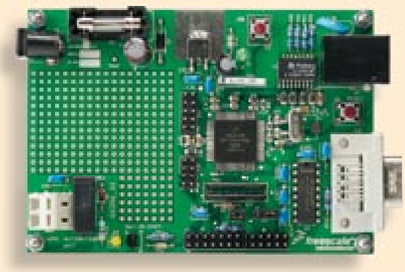

DigiButler

(May & April 2008)

A low-cost home automation server based on a Freescale Coldfire 32-bit microcontroller. The project has been designed with open source in mind and doubles as a powerful Coldfire development system using free CodeWarrior software from Freescale. DigiButler activates electrical appliances in and around the home, accepting on/off commands from a WAP phone, through an Ethernet network or via a webpage at an allocated IP address and with full access security.

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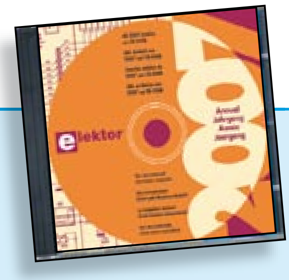

All articles published in 2007

Elektor 2007

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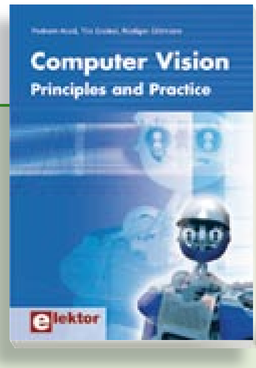

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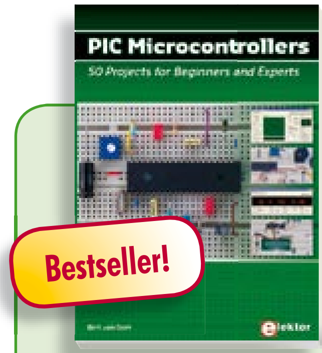

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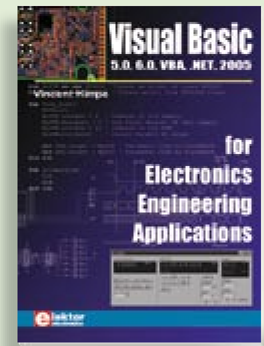

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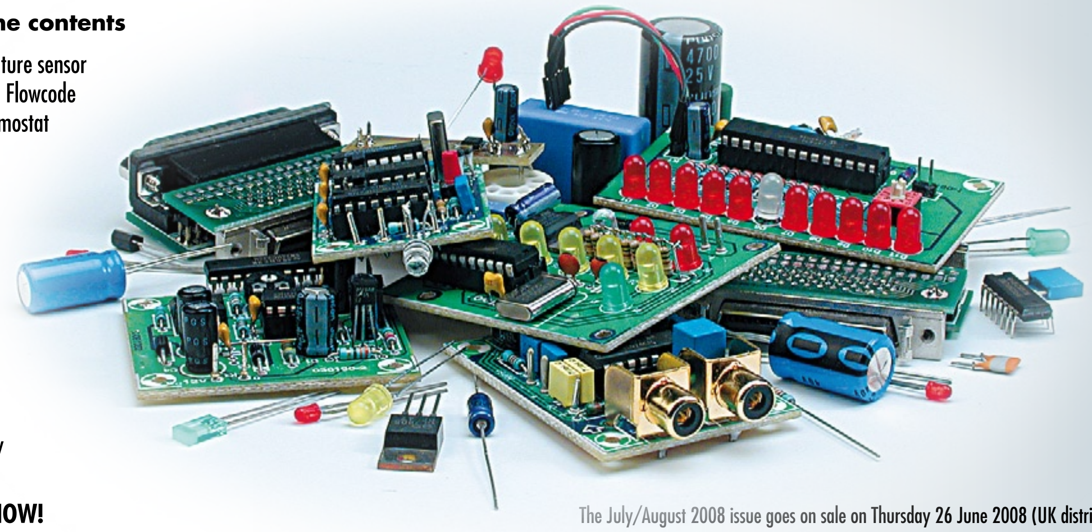

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