revolutionary audio amplifier

paX

DigiButler – a Coldfire home automation server
Sweep Generator – with a Parallax SX28 micro
ATM18 AVR Board – ATmega88 building block

Radio has come a long way

Elektor Internet Radio
NEW Jaycar Catalogue OUT NOW order on-line at www.jaycarelectronics.co.uk/catalogue

Automotive Kits

**Ignition System**

**KC-5442** £26.25 + post & packing

This advanced and versatile ignition system can be used on both two and four stroke engines. The system can be used to modify the factory ignition timing or as the basis for a stand-alone ignition system with variable ignition timing, electronic coil control and anti-knock sensing. Kit supplied with PCB, diecast case and all electronic components.

Features include:
- Timing retard & advance over a wide range
- Suitable for single coil systems
- Dwell adjustment
- Single or dual mapping ranges
- spark advance
- Optional knock sensing
- Optional coil drive

**Ignition Coil Driver**

**KC-5443** £13.00 + post & packing

Add this ignition coil driver to the KC-5442 Programmable Ignition System and you have a complete stand-alone ignition system that will trigger from a range of sources including points, Hall Effect sensors, optical sensors, or the 5 volt signal from the car’s ECU. Kit includes PCB with overlay and all specified components.

**Knock Sensor**

**KC-5444** £5.00 + post & packing

Add this option to your KC-5442 Programmable High Energy Ignition system and the unit will automatically retard the ignition timing if knocking is detected. Ideal for high performance cars running high octane fuel.

Requires a knock sensor which is cheaply available from most auto recyclers. Kit supplied with PCB, and all electronic components.

**Hand Controller**

**KC-5396** £25.95 + post & packing

This LCD hand controller is required during the initial setting-up procedure. It plugs into the main unit and can be used while the engine is either running or stopped. Using this Hand Controller, you can set all the initial parameters and also program the ignition advance/retard curve. Kit supplied with silk screened and machined case, PCB, LCD, and all electronic components.

**Three Stage FM Transmitter**

**KJ-8750** £6.50 + post & packing

This is a Three-Stage radio transmitter that is so stable you could use it as your personal radio station and broadcast all over you house. Great for experiments in audio transmission. Includes a mic, PCB with overlay and all other parts.

- Requires 9V battery (not included)
- Instructions included in kit

**How To Order**

- **ORDER ON-LINE**
- **ALL PRICING IN POUND STERLING**
- **MINIMUM ORDER ONLY £10**

**Post and Packing Charges**

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Expect 10-14 days for air parcel delivery

Check out the Jaycar range in your FREE Catalogue - logon to www.jaycarelectronics.co.uk/elektor or check out the range at www.jaycarelectronics.co.uk

**More Projects**

**Variable Boost Kit for Turbochargers**

**KC-5438** £8.00 + post & packing

It’s a very simple circuit with only a few components to modify the factory boost levels. It works by intercepting the boost signal from the car’s engine management computer and modifying the duty cycle of the solenoid signal. Kit supplied in short form with PCB with overlay, and all specified electronic components.

**Fuel Cut Defeat Kit**

**KC-5439** £6.00 + post & packing

This simple kit enables you to defeat the factory fuel cut-out signal from your car’s ECU and allows your turbo charger to go beyond the typical 15-17psi factory boost limit.

Note: Care should be taken to ensure that the boost level and fuel mixture don’t reach unsafe levels. Kit includes PCB with overlay, and all electronic components.

**10A 12VDC Motor Speed Controller**

**KC-5225** £7.75 + post & packing

Use this kit for controlling 12V DC motors in cars such as fuel injection pumps, water/air intercoolers and water injection on performance cars. You can also use it for headlight dimming and for running 12VDC motors in 24V vehicles. The kit will control loads up to 10 amps, although the addition of an extra MOSFET transistor will double that capacity to an amazing 20 amps.

- Kit includes PCB plus all electronic components to build the 10A version.
BitScope DSO is fast and intuitive multi-channel test and measurement software for your PC or notebook. Whether it’s a digital scope, spectrum analyzer, mixed signal scope, logic analyzer, waveform generator or data recorder, BitScope DSO supports them all. Capture deep buffer one-shots or display waveforms live just like an analog scope. Comprehensive test instrument integration means you can view the same data in different ways simultaneously at the click of a button.

BitScope DSO may even be used stand-alone to share data with colleagues, students or customers. Waveforms may be exported as portable image files or live captures replayed on other PCs as if a BitScope was locally connected.

BitScope DSO supports all current BitScope models, auto-configures when it connects and can manage multiple BitScopes concurrently. No manual setup is normally required. Data export is available for use with third party software tools and BitScope’s networked data acquisition capabilities are fully supported.

www.bitscope.com
Spring time!
New initiatives at Elektor

I do hope spring is in the air when you read this, because at the time of writing I can only see hail and sleet from the windows of Elektor House, and the wind is howling in the chimneys. Elektor staff, including myself, has just returned from the Embedded 2008 show in Nuremberg, Germany. We were happy to see not only representatives of small, large and would-be companies active in the microcontroller arena, but also a good many readers of our publications. Long time subscribers, occasional newsstand buyers, newcomers... thanks for dropping by and letting us know what you like (and hate) about Elektor. Remarkably, none of our direct competitors had a presence at the Embedded show, and even the Circuit Cellar booth was empty. Although the ATM18 and DigiButler projects published in this issue were developed well before the Embedded 2008 show, it was good to meet up with our contact persons at the companies behind the initiatives and discuss the progress. In the case of the ATM18, a working quadrocopter could be seen in action at the Elektor booth (video on YouTube soon). DigiButler, our open-source Coldfire home automation server, was demonstrated on the impressive Freescale stand. It’s difficult if not impossible to pinpoint a single trend from this year’s Embedded show, but the buzzwords are definitely C-to-hardware, open-source, development kits, CAN, fabless companies, core licensing and fun applications. Unfortunately, there was also a lot of vapourware around.

Back to the world of discrete components and (mostly) analogue design, I guess publishing an audio power amplifier using error correction can also be called an initiative on our part, if only because the high-end audio scene seems to have regurgitated conventional feedback concepts for more years than I care to remember. Elektor having a fine reputation for high-end audio designs that can be built at home, it’s time for a fresh, audacious, approach!
The concept of i-TRIXX — simple circuits from the Elektor labs combined with ‘geeks & gadgets’ stuff supplied through a free weekly newsletter — has proved very successful in Germany and The Netherlands over the past year or so, and you may have seen a crop of i-TRIXX circuits already in our December 2006 and 2007 issues. The English language version of i-TRIXX was launched on 5 March — have a look at www.i-trixx.com and play the quiz — I did badly.

Jan Buiting
Editor
Nowadays you can access every Internet radio programme in the world by receiving, buffering and decompressing IP packages. This is all very easy with the state-of-the-art hardware described in this article. All open-source!
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.
FPGA Course on CD-ROM

Modern technology for everyone

FPGAs have established a firm position in the modern electronics designer’s toolkit. Until recently, these ‘super components’ were practically reserved for specialists in high-tech companies. That’s all changed now, also because of the Elektor FPGA module. The combination of the module and the prototyping board is the perfect introduction to FPGAs. The nine lessons on the courseware CD-ROM are a step by step guide to the world of Field Programmable Gate Array technology. Subjects covered include not just digital logic and bus systems but also building an FPGA webserver, a 4-channel multimeter and a USB controller. The CD also contains PCB layout files in pdf format, a Quartus manual, project software and various supplementary instructions.


Free of charge with FPGA product bundle!
Early experiments with a radio and U-series valves
At the age of a secondary-school student (15), I received a radio from my grandparents. It had an attractive brown Bakelite case with a loudspeaker at the rear and a small grille covered with cloth. It was a fairly lightweight set, without a heavy built-in transformer. The Bakelite case could be removed easily by loosening two screws at the rear. There were lamps inside: U-series valves with thin steel pins fitted in valve sockets. I can still remember that one of them was a type UCH21. If I interchanged the positions of the valves, the radio stopped working. Evidently they were different types of valves... The filaments of all the valves were connected in series, as I quickly discovered. If I pulled out one of the valves, the filaments of the other valves went dark. The high voltage was taken directly from the (then 220 V) AC mains, and it was connected directly to the chassis. Safety was apparently not an issue! With a bit of experimenting, at that time I already found out that rectifying 220 V AC produces a much higher DC voltage than 220 V! Only much later did I really understand why.

With further experimenting, I also noticed that the chassis was sometimes 'live'. That proved to be related to which way the power plug was plugged in. With nail polish borrowed from my sister, I painted a small line on the AC plug and socket. Then I could work 'safely' as long as the plug was the 'right way round' in the socket (Ed.: older AC wall outlets in The Netherlands did not have plug polarisation).

By twiddling the trimmers, I managed to shift and stretch the medium-wave band so much that I could receive Scheveningen Radio coastguard. After that it was impossible to make the tuning scale correct again, but that didn’t bother me. The radio set proved to cause interference to the radio in the sitting room. By experimenting, I found a sensitive point in the radio. If you touched one of the components, a whistling sound came from the other radio. Later I managed to connect a crystal headphone to the radio and use it as a microphone. The result could be heard a block away: the pirate transmitter ‘Grannie’ was born! However, the neighbours were not at all pleased, and the local policeman was equally unhappy.

However, this problem was sorted out quite quickly. I often experimented with the set while it was connected to the AC mains. This involved operating the radio while it was upside down on the table. At a certain point I dropped a component in the radio, and without thinking I tried to grab it. I received an enormous electric shock, and my hand tore the wiring to pieces. Most likely my muscles contracted due to the current that flowed through my hand. The short circuit in the radio caused the fuse to blow. That wasn’t anything special for my parents – my father knew how to repair fuses with a bit of wire on the outside of the porcelain cartridge.

Looking back on this adventure, I realise how lucky you can be with electricity. But I still keep saying, ‘Don’t try to do it yourself this way!’

Kees de Groot (Netherlands)

This bit of electronics nostalgia will no doubt bring back fond memories for many of our readers.

E-blocks for vocational secondary schools
Dear Editor — we want to have students at a vocational secondary school learn a programming language that they can ultimately use to control devices or equipment via a PC and an I/O module (possibly separate).

We formerly used Pascal for this, but it is now too old. We presently have your Flowcode, E-blocks, Visual Basic, etc. What would you recommend?

Edward Ransbury (UK)

The E-blocks and ECIO units available from us are without question a convenient and fun way to let students get acquainted with programming by using Flowcode.

As E-blocks is a modular system, you can always expand it in order to provide your students with a constant stream of new challenges and let them discover new areas of interest. A large number of schools all over Europe have now discovered the benefits of the E-blocks system for educational purposes and are already using it.

Enclosure and heat sinks for the Mugen final amp
Dear Elektor — how can I obtain the heat sinks for the Mugen hybrid amplifier described in your October 2007 issue?

Carl Hamlin (USA)

The enclosure used by the author has integrated heat sinks on the sides.

This enclosure comes from an Italian company and can be ordered here: www.modushop.biz/ecommerce/cat079J2.php?n=1 Description: Pesante dissipante 03/300N 3U 10mm BLACK

The German company Schuro can also supply a similar enclosure that can be used with this design. Have a look at: www.schuro.de/preisl-gehaeuse.htm

Mac programs
Dear Editor — in response to your answer in the Mailbox section of the February 2008 issue of Elektor, I would like to comment that the statement that software for programming microcontrollers is not available for Mac OS X is simply not true.

It is perfectly possible to program AVR microcontrollers under Mac OS X. There is a lot of software available in the open-source world, and as Mac OS X is a Unix-based system, in many cases it can be used without modification. I personally use the USBprog, which was featured recently in your magazine (October 2007), with my MacBook Pro to program a variety of AVR systems (AT2323, ATmega16 and ATmega32).

The required software consists of an assembler (AVRA) and a programmer (avrdude), along with a C compiler, etc. as necessary. You can find all of them, ready for direct use with Mac OS X, at http://www.osx-avr.org.

There are various packages of this sort in available, but I use the above-mentioned programs almost every day.

Finally, with regard to your suggestion to install Windows using Bootcamp, it is much less expensive and more convenient to install a Linux distribution (such as Ubuntu) on your Bootcamp partition. Windows XP is expensive, and it is not popular among Mac users for relatively irrational reasons.

Paul Boven (The Netherlands)

Some programs don’t work right out of the box, but in many cases there are pre-built images available with good installation guides. Although you may not always have a nice GUI environment for the microprocessor, it is often possible to configure Eclipse...
Intel ‘unplugged’ challenge

Dear Jan — I am a member of the group of students at the Technical University of Delft in the Netherlands that participated in the Intel Challenge. And I am proud to say that we received the Innovation Award, which you may have already heard. Now I am busy writing a scientific paper on this.

In the November 2007 issue of Elektor, I saw that you had also established a competition for the Intel Challenge. The article in that issue included a table of measurements for the energy profile of a laptop computer. We also performed similar measurements, and for this reason I find the table interesting for checking and comparison with our measurements for the paper.

I would like to ask you exactly how these measurements were made. The article includes all the usual information about the configuration and specifications of the laptop, but I would like to know where in the electrical path the measurements were actually made. Were they made directly at the input to the laptop, or ahead of the adapter? And was the battery installed in the laptop, and if so, was it fully charged?

Ivo Roos (The Netherlands)

Antoine Authier, the head of our Elektor lab, is the best person to answer this question.

To start with, my sincere congratulations to you for winning the competition!

In order to measure the energy profile of the laptop computer made available to us by Intel, we measured the voltage and the current drawn by the laptop directly at the power connector of the laptop (i.e. after the AC mains adapter). The battery was not installed in the laptop for these measurements.

(possibly with plugins) for the microcontroller you want to program, which means that you do not have to create any make files. In addition, much of the tooling is open-source and is maintained quite well by an enthusiastic user community (which can also provide a lot of support).

Best wishes from a programming OS X user!

Niels Langendorff (Germany)

Dear Elektor — I have been a Mac user for a long time now, and I speak from experience when I say that there is a lot of software available for programming microcontrollers under Mac OS X. This software supports the 8051, Microchip, RBC, AVR and ARM devices. If you Google ‘avr usb osx’, you will find the following links:

http://ccrma.stanford.edu/~matt/avr-osx.htm
http://www.eecs.berkeley.edu/~mseeman/resources/macmicro.html
http://chris.dwan.org/robot/

We are happy to pass these comments on to Mr Pantott, who asked the question last month, and of course to all other readers who use Mac systems.

For your information, I should also say that:
- The computer hardware allows the backlight of the TFT screen to be set to 8 different brightness levels, but we only made measurements at the minimum and maximum levels.
- We used glxgear to activate and load the 3D GPU.
- Audio output via the built-in speakers was also active during the measurements. We used three levels here: off (mute), half of maximum volume, and maximum volume. The current consumption only increased when signals with a strong bass content were being reproduced.
- The basic application load consisted of running Open Office and the GIMP on the laptop.
- The standard network application load consisted of constantly sending a file (using the SCP protocol).
- Full CPU loading was achieved by reading a DVD and DivX encoding.

Corrections & Updates

TV Surround Light
February 2008, p. 24-29, ref. 070487-1

In the parts list, the designations IC3 and IC4 should be interchanged. This does not affect the PCB or the circuit diagram. All passive SMD parts are rectangular shape, footprint SMD1206.

Of the ADC1175JM and ADC1175TC mentioned in the article, only the –JM version is a discontinued part. The PCB has been designed to accept both versions.

Contrary to what is stated in the article text on page 28, ready-built boards are not available through the Elektor Shop.

Digital Inspector
September 2007, p. 38-41, ref. 060092-1

The circuit diagram erroneously shows X1 as a 20 MHz crystal. This should be 10 MHz as stated in the parts list.

MUGEN — a Hybrid Audio Amplifier
October 2007, p. 20-29, ref. 070069-1

In the parts list, resistor R11 should be 18 kΩ, not 18 Ω. This does not affect the circuit diagram, which shows the correct value.

In the power supply schematic (Figure 3), the type code of transformer T2 should be 78057, not 78075.
Fanless System with Core Duo processor

New from BVM is the WPC-763, an innovative I/O-rich fanless micro computer designed for applications such as digital signage, POS terminals, kiosks, ATM, thin servers, in-vehicle displays, outdoor entertainment, gaming, multimedia system and building automation; anywhere where 24/7 operation, low noise and protection from dust are critical requirements. Based on the Intel 945 GM and ICH7M chipset, two versions are available, either the Core Duo 2 GHz or Celeron M 1.86GHz low power processors. The systems fully support Vista in addition to Windows XP and XP Embedded. With six COM ports, a GPIO port for data collection and unit management, two USB 2.0 ports and an LPT port, the I/O-rich unit is ready-configured to accept the barcode scanners, photo sensors, card readers, limit switches, printer and other peripherals required in POS and kiosk applications without having to install additional cards.

RF amplifiers From AR offer unique impedance-matching capabilities

Most RF amplifiers have a nominal internal impedance of 50 ohms, which is fine for most RF applications. But since more and more low to mid-frequency RF applications are now characterized by impedances other than the usual 50 ohms, AR RF/Microwave Instrumentation has created a family of RF power amplifiers that can incorporate a variable output impedance.

The A3 amplifiers feature an internal impedance transformer with selectable output impedance values of 12.5, 25, 50, 100, 200 and 400 ohms. An external impedance transformer is also available for applications requiring an extended range from 8 – 2000 ohms.

The A3 family presently includes three amplifiers: Model 800A3 (800 watts), Model 1500A3 (1500 watts), and Model 5000A3 (5000 watts). Each of the amplifiers covers the 10 kHz to 3 MHz frequency range.

The unique impedance-matching capabilities along with the excellent mismatch tolerance makes the A3 series amplifiers extremely well suited to the ever-changing requirements of research & development applications as well as general purpose lab use. A3 amplifiers are currently being used in applications for fluorescent lighting, ultrasound, plasma generation and testing, mass spectrometers, piezoelectric crystals, EMC, and a variety of low to mid-frequency RF applications. For other applications and more information on impedance matching, please see AR RF/Microwave Application Note #47 – available in the Application Notes section of AR Information Resource Center on the company’s web site.

www.arww-rfmicro.com
www.emv.nl

PicoScope 6 update

PicoScope Technology has released the latest version of PicoScope 6. This version is the first to support Pico’s entire range of USB PC Oscilloscopes, and has a number of new features.

Owners of the high-performance 5000 Series scopes are already familiar with the improved layout and advanced triggering options of PicoScope 6. From now on, it will support all Pico oscilloscopes from the entry-level 2000 Series, through the general-purpose and high-precision scopes of the 3000 Series, up to the high-performance 5000 Series with 1 GS/s real-time sampling rate. The most exciting new feature in PicoScope 6 is resolution enhancement. This filtering algorithm adds up to four bits to the effective resolution of a scope. For example, it can boost the effective resolution of a PicoScope 5203 or 5204 from 8 bits to 12 bits, and the 12-bit PicoScope 3224 and 3424 high-resolution scopes can now deliver up to 16 effective bits. The resolution enhancement is selectable in increments of 0.5 bit.

PicoScope 6 now has independent horizontal zoom, using a new control that is easily accessed from the toolbar to give precise control over timebase magnification. The familiar windowed zoom tool is still there to allow quick inspection of waveform details.

Finally, the text file export feature has been improved so that text format data files up to 1 million samples long can now be exported. PicoScope 6.0.12 is available for download now, free of charge, from the Pico Technology website.

www.picotech.com
USB Connected
High Speed
PC Oscilloscopes

PicoScope 5000 Series
The No Compromise
PC Oscilloscopes

With class-leading bandwidth, sampling rate, memory depth and an array of advanced high-end features, the PicoScope 5000 PC Oscilloscopes give you the features and performance you need without any compromise.

Advanced Triggers
In addition to the standard triggers the PicoScope 5000 series comes as standard with pulse width, window, dropout, delay, and logic level triggering.

250 MHz Spectrum Analyser
High-speed USB 2.0 Connection
Automatic Measurements

Arbitrary Waveform Generator
Define your own waveforms or select from 8 predefined signals with the 12 bit, 125 MS/s arbitrary waveform generator.

Waveform Playback Tool
PicoScope software now allows you to go back, review, and analyse up to 1000 captures within its waveform playback tool.

The PicoScope 3000 Series of oscilloscopes from Pico Technology includes general purpose and high resolution models: With 12 bit resolution and 1% accuracy, the 10MHz PicoScope 3424 is able to detect changes as small as 0.024% (244ppm) – making it the ideal 4-channel oscilloscope for analog design and analysis. The higher speed 8 bit models in the PicoScope 3000 series feature sampling rates up to 200MS/s and up to 1 MS/s record lengths for general purpose and portable applications.

The PicoScope 2000 series oscilloscopes offer single and dual channel units that offer highly portable/low cost solutions to general purpose testing. The award winning 25MHz handheld PicoScope 2105 fits comfortably into the palm of your hand yet still includes the powerful features found in larger oscilloscopes.

VISIT
www.picotech.com/scope464
to check out our full line of PC-based instruments or call 01480 396 395 for information and a product catalog.
QVGA for Microchip PIC24F/H micros

Microchip announces a QVGA Graphics Solution for implementing graphics display and control in cost-sensitive applications. The new, easy-to-use solution for PIC24 16-bit microcontrollers includes a free, highly optimized graphics library with source code; third-party library support; and the new Graphics PICtail™ Plus daughter board.

The free Microchip graphics library supports rapid, low-risk development using two- and three-dimensional objects, including text, circles, rectangles, buttons, meters, windows, progress bars and more, along with images, animation, and touch screen capabilities. In addition, Microchip's third-party partners, Segger (www.segger.com) and Ramtex (www.ramtex.dk), offer compatible graphics libraries to provide even greater flexibility. Microchip's new Graphics PICtail Plus daughter board is designed to plug into the (Elektor) Explorer-16 development board and includes a Thin Film Transistor (TFT) LCD module that supports 320x240 (quarter VGA) graphic resolution and 65,000 colours along with touch-screen operation.

The new QVGA Graphics Solution supports any of Microchip's existing PIC24F 16-bit microcontrollers, and will offer support for future PIC24H 16-bit microcontrollers, 16-bit dsPIC® digital signal controllers, and the new 32-bit PIC® 32MX microcontrollers. The PIC24F family of devices provide a parallel master port interface, 4–8 kB of RAM and 16–128 kB of Flash program memory, offering maximum flexibility in supporting different LCD panel options. For example, using a 28-pin PIC24F microcontroller can enable high system performance, an extremely small footprint and reduced total system cost.

The graphics library, application notes and additional design resources are all available from Microchip's website today, and the Graphics PICtail Plus daughter board can be purchased from www.microchipsdirect.com. For further information visit Microchip’s website below.

www.microchip.com/graphics

Compact 5.7-inch VGA TFT display with LED backlight

Hitachi Display Products Group recently launched the TX14D14VM1BAB that brings VGA resolution and a 40,000 hour LED backlight to the existing range of compact 5.7 inch LCD TFT displays. The 640(w) x 480(h) VGA resolution display delivers 262,000 colours while a contrast ratio of 350:1 and typical brightness of 350cd/m2 ensure clear, bright images for all lighting conditions and environments. With module dimensions of (w)131.0mm x (h)102.2mm x (d)10.9mm, the TX14D14VM1BAB form factor is compatible with the other compact displays in the 5.7 inch range and features an active matrix, transmissive TFT LCD display. A touchpanel version of the display, the TX14D14VM1BPB, is also available, making this product ideal for a huge range of embedded industrial solutions from handheld data loggers to human-machine interfaces.

Both product versions are available immediately via Hitachi Display Product Group’s distribution partners across Europe. Hitachi Display Products Group is also able to design and develop customised display modules for specific customer requirements.

www.hitachi-displays-eu.com

IP68 rated temperature sensors

One of the main problems with temperature sensors is the ingress of moisture which can seriously affect the sensor performance — the weakest point often being the lead/sensor interface.

So ATC Semitec have developed a range of TPE encapsulated sensors where the leads and sensor are made from the same material. This creates a waterproof barrier which is rated to IP68 and can operate up to 105 °C.

These cost-effective sensors ensure absolute integrity when used in outdoor locations (e.g. solar panels) as well as in under-floor heating and other HVAC applications. There are also other options such as stiff lead versions and a high temperature variant rated to150 °C.

Double-insulated and rated to 4 kV, these IP68 sensors offer complete peace of mind in applications where moisture ingress has previously been a problem.

http://www.atcsemitec.co.uk/

INFO & MARKET NEWS & NEW PRODUCTS

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Gain the best start with PIC microcontrollers with MikroElektronika’s EasyPIC development system. High-speed USB PIC programmer, in-circuit debugger and plentiful I/O devices on one board from £79.

Start experimenting with robotics with the Robo-Box 3.0 robot kit. Contains everything required to build wheel and track-based robots and carry out a large range of fun experiments from £79.

The PoScope features a logic analyser with serial bus decoding, oscilloscope, pattern generator, spectrum analyser, chart recorder and square-wave/PWM generator in one low-cost instrument from £79.

Similar boards available for 8051, ARM, AVR, dsPIC and PSoC, plus compatible add-on boards and compilers.

Other robot kits available based on 68HC11, 8051, AVR, BASIC Stamp and PIC, plus large range of accessories.

The new range of high-specification logic analysers from ZeroPlus now also available.

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

Other training systems available for microcontroller and electronics teaching.

We stock prototyping products from breadboards to advanced digital and analogue circuit labs.

Please see our updated website at www.paltronix.com for even more new products
New PicoScope 2000 series scopes

Each new model in the PicoScope 2000 series is an oscilloscope, spectrum analyser, signal generator and arbitrary waveform generator (AWG) all in one unit, making it extremely versatile and economical. Unbeaten for functionality and price, with bandwidths up to 2.5 MHz and sampling rates up to 200 MS/s, the new scopes have a compact footprint of 135 mm x 135 mm (3.93 in x 5.31 in), small enough to fit easily into a laptop or travel bag.

The new PicoScope 2000 series scopes have two BNC input channels, a third BNC for a signal generator and arbitrary waveform generator output, and a USB port. Power is taken directly from the PC, and the scopes use the full USB 2.0 bandwidth of 480 Mbps to achieve rapid display updates without compromising accuracy and detail.

All PicoScope PC Oscilloscopes are supported by the same fully functional version of PicoScope 6 for Windows, which makes the most of the PC’s processing power, storage, graphics and communications. The familiar Windows interface and controls make the software easy to learn and operate, and convenient for everyday use.

PicoScope owners can download software updates, feature extensions and improvements that will remain free of charge for the lifetime of the product. They can also contact Pico's technical specialists for support by web, email, phone or Skype, at no extra charge.

PicoScope 6 can save data in a range of formats including CSV text, PNG and BMP images and MATLAB binary files. Drivers and examples are included for LabVIEW, C, C++, Delphi and Visual Basic for integration into custom applications.

The new PicoScope 2203, 2204 and 2205 PC Oscilloscopes are available from local distributors, or direct from Pico Technology, priced from £159 to £300 + VAT and delivery.

www.picotech.com (080073-II)

Rambus xdr (tm) memory architecture named 2008 Designvision winner

The International Engineering Consortium (IEC) has chosen the Rambus XDR™ memory architecture as the winner in the 2008 DesignVision Awards category for Semiconductors and ICs (IP). The IEC DesignVision Awards recognize technologies, applications, products, and services judged to be the most unique and beneficial to the industry.

Rambus recently announced that Toshiba has taken a license for the XDR memory architecture for its next-generation HDTV chipsets. In addition, Qimonda has begun shipping its first samples of XDR DRAM, and Elpida has begun shipping its first samples of XDR DRAM, and Elpida has begun shipping its first samples of XDR DRAM, providing a breakthrough performance of the XDR memory architecture.

- The XDR DRAM, a high-speed memory IC that turbo-charges standard CMOS DRAM cores with a high-speed interface capable of 4.0 GHz data rates providing up to 8 GB/s of bandwidth with a single device.
- The XIO controller IO cell providing the same high-speed signaling capability found on the DRAM, but adding additional enhancements like FlexPhase™ technology that optimizes timing and eliminates the need for trace length matching.
- The XMC memory controller, a fully synthesizable logical memory controller that is optimized to take advantage of innovations like Dynamic Point-To-Point which provides for capacity expansion while delivering the signal integrity benefits of point-to-point signaling.
- The XCG clock generator providing the system clocks with four programmable outputs, guaranteed to meet the clocking requirements for the XIO and XDR DRAM devices.

www.rambus.com (080073-IV)

SMS Electronics wins major deal

Nottingham based SMS Electronics Ltd have secured a multi year / multimillion pound deal with Siemens Enterprise Communications Limited to provide a range of services including Field Repair Unit support, Second user equipment refurbishment, Recycling (WEEE) and logistics. Under the terms of the deal SMS will acquire the Siemens Enterprise Communications Limited current operations based in Beeston Nottingham which will be transferred to a new company SMS Product Services Ltd.

SMS Product Services Ltd will be located in 40,000 sq ft building adjacent to the SMS Electronics Ltd current facility and increases the manufacturing floor space available to SMS to a total of 110,000 sq ft. The additional capacity is also required to cater for higher volumes from its existing customer base and recent contract wins.

SMS Electronics Ltd. have a long and successful relationship with Siemens and have also secured a further 5 year extension to their current Manufacturing agreement with Siemens Enterprise Communications Ltd.

www.smselectronics.co.uk (080073-VIII)
Quarter-brick DC-DC converters

The Bel Power division of Bel Fuse Inc. announced the ORQB-COU Series of open-frame isolated DC-DC converters. Housed in the industry standard ¼ brick (2.28” L x 1.45” W) package, the low-cost series provides up to 100 W of output power from a nominal 48 V input. Notably featuring a 4-to-1 input voltage range to accommodate both a 24 V and 48 V standard input voltage in the same module, it is moreover engineered with built-in input and output filtering to further minimize part counts. The highly reliable devices operate at efficiencies up to 91% over an ultra wide range of output voltages extending from 1.2 V to 12 V. Bel’s newest UL/cUL 60950-1 approved series may be confidently specified for employment in a broad array of distributed power architecture applications where space is limited, and overall weight is a factor. Among the most common uses for these high power density parts are in wireless networks, optical and access networks, as well as in industrial equipment. Additionally, their open-frame construction makes them ideally suited for convection-cooled environments. The isolated DCDC converters offer a full complement of control and protection features that include differential remote on/off, positive/negative remote sense, input over/under-voltage lockout, and over-temperature protection. Parts also offer output voltage trim, current limit, and short circuit protection. These devices switch at a fixed frequency (285 kHz) and have an operating temperature range of −40 to +85 degrees C.

www.belfuse.com

NanoBoards open up new hardware possibilities

Altium Limited has previewed its extended range of deployment NanoBoards at DesignCon 2008 and will showcase the new solution in Europe at Embedded World 2008.

Altium’s new deployment NanoBoards are standard, off-the-shelf design solutions that offer greater design flexibility for electronics designers. They can customize these cases to their own requirements. And by using Altium’s Innovation Station electronics designers can develop and test device intelligence and transfer that design into the deployment NanoBoards for a complete and marketable product.

Electronics designers can now, regardless of background or expertise, deploy a design into final hardware making the end product immediately available.

The extended range of deployment NanoBoards features the same motherboard and choice of daughter and peripheral boards as the Altium Desktop NanoBoard. Designers will have the choice of using a deployment NanoBoard as a final product, or integrating their deployment NanoBoards into larger systems such as mechanical devices. They will also be able to do semi-custom hardware design using the templates included with the Altium Designer software.

The Modular Commercial Enclosure system comprises basic units available in two sizes, a 1.0 and a 0.5 module. They can be configured by designers and come with a range of interchangeable components for an array of installation options. The system is designed to support the pluggable NanoBoard hardware deployment platform and includes all of the templates, mounting details and graphics specifications required to produce a fully customised application. The standard enclosures accommodate a motherboard with a choice of FPGA daughter boards and a 3.5 inch touch screen display. The standard 0.5 module provides for a maximum of two peripheral boards while the 1.0 module supports up to four peripheral boards. Altium’s range of deployment NanoBoards will be available later in 2008.

www.altium.com/Products/NanoBoard/
Internet radio is something quite special: even the most sensitive shortwave receiver cannot come close to providing such a broad range of programmes, and the sound quality is simply not comparable. As the ‘Internet broadcasters’ that provide these programmes do not have to pump several hundred kilowatts of RF energy in the air (with the resulting ‘electro-smog’), this type of broadcasting operation is also quite economical for relatively small target audiences.

We could say a lot more about the advantages of this new sort of radio (see inset), but what’s more important is to answer the question posed in the next section.

Why not use a pure software solution?

First of all, we have to say that there are several programs (WinAmp, iTunes, VLC, etc.) that are available entirely free of charge for all possible operating systems and can be used to listen to Internet radio. Every true 21st-century person has a PC, Mac or Linux machine available somewhere, so why should you spend money on a non-virtual, physical device, and on top of that build it yourself? Well, for one thing the hardware platform for a software radio consumes electricity, and quite a lot for this purpose. Anyone who spends a good deal of time listening to radio programmes with a PC is engaged in a very environmentally unfriendly activity. The solution proposed here manages to do the job with a power consumption of only 1 watt. If you use it 10 hours a day, the savings in electricity costs alone (relative to using a gamer PC as a radio) are enough to repay you investment within six months.

For another thing, there are applications for which a PC is not such a clever solution, such as connection to a stereo system. A DIY Internet radio based on Open Source technology is easy to extend and adapt to special requirements – and last but not least, the EIR keeps on working when your PC hangs or crashes.

Operating principle

As the EIR is a complex project that uses state-of-the-art hardware, it is impossible to deal adequately with all relevant topics in a single article. For this reason, the main objective of this article is to describe the hardware and tell you how to assemble it and put it into service. You can find additional information in documents on the Elektor website (www.elektor.com) and the project website [1], and there will be additional articles on this subject in future issues.

As you probably already realise, an Internet radio must receive, buffer and decode data streams. This means that one of its basic ingredients must be a reasonable microcontroller. As already mentioned in the last issue of Elektor [3], an ARM7 MCU [4] can provide the necessary processing power. The basic architecture is shown in Figure 1. The MCU is shown in the upper middle of the diagram, and it has access to a healthy 64 MB of SDRAM – which is sufficient for the buffer and quite a few ‘extras’. The MCU has room for the firmware, and there is also 4 MB of flash memory available for non-volatile data storage. A real-time clock backed up by a Supercap allows the circuit to be used to implement an alarm radio or other applications that depend on knowing the current time. To avoid having to exploit the full capacity of the ARM7 MCU, audio decoding is handled by a VS1053 IC [5], which is specifically designed for this purpose. The EIR also provides a comfortable selection of interfaces: beside the mandatory Ethernet port (since the EIR has to access the Internet somehow), there is a USB programming interface for downloading new firmware, a serial port and a JTAG port (useful for debugging), and three useful expansion connectors at the port level. To allow you to record broadcasts if you so desire, there is also a slot for an MMC/SD memory card.

General aspects

The incoming data streams are normally compressed to such an extent that they can handle sampled stereo data, which typically has a resolution of...
16 bits and a sampling rate of 44.1 kHz, using a data transmission rate as low as 192 kbit/s (or even less) instead of the normal rate of around 1.4 Mbit/s. This means that a buffer with a capacity of approximately 10 seconds can be implemented with around 256 KB of RAM. This may not sound like much nowadays, but it is still quite a hefty chunk of memory for a microcontroller. If you want to be on the safe side and also want to have room for Internet niceties and other ‘extras’, you can quickly end up with 512 kB or more. The ARM7 MCU selected for this design supports SDRAM, so the EIR with its 64 MB of RAM does not suffer from any shortage of memory.

We chose Nut/OS as the operating system. It is quite accommodating in comparison with Linux and can manage with less than 40 kB of memory. All in all, the software needs around 200 kB of memory. A capacity of 1 MB is ample for data storage. As the MCU already has 512 kB of flash memory on board for program data as well as an abundance of RAM, there are no bottlenecks. All of the software is Open Source, except for the flash programming software from Atmel.

Incidentally, the microcontroller has sufficient processing power to allow a second audio stream to be recorded on the SD card while another stream is playing. It will certainly not take very long for the Open Source community to devise upgrades that support this capability and other conceivable features.

In order to avoid constraining the form of any possible extensions, no user interface components (such as buttons or a display) are incorporated in the board. However, they can easily be connected via the expansion connectors. The EIR is intended to form the basis for user-designed expansions, and the firmware that comes with the board is thus designed to be used via an integrated website. However, the firmware is completely open, so other options are always possible.

Details

As you can see immediately from looking at the schematic diagram in Figure 2, this is a complex design. For this reason, the following description is based on the functional blocks.

- **Ethernet**
  Access to the Internet is via an Ethernet connector with an integrated transformer and two LEDs. The green LED lights up when data is being transferred, while the yellow LED indicates that a connection is present. The Ethernet traffic is handled by a specialised IC (IC10, a DM9000E). Buffer IC9

Figure 1. Block diagram of the Elektor Internet Radio.
Figure 2. As you can see immediately from the schematic diagram of the Elk, this is a sophisticated project.
allows the Wait input of the MCU to be used by expansion circuitry.

Audio decoder
Although the ARM7 would just be able to handle decoding of MP3 or AAC data in software, a dedicated IC such as IC7 considerably reduces the load on the MCU, and it is specifically designed to handle HE-AAC and even Ogg-Vorbis data in addition to the usual MP3 versions. Logically enough, this also simplifies the application software. We used a pre-production sample from VLSI in the prototypes. If you have trouble obtaining this IC, you can use the VS1033 version (without Ogg Vorbis capability) instead. Although the MCU has a 1.8-V output for powering peripheral devices, a separate 1.8-V voltage regulator is provided for IC7 for reasons of stability. If you use the VS1033, R39 and R42 must be changed to 100 kΩ because it needs a 2.5-V supply voltage.

Supplementary flash memory
It is necessary to store a large number of operational settings for the radio, and they must remain available even after a power outage (especially the station list). The internal flash memory of the MCU could be used for this purpose, but writing data to it is cumbersome. To simplify the process, a serial flash memory (ICS) is included in the design. With a capacity of 4 MB, it has room for extensive station lists and even more.

Power supply
To keep the power consumption of the EIR as low as possible, it is powered by a switch-mode supply built around IC12. It provides around 5 watts of power at 3.3 V with an input voltage in the range of 5–24 V. As the EIR takes only 1 W for its own use, there is enough left over for DIY hardware extensions.

Soldering
The EIR is built on a densely populated multilayer PCB with lots of tiny SMD components (see Figures 3 and 4), with some of the IC pins spaced only 0.5 mm apart. To avoid problems with DIY assembly, Elektor can supply a pre-assembled board with all SMDs already fitted (with the VS1053). All you have to do is to fit the relatively large components, which helps you avoid pernicious assembly errors. For the diehards, it is of course possible to build the board yourself using the layout artwork.

Functional test
For initial testing of the power supply, the load on the 3.3-V side should be at least several milliamperes (do not use it with no load). The voltage regulator should start working with an input voltage of at least 4 V and draw 50 to
150 mA, depending on the load. This will drop to 30–50 mA at 24 V. If everything is OK, LED1 will light up. After the ICs are fitted, you can use an oscilloscope to check that the crystal is working. If X1 is oscillating, the MCU should be ready for action.

The MCU comes with an on-board boot loader that supports communication from and to the RAM and with the flash memory as well as downloading new firmware. The AT91-ISPexe file available from Atmel (see reference [6]) installs the program SAM-BA, which runs under Windows. After installing this program, connect the EIR to your PC via the USB port. After the power is switched on, Windows should select the appropriate driver automatically. Now you can start SAM-BA. Select ‘USB’ as the connection type and ‘AT91SAM7SE512-EK’ as the device (this is largely compatible with the EIR).

You can download a simple testing firmware program from the Elektor website. With this firmware and an operational MCU and serial interface, you can check the other components, such as the Ethernet port and the audio decoder. After downloading the firmware to the MCU, you have to tell the EIR

Figure 3. The component layout of the EIR. To avoid assembly problems, a board with prefitted SMD components is available.

<table>
<thead>
<tr>
<th>COMPONENT LIST</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Resistors</strong></td>
</tr>
<tr>
<td>R1, R2 = 27Ω, SMD 0402</td>
</tr>
<tr>
<td>R3 = 1kΩ, SMD 0402</td>
</tr>
<tr>
<td>R4, R5, R6, R45 = 1kΩ, SMD 0402</td>
</tr>
<tr>
<td>R7, R8, R9, R10, R11, R12, R13, R14, R15, R16 = 10Ω, SMD 0603</td>
</tr>
<tr>
<td>R17 = 1MΩ, SMD 0402</td>
</tr>
<tr>
<td>R18 = 470kΩ, SMD 0402</td>
</tr>
<tr>
<td>R19 = 470kΩ, SMD 0402</td>
</tr>
<tr>
<td>R20, R21 = 470kΩ, SMD 0402</td>
</tr>
<tr>
<td>R22, R23, R24 = 1kΩ, SMD 0603</td>
</tr>
<tr>
<td>R25, R26, R27 = 1kΩ, SMD 0402</td>
</tr>
<tr>
<td>R31 = 6kΩ 1%, SMD 0603</td>
</tr>
<tr>
<td>R32 = 16kΩ 1%, SMD 0603</td>
</tr>
<tr>
<td>R37 = 22kΩ 1%, SMD 0402</td>
</tr>
<tr>
<td>R38 = 22kΩ 1%, SMD 0402</td>
</tr>
<tr>
<td>R39 = 22kΩ 1%, SMD 0402</td>
</tr>
<tr>
<td>R40, R41, R42 = 1kΩ 1%, SMD 0603</td>
</tr>
<tr>
<td>R43, R44, R45 = 10kΩ 1%, SMD 0402</td>
</tr>
<tr>
<td>R46 = 15kΩ, SMD 0402</td>
</tr>
<tr>
<td>R47 = 22kΩ, SMD 0402</td>
</tr>
<tr>
<td>R48 = 470kΩ 1%, SMD 0402</td>
</tr>
<tr>
<td>R49 = 470kΩ 1%, SMD 0402</td>
</tr>
<tr>
<td>R50 = 470kΩ 1%, SMD 0402</td>
</tr>
<tr>
<td>R100-R106 = 0Ω, SMD 1206 (not required)</td>
</tr>
<tr>
<td>* see text</td>
</tr>
</tbody>
</table>

| **Capacitors** |
| (SMD ceramic 6.3V unless otherwise indicated) |
| C1-C4, C16, C19, C30, C31, C35, C42, C46- |
| C51, C53-C59, C62-C65, C67, C68, C69, C71, C72, C73, C75, C76, C77, C79, C85, C87, C88, C89, C91-C97 = 100nF, SMD 0402 |
| C5, C6, C9, C10, C17, C20, C32, C33, C34 = 22pF, SMD 0402 |
| C7, C38 = 1nF, SMD 0402 |
| C8, C21, C22, C27, C28, C37, C100 = 10nF, SMD 0402 |
| C24, C25, C26, C43 = 1μF, SMD 0805 |
| C36 = 0.1F, Double Layer Cap |
| C40 = 1μF, SMD 1206 |
| C41 = 1μF, SMD 1206 |
| C98 = 100μF 16V tantalum, SMD |

| **Inductors** |
| L1 = DLW5BT102SQ2 (Murata) |
| L2 = 10μH, MSS5131 (Coilcraft) |
| L3 = BLM31A (Murata) |

| **Semiconductors** |
| D1, D2, D3, D5 = PMEG3005AEA (Philips) |
| D4 = SM6T24CA (STM) |
| IC1 = AT91SAM7SE512-AU (Atmel) |
| IC2 = MAX3222ECWN (Maxim) |
| IC3, IC6, IC9 = 82A408B diode array |
| IC4 = MT48LC32M16A2 |
| IC5 = AT45DDB320-256U (Atmel) |
| IC7 = VS1053C-L (VLSI) |
| IC9 = NC7WZ07P6X (Fairchild) |
| IC10 = DM9000E (Davicom) |
| IC11 = PCF8563T (Philips) |
| IC12 = LT1616 (Linear Technology) |
| IC13 = LTC1844E55-SD (Linear Technology) |
| LED1 = KP1608URC, red, SMD 0603 |

| **Miscellaneous** |
| X1 = 18.432 MHz quartz crystal, SMD HC49SM |
| X2 = 12.288 MHz quartz crystal, SMD HC49SM |
| X3 = 25.000 MHz quartz crystal, SMD HC49SM |
| X4 = 32.678 kHz quartz crystal, SMD MC-146 |
| F1 = fuse, 0.5A, fast, with holder, SMD OMNI-BLOK (Litelfuse) |
| K1, K2, K3 = 40-way SMT pinheader, lead pitch 2.54mm |
| K4 = USB-B socket, AMP-787780 |
| K5 = 9-way sub-D plug, angled pins, US standard |
| K6 = 20-way boxheader, 2.54mm lead pitch |
| K7 = SD-card socket, SMD, FPS009-2700 [Yamaichi] |
| K8, K9 = 3.5-mm stereo jack socket, SMD, SU-1515 [CUI] |
| K10 = RJ-45 socket with Ethernet transformer and LEDs, SMD, RJLD-043TC (Taimag) |
| K12 = DC adaptor socket with 2-mm pin, TDC-002-3 |
| JP1 = 6-way 2-row pinheader with 2 jumpers, 2.54mm lead pitch |
| S1 = pushbutton, SMD, LSH [Schurter] |
| PCB with pre-mounted SMD parts, Elektor Shop # 071081-1 |
| Project software, archive 071081-11.zip; free downloads from www.elektor.com |
that it should boot from this firmware when it restarts. To do so, select the routine ‘Boot from Flash (GPNVM2)’ under ‘Scripts’ and click ‘Execute’.

Figure 4. As you can see from the fully assembled prototype, DIY soldering isn’t so easy here.

Then close SAM-BA and press the Reset button. Now the EIR can communicate with the PC via the serial interface and a null-modem cable (pin 2 & 3 leads swapped), and you can use a terminal emulator to send commands to the EIR (we recommend TeraTerm [7] for Windows or Miniterm for Linux, and Macs have a built-in terminal utility).

**Listening to the radio**

Before you can start listening to the radio, you have to delete the test firmware from the EIR and install the radio firmware. To allow new firmware to be loaded, first connect pins 34 and 36 of connector K3 with a jumper, then press Reset, and finally remove the jumper. After this, the EIR will start up again with the boot loader, and you can use SAM-BA to download the radio firmware.

Now connect the EIR to your local network via the Ethernet port (using a hub, a switch, or an Internet router with several ports) and connect the audio output to a headphone or an amplifier. If the LAN or the router you are using has an active DHCP server, the EIR will fetch a valid address and start playing the programme from the default station. If you prefer to use fixed IP addresses, proceed as follows. When you install Nut/OS, a small utility called ‘Discover’ is installed on the PC, and you can always use it to find the EIR (see Figure 6) and then configure the desired IP address. Enter the router address under ‘Gateway’, as illustrated in Figure 7. After this, you should be able to listen to the radio (Figure 8) with fixed IP addresses.

**Prospects**

As already mentioned several times, the EIR is a completely open-ended concept. The software and hardware (via the expansion pins) are both fully and freely available.

Table 1. Expansion connector K1

<table>
<thead>
<tr>
<th>Pin</th>
<th>Signal</th>
<th>Use</th>
<th>Pin</th>
<th>Signal</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>PA0</td>
<td>Free</td>
<td>2</td>
<td>PA1</td>
<td>Free</td>
</tr>
<tr>
<td>3</td>
<td>PA2</td>
<td>Free</td>
<td>4</td>
<td>PA3</td>
<td>TWI SDA</td>
</tr>
<tr>
<td>5</td>
<td>PA4</td>
<td>TWI SCL</td>
<td>6</td>
<td>PA5</td>
<td>UART0 RxD via JP1</td>
</tr>
<tr>
<td>7</td>
<td>PA6</td>
<td>UART0 TxD via JP1</td>
<td>8</td>
<td>PA7</td>
<td>UART0 RTS</td>
</tr>
<tr>
<td>9</td>
<td>PA8</td>
<td>UART0 CTS</td>
<td>10</td>
<td>PA9</td>
<td>DEBUG RxD via JP1</td>
</tr>
<tr>
<td>11</td>
<td>PA10</td>
<td>DEBUG TxD via JP1</td>
<td>12</td>
<td>PA11</td>
<td>Data Flash Chip Select</td>
</tr>
<tr>
<td>13</td>
<td>PA12</td>
<td>SPI MISO</td>
<td>14</td>
<td>PA13</td>
<td>SPI MOSI</td>
</tr>
<tr>
<td>15</td>
<td>PA14</td>
<td>SPI SPCK</td>
<td>16</td>
<td>PA15</td>
<td>MMC Chip Select</td>
</tr>
<tr>
<td>17</td>
<td>PA16</td>
<td>MMC Clock</td>
<td>18</td>
<td>PA17</td>
<td>MMC Command</td>
</tr>
<tr>
<td>19</td>
<td>PA18</td>
<td>MMC DAT0</td>
<td>20</td>
<td>PA19</td>
<td>MMC DAT1 via R7</td>
</tr>
<tr>
<td>21</td>
<td>PA20</td>
<td>MMC DAT2 via R8</td>
<td>22</td>
<td>PA21</td>
<td>Free</td>
</tr>
<tr>
<td>23</td>
<td>PA22</td>
<td>Free</td>
<td>24</td>
<td>PA23</td>
<td>SDRAM DQMH</td>
</tr>
<tr>
<td>25</td>
<td>PA24</td>
<td>SDRAM A10</td>
<td>26</td>
<td>PA25</td>
<td>SDRAM CKE</td>
</tr>
<tr>
<td>27</td>
<td>PA26</td>
<td>SDRAM Chip Select</td>
<td>28</td>
<td>PA27</td>
<td>SDRAM WE</td>
</tr>
<tr>
<td>29</td>
<td>PA28</td>
<td>SDRAM CAS</td>
<td>30</td>
<td>PA29</td>
<td>SDRAM RAS</td>
</tr>
<tr>
<td>31</td>
<td>PA30</td>
<td>IRQ1, MP3 Interrupt</td>
<td>32</td>
<td>PA31</td>
<td>MP3 Command Select</td>
</tr>
<tr>
<td>33</td>
<td>Vref</td>
<td>ADC Reference</td>
<td>34</td>
<td>3.3V</td>
<td>Power</td>
</tr>
<tr>
<td>35</td>
<td>AD4</td>
<td>Analogue input (free)</td>
<td>36</td>
<td>AD5</td>
<td>Analogue input (free)</td>
</tr>
<tr>
<td>37</td>
<td>AD6</td>
<td>Analogue input (free)</td>
<td>38</td>
<td>AD7</td>
<td>Analogue input (free)</td>
</tr>
<tr>
<td>39</td>
<td>GND</td>
<td>Ground</td>
<td>40</td>
<td>GND</td>
<td>Ground</td>
</tr>
</tbody>
</table>

Figure 5. Screen shot of SAM-BA running under Windows 2000.

Figure 6. You can use this program (here running under Linux KDF) to find the EIR even if its IP address is unknown.
Internet radio

If you take a look on the Web, you’ll be astounded to see that Google presently finds more than 21 million hits for ‘Internet radio’, so it’s obviously a hot topic. The first experiments with packet-based ‘broadcasts’ were carried out as early as 1993, at around the same time as the first usable browser (NCSA Mosaic) and thus the dawn of the commercial Internet era. Quite early on, ‘real’ radio stations started broadcasting their programmes via Internet streaming in addition to conventional radio waves. Today you can receive tens of thousands of radio programmes with an ordinary Internet connection. In addition to a plethora of highly diverse niche programmes, you can now access nearly all public and commercial broadcasters.

The term ‘streaming’, which covers near-real-time transmission of time-referenced data such as audio or video content, refers to data streams that are as continuous as possible and require the originator to transmit a separate stream for each client, which can generate an enormous traffic volume and thus be a costly proposition if there are a lot of listeners. To keep the data rates within acceptable bounds, a lossy compression is usually used to compress the data before transmission, and the data is subsequently decompressed by the receiver. This means that an Internet radio receiver must incorporate a commonly used streaming decoder, such as MP3, Ogg Vorbis or Real Audio, regardless of whether it is purely software-based or uses dedicated hardware.

As it is not possible to guarantee a constant propagation delay for individual data packets with the HTTP and FTP protocols normally used on the Internet, the receiver must also have a data buffer with sufficient capacity, which delays reception by a few seconds and means that it is only ‘quasi live’. This makes fast zapping between stations impossible. However, thanks to digitalisation this drawback is offset by stable audio quality, extreme (worldwide!) range, and a truly fathomless diversity of programmes. It is also possible to receive previously recorded programmes (missed broadcasts) by means of ‘audio on demand’, which no conventional radio station can offer.

References and web links

[1] egnite project website: www.ethernut.de/de/hardware/eir/
Most solid state power amplifiers employ some form of global negative feedback to reduce non-linearities and output impedance. In some cases, designers exploit alternatives like feedforward to circumvent perceived disadvantages of global negative feedback. The present design uses error correction as (re)defined by Malcolm Hawksford around 1984 [1].

In part 1 of this article the author discusses error correction for audio amplifiers and presents an audio output stage based on error correction. Part 2 will extend the principle to the voltage amplifier stage and present a complete error correction power amplifier. In a separate article next month the protection circuitry is discussed in more detail.

Negative feedback is not negative
This is not an article against negative feedback (nfb). Negative feedback, as a general principle, is one of the most powerful tools available to the designer to build amplifiers that are transparent to the signal they amplify. With that I mean that they do not add anything to, or subtract from, the input signal. In reality, circuits are never ideal, but the changes to the signal can be made so small that inaudibility of the change is pretty much guaranteed. Negative feedback is also fully understood, and although bad-sounding feedback amplifiers are still being sold, it is totally unnecessary. So, you may ask, why bother with error correction (ec)? For one thing, it is different; and different roads to the same goal are often enjoyable to travel and explore. Secondly, although we will see that ec is in many respects another face of nfb, with similar advantages and disadvantages, there are some interesting differences and different challenges leading to better understanding of the processes inside any feedback amplifier.

What the H.ec?
Let’s start by narrowing down what we mean by ec in the context of this article. I refer specifically to Malcolm Hawksford’s paper referenced above. I will use the term ‘H.ec’ to refer to Mr. Hawksford topology, and ‘ec’ to refer in general to error correction. Figure 1 is the basic topology from that paper. We see an amplifier block N, on which the error correction will be ap-
plied. The difference between the input and output of that amplifier is either added to the input via block ‘a’ (error feedback), or to the output via block ‘b’ (error feedforward). All the summing and differencing blocks have unity gain (1×). Of course it is important that the error correction signal is added in just the right proportion to cancel the original error. In this design I use the correction via block ‘a’, added to the input.

We will further assume that the amplifier block ‘N’ is an output stage from an audio power amplifier with a gain only just below 1. The object here is to make this gain exactly 1, independent of output load, frequency and signal level. If we succeed, we will have an ideal output stage. Of course we won’t get that far, but as we will see, we can get pretty close.

We now get to our conceptual circuit in Figure 2. The output stage we want to linearise is ‘A’, with a gain of ‘about 1’. In practice, most output stage gains are anywhere between 0.92 and 0.98 depending on the topology, loading, signal frequency etcetera. We see immediately that $V_e$, the signal that is fed back to the input, is $V_{out} - V_e$, where $V_e$ is the effective input signal to the output stage. We can now calculate $V_e$ as

$$V_e = V_{in} - (V_{out} - V_e).$$

We also know that $V_e = V_{out}/A$, and if we plug that into the former equation and rearrange terms, we get:

$$V_{out} = V_{in}.$$
What is significant here is that the actual amplifier gain $A$ is no longer part of the equation. Whatever the shortcomings, non-linearities or errors of $A$, we got rid of all of those. This is our ideal output stage!

If you are familiar with practical audio amplifiers, you probably are feeling a bit uneasy now. An ideal power stage? That would be the first one ever! And you are right — in reality, we can’t make that ideal.

The reason is that we assumed that the summers in Figure 2 are ideal summers, without flaws. That cannot be. Those summers consist of passive and (most probably) active devices that have their own non-linearities, so the basic accuracy will not be ideal. Their characteristics will also vary with frequency, so the correction accuracy will vary with frequency. As the output stage gain will also vary with frequency and load, the amount of correction required will vary with frequency and load, meaning that signal levels in the summers vary with frequency and load as well. This further leads to accuracy limitations. Nevertheless, it is possible to greatly improve the performance of the output stage with relative simple means, as we will see.

**Thermal memories**

There was one other goal I had with this amplifier. In most power amplifiers, the thermal bias compensation is obtained by mounting a transistor in the bias circuit on the same heatsink as the output devices. In that way, if the output devices heat up and start to draw more current, the bias transistor also heats up. That causes the bias voltage to decrease, and the object is to dimension this thermal feedback loop such that the bias current in the output devices remains stable with temperature. But because it takes time for the heatsink to heat and cool and transfer this changing temperature to the bias transistor, this loop reacts relatively slowly at several seconds or more.

The first time I read about this was in an article by a French audio (not fashion) designer authoring under the pseudonym Hephaistos [2]. He realized that the dissipation levels in the output and driver devices vary with signal output levels, related to music level variations, and that they are much faster than the reaction time of the thermal bias compensation circuit. When a high level signal burst appears, the devices’ biasing point would shift, and would return to the earlier state only seconds after the high level burst had disappeared. Such a burst is too short for the thermal feedback to adjust the bias. A smaller signal after the burst would thus be processed with different operating conditions than before. He called this ‘thermal distortion’.

In my design I wanted to get rid of this problem as well. Therefore I selected Sanken STD03N and STD03P devices for the output stage. These are Darlington, with a bias diode integrated on the transistor chip. By using this diode in the bias circuit, it can track thermal cycles in the output devices instantaneously, thus hopefully eliminating thermal distortion. Because it is a Darlington, any (pre) driver dissipation would also be low enough to avoid memory distortion.

There’s one catch: the on-chip sense diodes need to be run with a specific current to make their thermal bias changes in millivolts per degree, equal to the $V_{be}$ changes of the driver and output devices in millivolts per degree. This requires a different bias circuit from the usual $V_{be}$ multiplier.

### Error correction basics

Figure 3 shows the basic topology of the output stage without error correction. You will notice the integrated bias diodes in the output devices. To get a precise matching between these diodes and the output Darlington’s b-e junctions, Sanken’s engineers used a string of five Schottky diodes in the P-device and a single silicon diode in the N-device.
The datasheet specifies a bias current of 2.5 mA through the diodes, and this current is set by the current mirror formed by Q19-Q20 and Q18-Q11. The current is set with R44 and mirrored into the diodes. To keep this current stable, the supply voltage for the current mirrors is regulated by zener diodes D10-D11 to 15 V. The bias for the zeners is coming from the main supply via R36-R37 and R35-R38. To keep exactly that supply stable, the junction between those resistors is bootstrapped from the output via C11-C12. The result is that with varying output signal levels, the zener diodes can always provide a constant supply voltage for the current mirrors.

The datasheet for the output devices also specifies a quiescent current of 40 mA through the output Darlington for best thermal tracking. Although the diodes track the changes in the Darlington Vbe quite well, the absolute value of the diode threshold values varies from unit to unit. Thus, it is necessary to be able to adjust it, and that is the purpose of RV1. So, we should set RV1 for 40 mA through the output stage. OK, so now we have a nice and stable output stage, but we need to drive it with a signal. That is done through R60 to the junction of R19-R20. Suppose that the input signal goes positive: the junction of R19-R20 goes positive so there will be less current through R19. Since the current coming out of the collector of Q20 is fixed, there will be more current into the base of the Darlington and the output signal will also go positive, following the input signal. In this case there will also be more current through R20 so less from the base of the P-device.

This will work quite well for DC and low frequencies and nominal, resistive (8 ohms) loads, where the Darlington pairs have a very high gain and the current mirrors are almost perfect. However, with increasing frequency and increasing load currents, the Darlington on more input current, so capacitors C7 and C8 are added to bypass R19-R20 so the input source can directly drive the output devices.

This output stage is quite simple, reasonably linear and satisfies the requirement for accurate temperature tracking of the instantaneous output device dissipation. The next step is to wrap error correction around it. Because the stage has no excess gain, you cannot use a global nfb loop around it. The nfb loop that normally includes the output stage of a feedback amplifier of course relies on the excess gain in the voltage amplifying stage to work its distortion-reduction trick.

The Current Conveyor

For ec we need to derive the difference between the input and output signal, and add that difference to the input signal, as shown in Figure 2. Subtracting two signals that are of similar level, and adding two signals that are of similar level is trivial with opamp circuits. We can use one opamp (S2) to subtract \( V_{out} \) from \( V_{in} \) and another (S1) to add the resulting \( V_{+} \) to \( V_{-} \). But in the spirit of ec I didn’t want to use an obvious high global feedback element in this circuit.

After a lot of head scratching and many Internet searches, I came up with the idea to use a current conveyor [3]. The basic circuit is shown in Figure 4a. This is a very interesting circuit: basically, whatever you send into the Y terminal comes out in opposite direction from the Z terminal, which works as a current source.

Hence the name current conveyor: the current at the input is conveyed to the output. This particular type is called a second-generation conveyor, generally shown as a ‘CCII’. Terminal X is a reference terminal for the current input, and the voltage at Y will be kept the same as that at X.

What is this good for? As an example (Figure 4b), if you connect a signal to Y via a resistor, you know that the current into that resistor will be the signal minus \( V_e \) (remember, \( V_1 = V_2 \)). So the current into Y is this voltage across the resistor divided by the resistance. That same current comes out of Z, so you have now converted a signal level to a current that can be converted back to a signal via another resistor.

If the second resistor on Z is twice the input resistor on Y, you have a gain of 2, without a feedback loop. You can set the gain of this circuit with just two resistor ratios, as shown in Figure 4b. The nice thing here is that we can accurately set a gain (or attenuation, if that would be required) without having to resort to nfb.

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How H.ec differs from Global Negative Feedback - or not.

Error correction works by feeding back (part of) the output signal to the input of the amplifier. It has many similarities to a classical negative feedback loop. But how is it different?

Two sides of the same medal. Figure 1a is the basic H.ec topology. You can identify two feedback loops: one positive feedback loop via \( V_s \) to \( V_e \) and back to \( V_c \); and a negative feedback loop from the amplifier output to \( V_e \). That particular arrangement makes H.ec so interesting. Let’s assume that the output stage ‘A’ is ideal and has a perfect gain of 1. In that case, the correction signal at \( V_e \) is 0, because there is no difference between \( V_e \) and \( V_m \). We could just throw away the whole error correction part. But if the gain A is just below 1, \( V_e \) is a negative signal which is subtracted from \( V_e \), and the effect is that \( V_e \) increases. This works as a positive feedback loop. In the case where the gain A would be larger than 1, the signal at \( V_e \) is a positive signal, which will be subtracted from \( V_e \) to decrease \( V_e \). In this case, the system works as a negative feedback loop. So, what you see is a combined feedback loop that can act either as a positive or negative feedback loop, or not at all, depending on the error of the main amplifier block. It looks as if the phase and level of the loop adjusts itself as needed. The validity of treating a combined feedback loop by ‘summing’ the individual loop contributions has been established by several researchers in the past. Gerald Graeme, at the time analogue IC development manager of Burr-Brown, wrote several articles about it [1].

How does this differ from a ‘classical’ negative feedback loop? We can take the two feedback loops in H.ec apart as in Figure 1b. Error correction can be seen as a classical global nfb loop with a positive feedback loop embedded. For comparison, Figure 1c shows the global nfb topology for a unity-gain amplifier.

Less complexity is better. In the classical case, the high loop gain, necessary for negative feedback to reduce distortion, is obtained by means of a high-gain (ideally infinite-gain) forward amplifier block. In the case of H.ec, the high forward gain is obtained by a positive feedback loop, and the forward amplifier block can have any open-loop gain. To keep the task of a practical error correction circuit as small as possible (and therefore optimise the circuit linearity), the error signals should be minimal. For this, an open-loop gain equal to the required closed-loop gain is best. That means that with H.ec, similar results as with classical feedback can be reached with a much simpler amplifier. In the case of a unity gain amplifier, just an emitter follower would be sufficient, while in the classical case, even if we wanted a closed-loop gain of 1, we would still need a very high-gain amplifier block. If nothing else, this leads to the practical advantage that the forward amplifier can be much simpler. Of course, there is no such thing as a free lunch (TANSTAFL): we have diverted some of the complexity to the two summers that must be precise circuits to make it all work. As always in audio engineering, the final advantage depends on how smart you are at implementing the various circuit parts.

Less gain is better. There is another advantage to H.ec. When a negative feedback amplifier clips, the feedback loop tries to make the output following the input by increasing the input signal more and more. But that output cannot increase beyond clipping, and as a result the amplifier is overdriven. This can be quite drastic: consider an amp with a 1 V input signal and an open-loop gain of 60 dB (1000 times) and a closed-loop gain of 30 dB (30 times) that clips at 30 V_out.

If the output signal is 30 V, the effective input signal to the 60 dB gain amplifier \( V_{in} = \frac{V_{out}}{A_{open}} \) is 30 V divided by the open-loop gain, or about 30 mV. If we overdrive this amplifier by doubling the input signal to 2 V, the feedback signal cannot increase due to clipping. So the effective input signal to the 60 dB gain amplifier jumps from 30 mV to 1 V! (2 V input – 1 V feedback).

The clipping will become very hard, and the output wave looks as a sine wave with the tops sheared off. There is a danger of heavy internal stage overdrive, and it is possible that it takes some time, after the clipping ends, until all internal stages are returned to their stable operation point. Many amplifiers will have measures to try to avoid these conditions but it does add to the complexity. With an H.ec amplifier, the mechanism is similar. The error correction signal will increase and the input signal to the amplifier block is increased in an attempt to enable the output to follow the input. But now the amplifier block is a low-gain block, typically having a gain of only the closed-loop gain, for example only 30 dB, instead of the very high open-loop gain of 60 dB of the negative feedback amplifier. As a result, clipping and internal overdrive is not as hard. In my opinion, this is an important advantage, which is shared with valve amplifiers. Valved amps of moderate power output can sound quite pleasant, despite relatively high distortion factors, which is to a large extend caused by their soft clipping characteristics. It is also one of the reasons why very high power (300 W or more) solid state amplifiers sound better than 50 W amps with the same distortion: the high power amp clips far less than the low power amp, so the hard clipping, which can make the sound so harsh, is greatly reduced.

The current conveyer does not use global feedback; it is an open-loop circuit. As an aside, current conveyors consist internally mainly of current mirrors; and it can be argued that current mirrors use 100% local feedback. But we won’t get into that discussion here!

There is our summer circuit: we will use equal resistors for unity gain (1).

The error correction loop around my output stage is shown in Figure 5. The error between the input and the output appears across R34 and develops a current that is ‘conveyed’ to R25. This adds the correction signal to the V_in to make the H.ec work as we discussed before in Figure 2. The positive feedback loop in Figure 2 from V_e through V_c back to V_e is realized with the connection of Z to X in Figure 5.

So, at this point, we need to get practical: where do we find this CCII thing? There are CCII’s around, often designed in low-voltage CMOS IC technology, and mostly used in laboratories in academic surroundings. They might as well be made from ‘unobtanium’.

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But, interestingly, CCII’s are part and parcel of current feedback opamps and so-called ‘diamond transistors’.

Figure 6 shows the simplified diagram of the internals of an AD844 current feedback opamp. We recognise the CCII terminals: pin 3 is the high-impedance X terminal, pin 2 the low-
impedance current input Y and pin 5 labelled Tz is the current source output Z. It is readily seen that whatever current is injected into pin 2 (Y) comes out at pin 5 (Z) but in opposite direction. It seems this part has been custom designed for us! Other similar parts are Maxim’s MAX435 and MAX436 (now obsolete) and TI’s OPA860, which superseded the OPA660 and OPA2660. We can use the input stage for the CCII function, and the buffer to drive the output stage to isolate the input summer from the output stage’s non-linear input impedance. We see that the current output terminal is already internally connected to the buffer input, again, just what we need! **Figure 7** shows the full output stage circuit, with component values. 

![Figure 6. Basic AD844 CCII diagram plus output buffer.](image)

![Figure 7. Full unity-gain output stage with Hawksford error correction.](image)
that the amplifier input is at pin 5 of the AD844, not at pin 2 or pin 3 as we would expect in a classical opamp circuit. This is NOT an opamp circuit, but I’m sure a lot of people will be confused by this...

**Putting it all together**

This output stage has two pairs of output devices. The design goal was 100 watts in 8 Ω and 200 watts in 4 Ω. For a pure resistive load, one pair of devices would have been sufficient. However, speakers are not purely resistive; depending on the signal frequency they can act capacitive or inductive, especially if there is a complex crossover filter. This leads to phase shifts between the output voltage and output current, so you can get the situation that the output voltage is negative,
but that the current is coming from the positive side (the N-device). The N-device will have a quite large $V_{ce}$, and the current it is allowed to source is much smaller with a large $V_{ce}$ than what you would think from the allowable dissipation.

Further details about the safe operation area of the output devices will be given in a separate article next month. Anyway, because of the dual output devices, there is also an additional current source to bias the thermal tracking diodes, as well as an extra bias adjust trimmer.

There are a few extra components in the circuit which we haven’t mentioned before.

R60 is a small resistor in series with the AD844 buffer output stage. A large part of the output drive goes via the two capacitors C2 and C4 to bypass the current mirrors. R60 isolates the buffer output from capacitive loads ensuring stability.

Another capacitor, C3, is placed across R25. As the frequency increases, the loop through the output stage as well as the current conveyor will exhibit phase shift. In a ‘classical’ feedback amplifier, if the phase shift becomes too large, it will turn the nfb into pfb which, as we all know, will lead to instability and even oscillations. In H. ec this is also the case of course (it shares many attributes with a feedback amplifier), so we need to roll off the loop gain for higher frequencies, just as in a classical nfb amplifier. C3 does just that by decreasing the effective correction impedance ($R_{25}/C_{3}$) with increasing frequency.

Also remember that this stage needs to be driven from a low impedance source, because the source output impedance forms part of the ec scaling resistor R25.

Finally, there is the 6-pin connector J10 and some associated resistors. This is the connection to the protection board which we will discuss separately. It provides the $V_{ce}$ and $I_{c}$ related information of the output devices to the protection circuitry.

This output stage is pretty linear as attested by the curves in Figure 8. The output stage can perfectly stand on its own when driven by a suitable voltage amplifier (Vas) stage. So, let’s take a break here; we’ll attack that Vas, and the power supply, in the next installment and develop a full-fledged, high quality audio power amp. Stay tuned.

Literature and note


[3] In the early 90’s, an IC designer, Doug Wadsworth, designed a current conveyor for audio on his own money (PA630). The chip, the ‘Swift Current’ chip, eventually found its way into Wadia DACs. It is no longer available for other parties but I had bought some from him and knew they were a well kept secret for hi-end audio.
Atlas DCA55
Semiconductor Analyser
Identifies type and pinout!

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Atlas ESR60
ESR and Capacitance Meter
Resolution of 0.01 ohms!

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New Low Price!

Atlas SCR100
Triac and Thyristor Analyser
Auto gate test current up to 100mA

£99

New Low Price!
A Coldfire 32-bit home automation server

Part 1: introduction and circuit descriptions

Richard Sumka (Freescale Semiconductor Inc.), Luc Lemmens & Jan Buiting (Elektor)

This project employs a Freescale Coldfire micro and associated PC software that allows remote switching of electrical loads across networks including the biggest we know – the Internet. The ingredients from the Freescale/Elektor kitchen: 32-bit embedded technology, free software, a low-cost kit for the hardware and free tools to expand the functionality of the server to your own liking. In the first instalment we describe the general structure of the server and the optional Turbo BDM programmer for Coldfire devices.

Out for the night and forgotten to switch off the lights at home, or the heating? This project could be the solution, providing the ability to control equipment remotely over the Internet using a web browser or WAP enabled phone. Sure, that application alone may look trivial considering the sheer power of the microcontroller used but that’s also the crux of the project: it’s expandable and totally geared to open-source development as we have made sure that...
all resources are available either free (software) or at low cost (hardware).

**Networked home automation server**

Connecting applications together is fast becoming a necessity rather than an option, especially where Ethernet networking is concerned. This home automation server using a Freescale 32-bit Coldfire device and Freescale software allows remote switching of loads across Ethernet networks and the Internet. And with some ingenuity, simple modifications allow the server to be used for remote sensing and monitoring.

**Crossing the internet (and WAP gateways)**

Web pages are transferred across the Internet using HyperText Transport Protocol (HTTP). HTTP is a request-response protocol and can be used to send any type of data including binary data. The client – a web browser – requests a web page from a web server and the web server responds with the web page contents. Simple as that may sound, there’s a lot of technology behind it all!

As illustrated in Figure 1, DigiButler is a mini web server that will happily sit behind an Internet connected router. Alternatively, it may be connected to a local network or directly to a PC. For most of this article we will describe the connection as though it were behind a router.

The unit will accept commands from, and return data to, any Internet-connected PC or WAP telephone that has DigiButler’s IP number. Password protection is also provided by the client software.

**About the MCF52231**

The Freescale Coldfire MCF52231CAF60 in its LQFP80 case is a member of the MCF5223x family of 32-bit connectivity microcontrollers. Its architecture is shown in Figure 2. The two key features of the family are the integrated 10/100 Mbit/s Fast Ethernet Controller (FEC) and Ethernet Physical Layer (EPHY); in brief, everything needed to get a single chip application onto an Ethernet network. If you want to delve really deep into this, there’s a must-read article available from Eric Gregory [1].

This device also has a CAN 2.0B controller. CAN is commonly used as an...
• 128 kB of embedded Flash memory
• 32 kB of SRAM
• 60 MHz Coldfire V2 32-bit CPU
• Up to 56 bits of general purpose I/O
• Three UARTs
• Serial peripheral interface (QSPI)
• PC bus interface
• Four 32-bit timer channels with DMA capability

• 4-channel, 16-bit timer for capture, compare and PWM
• 2-channel periodic interrupt timer
• 4-channel, 16-bit or 8-channel, 8-bit PWM generator
• Two 4-channel, 12-bit analogue-to-digital converters
• 4-channel DMA controller
• Up to 73 general-purpose I/Os
• PLL, watchdog, real time clock, range of reset sensors
• On chip background debug module (BDM)
• Single 3.3 volt supply

Figure 3. Schematic of the home automation server. The circuit has been designed for expandability — in fact it makes a great development system for Coldfire 32-bit microcontrollers.
industrial control serial data bus because of its suitability for use in real-time communication environments and its reliable operation in conditions of harsh EMI. The MCF52231’s bigger brother the MCF52235 also has Cryptographic Acceleration Unit and random number generator for secure hardware encryption. Some of the other important features of the MCF52231 are listed in the inset.

Electronics
If we include the transistor and the voltage regulator, there are four active components in the circuit diagram in Figure 3. Let’s take a tour of the schematic.

Everyone’s encouraged to improve & extend the DigiButler C code and let us know the results

At the heart of the circuit sits the Freescale MCF52231 Coldfire device (U1). The 10 or 100 Mbit/s 802.3 ready Ethernet interface is provided by isolation transformer T1 and the physical RJ45 Ethernet connector J2. Crystal Y1 (25 MHz) sets the clock frequency of the Coldfire microcontroller. This is multiplied up by the device’s internal PLL to give a core clock frequency of 60 MHz. Crystal Y1 (25 MHz) sets the clock frequency of the Coldfire microcontroller. This is multiplied up by the device’s internal PLL to give a core clock frequency of 60 MHz. Eight 12-bit analogue inputs are available on connector J11. These are routed directly to the ADC pins of the Coldfire. A further six of the Coldfire’s digital input/outputs are available on J12. All can be used as general-purpose I/O and two may be configured to connect to the I²C module in the microprocessor. The two I²C lines, SDA and SCL, are fitted with 10 kΩ pull-up resistors. The I²C can operate at up to 100 kbps with maximum I²C bus loading and timing, and even faster if the bus loading is reduced.

J1 is the BDM (Background Debug Mode) interface, allowing in-circuit debugging of the application code and Coldfire Flash memory erasing and programming. The associated programmer (for optional use) is described further on. RS232 port J13 is driven by the internal UART of the Coldfire and voltage level translation is provided by U4, the familiar MAX232. A regular RS232 cable should be used to connect the port to a PC, i.e. not a null-modem cable. Pushbutton S1 is the main Reset and its activation will restart the application code. S2 is directly connected to pin IRQ7 of the Coldfire, with a pull-up to the +3.3 V supply. acts as a general purpose pushbutton input. If you want to ‘program it in’, feel free to do so! Jumpers JP1 and JP2 on the board are for programming purposes and will be discussed in part 2.

It’s not shown in the circuit diagram, but a large prototyping area on the board gives the user lots of room for experimentation and to expand the board’s functionality. Any low-cost regulated or unregulated power adapter with an output voltage of 5-8V DC at about 500 mA is suitable for powering the circuit. This input minus the drop across D1 is used to supply relay RE1, which has a maximum coil voltage rating of 8 V. As would be expected for such a design, there is reverse polarity (D1) and over-current protection (F1), and an LED (D2) to indicate power on.

Voltage regulator U2 steps the input voltage down to provide the Coldfire device with a stable 3.3 V, which is further decoupled by lots of 100 nF and 220 nF SMD capacitors in key positions. The VDDA supply for U1 is also derived from the +3.3 V line and has additional filtering by ferrite bead FB1 and a pair of low-voltage SMD 4.7 µF capacitors, C20 and C21. Clean as whistle!

Relay control
A key feature of the home automation board is its capacity to control hardware remotely via the Internet. The ability to control mains voltage equipment is especially interesting but requires special precautions. As with any life threatening voltages, safety is paramount and there must be electrical isolation between the low voltage of the board and any mains voltage. Isolation is provided by relay RE1 whose contacts can switch a 250 VAC, 2 A load, the current capacity being limited by the width of the PCB tracks from RE1 to connector J14. Yellow LED D4 shows the relay on/off status.

DigiButler software
The project firmware is a modified version of the Coldfire Lite HTTP server software available free from Freescale and described in Application notes AN3455 [2] and AN3470 [3]. A wealth of information covering the software operation and including training presentations can be found at [4] and [5]. In this project, modifications have been made to the Freescale software to pro-
Yes, Milord

- The project is open-source with all C code available free for everyone to alter, recompile and flash
- The hardware and software are designed for expansion and experimenting
- You are working with real 32-bit embedded technology
- The project has been designed and tested in close cooperation with Elektor labs
- The PCB in the kit comes with the micro programmed and SMD parts pre-soldered
- The hardware is fun to build on a high-quality board with SMDs pre-stuffed
- There is a large community of knowledgeable Freescale microcontroller users
- The CodeWarrior programming suite is free and easy to use
- East Kilbride is a wet & windy place
- There may well be several Coldfire micros in your new car

 TBLCF is optional, open-source, has USB and costs less than $10 to build

BDM is used to access the micros. Spyder [6] is a BDM for MC9S08 micros. A "Turbo BDM Light Coldfire Interface" (TBLCF) for use with CodeWarrior was developed by Daniel Malik. It is found on the Freescale 68K/Coldfire Processors forum [7]. In good community spirit Daniel released all relevant material on his design into the freeware domain. If you master the art of 'judicious sampling', TBLCF should not cost more than a tenner for parts.

An important point to mention is that TBLCF is optional for the present project. The DigiButler board in the kit supplied by Elektor contains a ready-programmed MCF52231 micro that will not normally require re-programming or debugging. So, TBLCF is for advanced users wishing to modify the DigiButler firmware — everyone is encouraged to do so and show the results. Daniel Malik’s description of TBLCF is exhaustive and eminently present in free documents and even artwork to make the PCB. There’s an associated DLL and a step-by-step software installation guide. Here, we will limit ourselves to a condensed circuit description referring to Figure 5, courtesy Daniel.

TBLCF has USB connectivity to the PC. The hardware has two main parts: the MC68HC908JB16 MCU and the BDM interface driver based on a 74VHC14 buffer. The 'VHC14 is used to achieve low-cost translation of BDM signals with voltages anywhere between 3.3 V and 5 V to the 5 V logic of the MCU. The VHC logic accepts overvoltage on inputs, however the output voltage swing is limited by the power rail voltages. When the 74VHC14 is powered by a 3.3 V source, resistors R3 and R4 would not be able to pull the signals above the 3.3 V rail and would only inject current into the power rail of the 74VHC14. Alas, 3.3V is below the minimum High level input voltage of the MC68HC908JB16 and the circuit would not be guaranteed to work. Diodes D2 and D3 have

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**TABLE**

<table>
<thead>
<tr>
<th>Freescale Web Server</th>
<th>Freescale Compile Time FFS</th>
<th>Freescale Run-Time FFS</th>
</tr>
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<tbody>
<tr>
<td>ColdFire_TCP/IP_Lite Rtos and Console</td>
<td>ColdFire_TCP/IP_Lite Mini-Socket TCP API</td>
<td>ColdFire_TCP/IP_Lite Hardware API</td>
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<td>ColdFire_TCP/IP_Lite Mini-Socket TCP API</td>
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<td>ColdFire_TCP/IP_Lite UDP</td>
<td>ColdFire_TCP/IP_Lite ICMP</td>
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<td>ColdFire_TCP/IP_Lite ICMP</td>
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<td>ColdFire_TCP/IP_Lite ICMP</td>
<td>ColdFire_TCP/IP_Lite DLL</td>
<td>ColdFire_TCP/IP_Lite Console</td>
</tr>
</tbody>
</table>

**Figure 4.** ColdFire_TCP/IP_Lite stack implemented on the Coldfire micro.

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**Note:**

- TBLCF is a BDM Light Coldfire Interface for use with CodeWarrior.
- TBLCF has USB connectivity to the PC.
- The hardware has two main parts: the MC68HC908JB16 MCU and the BDM interface driver based on a 74VHC14 buffer.
- Diodes D2 and D3 have
been added to increase the high level voltages. The better alternative, two N-channel MOSFET transistors, would increase the cost and complicate the PCB layout. The RSTO signal is brought to two different pins of the MCU. This is strictly speaking not needed and a connection to pin PTE1 would be sufficient. However connecting the signal to PTA6 as well simplified the PCB design!
The ColdFire BDM connector has been here for a long time. In the past, boards usually contained a lot of components and were fairly large. A 26-way connector with 0.1" spacing was therefore of a reasonable size. Size of boards is however shrinking and the connector is becoming too large for smaller applications. Two optional enhancements have been made to the standard BDM connector:

1. Where the 26-way connector is too large you can use a 10-way subset of the connector (pins 1 through 10). The only signal which is then missing is TA (Transfer Acknowledge) on pin 26, but this is only needed in systems with external memory bus differentiation of the May 2008 issue of Elektor. But it is planned to have kits for the Digi-Butler project available with the publication of the May 2008 issue of Elektor. We then finish the article by discussing hardware assembly and test, network connection, Ethernet setup and creating and uploading web pages. For advanced users, CodeWarrior-driven compilation and reflashing of the MPU is also discussed.

References and Internet Links
Note: documents also available from the project web page: www.elektor.com/digibutler_en


Next month
It is planned to have kits for the Digi-Butler project available with the publication of the May 2008 issue of Elektor. We then finish the article by discussing hardware assembly and test, network connection, Ethernet setup and creating and uploading web pages. For advanced users, CodeWarrior-driven compilation and reflashing of the MPU is also discussed.

Figure 5. Circuit diagram of TBLCF, the open-source, optional debugger/programmer for Coldfire micros. TBLCF should not cost you more than $10 to build.
This new series of articles presents a tiny processor module based on an ATmega88 microcontroller, ideal for use at the heart of any number of different projects. We begin with a reaction time tester and quickly move on to more advanced projects such as a precision weather station and a 3D magnetometer. Our most ambitious and final project will use the ATmega to provide autonomous control to a four-motor aircraft. Each application example provides an easy-to-understand demonstration of how to work with AVR microcontrollers.

Elektor readers will already have seen the ATmega8, ATmega16 and ATmega32 used in real-world applications. In this series we will be using the ATmega88, which is a small, lightweight and powerful microcontroller (see text box). In comparison to the ATmega8, which is the same physical size, the device offers a higher clock rate, up to six PWM outputs, and many other extras to make life easier for developers.

Our AVR projects centre around an ATM18 microcontroller module fitted with an ATmega88. To make the unit universally useful, it has been designed to be as small and lightweight as possible. The printed circuit board is tried and (thoroughly) tested: it is based on a design that has been used successfully for years in autonomous aircraft made by Microdrones in Germany, adapted to suit our particular needs. Anyone who has seen one of these four-propeller aircraft in operation (for example, at Embedded World 2008) will appreciate how important it is to pack as much computing power as possible into a tiny volume.

The project essentially consists of two printed circuit boards. The first is the ATM18 microcontroller module, measuring 18 mm square; the second is the ATM18 test board, which sports a wide range of interfaces and which is intended to be used to help with development. Of course, surface-mount technology is inevitable in a project like this, and so manually populating the boards is somewhat tricky. However, Elektor comes to the rescue with ready-made modules and test boards: only the connectors need to be soldered manually. This has the advantage that the connectors not required for a particular application need not be fitted. In some applications it is appropriate to connect the microcontroller module directly to other printed circuit boards or sensors, and so the module is also available as a separate item so that you can use a single test board to develop a range of different projects based on the module.

The ATM18 microcontroller module

The module takes the form of a carrier board, similar in style to that featured in the R8C project which will be familiar to Elektor readers. We have used a special thin material for the printed circuit board to keep the weight and overall size of the module to a minimum.
The TQFP32 version of the ATmega88 is used (the device is also available in a 28-pin DIL package). Also featuring on the board is a 16 MHz crystal and the necessary SMD capacitors, and two resistors. Measuring just 18 mm square the unit is smaller than a postage stamp, and, once programmed, it forms a self-contained autonomous unit. For reasons of space, the header connectors are laid out on a 2 mm pitch; in very space-critical applications the headers can be replaced with a cable soldered directly to the board. Headers with a 2 mm pitch are reasonably widely available since they have long been in common use in Japan. Unfortunately, we cannot use standard perforated board with the module, but of course we can use the test board, which brings the signals out to 2.54 mm (0.1 inch) pitch box headers. Experiments can then be performed very simply using insulated wire (0.8 mm) to connect the various inputs and buttons.

Figure 1 shows the pinout of the ATmega88 and Figure 2 shows the pinout of the module: the similarities (and the differences) should be evident. A total of 32 pins is reduced to 29, as the GND and VCC connections are repeated on the TQFP package. The connections required for in-system programming (ISP) are made available in a single row to simplify connection to a programmer.

The crystal and a couple of capacitors are located on the reverse of the module (see Figure 3). This is all that is needed to get the microcontroller running: see the circuit diagram in Figure 4. The analogue supply voltage AVCC is derived from the main supply via a filter comprising R1 and C3, and there is a 10 kΩ pull-up resistor (R2) on the reset input.

The printed circuit board layout is shown in Figure 5, with the 2 mm pitch pin headers on all four sides clearly visible. When these are fitted to the board, they mate perfectly with the corresponding sockets on the test board.

When soldering these headers it is important to ensure that they are mounted exactly vertically: it is possible to use the test board as a jig to simplify the job: mate the pin headers with their corresponding sockets on the test board and then place the microcontroller module on top. This

The ATM18 Project on Computer:club²

ATM18 was developed jointly by Elektor and Computer:club² (www.cczwei.de) with contributions from Udo Jürrs, the main developer of www.microdrones.de. Elektor is pleased to support the project through articles in the magazine, ready-stuffed boards supplied through the Elektor Shop, supplementary information, software downloads and the forum at www.elektor.com.

Each month, the latest developments and applications of the ATM18 system are presented by Wolfgang Rudolph of Computer:club² in a TV broadcast on the German NRW-TV network. The boards and example programs from this article installment can be seen in Broadcast #9 of CC²-tv on 20 March 2008. Some understanding of German required!

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.
will keep everything at the correct angle while soldering. Do a single pin on each connector first, and then make a thorough visual inspection, adjusting the positions of the connectors if necessary. When everything is in order the remaining pins can be soldered.

**The test board**

This printed circuit board is of course rather larger. It provides a wide range of external interfaces as well as a power supply for the ATM18, providing an easy way to experiment with the module and connect extra hardware, sensors, actuators and other bits and pieces. The board measures 80 mm by 50 mm and the mounting holes are spaced at 72 mm and 44 mm. **Figure 6** is the circuit diagram of the test board. IC1 is a type LM2594-5.0 step-down converter, which provides a regulated supply voltage of 5 V for the microcontroller and peripherals from an input supply (on connector K1) of between 7 V and 16 V without dissipating large amounts of power as heat. Current demand is low, and a simple mains adaptor can be used. Battery power, using rechargeable or dry cells, is also feasible. Diode D1 protects against accidental reverse polarity connection of the power supply: a Schottky diode is used as it has a lower forward voltage drop. The regulated voltage, EXT+5 V, is used as the supply for the board if jumper JP6 is set to ‘EXT’, bridging pins 1 and 2. If JP6 is set to bridge pins 2 and 3 (‘USB’), the supply is obtained from K2, the connector for the UART-level serial interface. If an FTDI TTL-232R adaptor [1] is connected to K2, the 5 V supply will be taken from the connected PC via its USB port. The adapter will be available from the Elektor shop in the near future. There is also a 3.3 V version of the adaptor, which can equally well be used. The selected supply voltage is available on eight pins of connector K8. There are

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**ATM18 microcontroller module**

**Quick data**

- **Microcontroller:** ATmega88
- **Operating voltage:** 2.7 V to 5 V
- **Processor clock:** 0 Hz to 20 MHz (typically 16.0 MHz)
- **Current consumption:** approximately 18 mA (at 5 V and 16 MHz)

**Hardware features**

- Two 8-bit counter/timers (Timer0, Timer2)
- One 16-bit counter/timer (Timer1)
- One synchronous serial interface (SPI)
- One asynchronous serial interface (UART)
- One two-wire interface (I²C)
- One 10-bit A/D converter with 8 inputs (ADC0 to ADC7)
- One analogue comparator
- Up to 23 digital I/O lines

**Figure 1.** The pinout of the ATmega88 in a TQFP package.

**Figure 2.** Pinout of the ATM18 microcontroller module.

**Figure 3.** Top and bottom views of the ATM18 microcontroller module.

**Figure 4.** ATM18 Pinout Top View

**Figure 5.** Pinout of the ATM18 microcontroller module.

**Figure 6.** The circuit diagram of the test board.
AVR, ATtiny and ATmega

It was decided to use an Atmel ATmega microcontroller for this project. This comprises an entire family of devices, with the main difference between individual devices being in their processing power. The design is particularly flexible and modern and ideal for low-cost implementations. The original AVR design was produced at the Norwegian Institute of Technology in Trondheim before being bought by Atmel. The AVR core is particularly small and can be implemented in as few as 4000 gates. Atmel, the only manufacturer of processors using this core, produces two series of devices: the ATtiny series and the ATmega series. The AVR has a RISC (reduced instruction set computer) architecture; traditional CISC (complex instruction set computer) architectures offer more powerful and sophisticated instructions, but decoding such an instruction takes considerably longer than does the decoding of a RISC instruction. Furthermore, a CISC processor generally takes longer to respond to an interrupt request than a RISC processor, impairing real-time performance.

All ICs in the AVR family are structured in essentially the same way, differing only in the quantity of memory available and the number and types of timers provided. Some also feature an A/D converter or a UART (universal asynchronous receiver/transmitter) to provide a serial interface on the chip.

The AVR was designed with the efficient execution of programs written in high-level languages in mind. From the point of view of both price and performance a RISC microcontroller of this type makes the ideal basis for our projects.

Figure 4. Circuit diagram of the ATM18 microcontroller module.

Figure 5. Printed circuit board for the ATM18 microcontroller module.

COMPONENTS LIST
ATM18 controller module

Resistors (SMD 805)
R1 = 10Ω
R2 = 10kΩ

Capacitors (SMD 805)
C1,C2,C3 = 4µF 6.3 V (Farnell # 922-7857)
C4,C5 = 22pF

Semiconductors
IC1 = ATMega88 (TQFP32 case), Atmel

Miscellaneous
Q1 = 16MHz quartz crystal, SMD (7mm x 5mm)
3x 8-way pinheader, 2mm lead pitch
1x 5-way pinheader, 2mm lead pitch
PCB, ref. 071035-1 (track layouts free download from www.elektor.com)
PCB, ready populated with SMDs, tested, including pinheaders, Elektor-Shop # 071035-91
invoking motors and relays directly. Seven LEDs (with current-limiting resistors) are provided to show the states of the output signals. The inputs to the power driver IC are available on K10, allowing them to be connected to any desired port on the microcontroller as required by the user or programmer.

One of the most important interfaces on the board is ISP connector K7, used for connection to a programmer. The pinout is compatible with the six-pin ISP connector on the STK500 as well as Atmel’s ISP mkII. A less expensive option is the Elektor USB AVR programmer, compatible with the ISP mkII. This design will appear in next month’s issue, but the unit is already available in conjunction with the ATM18 test board. The USB AVR programmer is based on the popular general-purpose USBprog programmer published in the October 2007 issue of Elektor. Another alternative is to make a simple Pony-Prog compatible connection directly to the connector on the processor module board.

The power supply and interface options are summarised in the accompanying text boxes.

Rapid prototype

The ATM18 test board is fitted with a large number of 2.54 mm pitch connectors. These can be connected without the need for a soldering iron: any desired configuration can be realised quickly and simply using lengths of insulated wire with stripped ends. Wire with a gauge of 0.8 mm is ideal: with a few 8 cm lengths of such wire to hand the necessary connections can be made and changed as needed for any desired application or experiment (Figure 8). If connections to external modules or devices are needed, a pin header can be used along with a suitable length of ribbon cable.

Software

Udo Jürss [2], the designer of the ATM18 system, is a professional engineer and normally uses professional software tools. For the applications we will be looking at, the IAR C compiler fits the bill: it provides a powerful development environment offering almost every conceivable feature. As is so often the case with such powerful tools, it is not always easy to use at first, and there is a degree of ‘running in’ as the programmer learns how to use the compiler to the desired effect. Time- or memory-limited demonstration versions of the compiler are available from the IAR website download area [3]. The latter version is adequate for many applications. The ‘Kickstart Edition’ of IAR Embedded Workbench for the Atmel microcontroller is not time limited, but can only generate code up to a maximum of 4 kbytes. A number of questions must be answered on the website before the software download can begin. We have arranged for a project file to be available for readers to download from the Elektor website: this greatly simplifies configuring the IAR compiler. All programs that feature in this series are also available for download as hex object files.
Users who prefer not to use C and a sophisticated development environment can work with assembler or BASCOM. BASCOM-AVR is a very efficient high-level language for the AVR microcontroller, broadly comparable to QBASIC. Programs are very clear and straightforward to write as complex commands save the programmer a great deal of work. The demonstration version of BASCOM can be downloaded for free from the Internet [4]; again, there is a 4 kByte code size limit, but there are no functional limitations and the system is perfectly adequate for our applications. BASCOM-AVR runs under Windows 95, 98, NT and XP and, with minor restrictions, under the Wine emulator on Linux platforms.

**LED running light in BASCOM**

Our first programming example with BASCOM-AVR is the now classic first test of a new microcontroller system, a LED running light. Note that the program (Listing 1) must specify the file m88def.dat; alternatively, the microcontroller type can be specified in the options. The crystal frequency (16 MHz) is given here in units of Hz; the value is needed so that the delays in the program have the correct timing. We have chosen to drive the LEDs from port C, which is therefore configured as an output. Finally a byte variable ‘Leds’ is declared, initialised to 1 (corresponding to just the first LED being lit).

In the infinite loop (from ‘Do’ to ‘Loop’) this single set bit is shifted left one place at a time: this corresponds to a repeated multiplication of the variable by two: 1 becomes 2, 2 becomes 4 and so on. In this way the program drives LED being lit).

In the infinite loop (from ‘Do’ to ‘Loop’) this single set bit is shifted left one place at a time: this corresponds to a repeated multiplication of the variable by two: 1 becomes 2, 2 becomes 4 and so on. In this way the program drives...
the outputs high one after the other. After each change there is a delay of 100 ms.

To test the program we first have to connect port C (six pins) to the inputs of the ULN2003 LED driver (seven pins). The lower six bits, PC0 to PC5, are used, and the seventh input to the ULN2003 is left unconnected. If desired, a bit from another port could be used, or port D, which has eight pins, could be used instead of port C.

Next we must flash the code into the microcontroller. For this we need a suitable programmer such as the STK500 [5] or the Elektor USB AVR programmer mentioned above. If you wish (and provided your PC has a parallel port) you can also use a simple parallel port programmer described in a free bonus article available from the Elektor website. An AVR ISP programming adaptor for the PC serial port was described in the ‘Mini ATMega Board’ article in the May 2006 issue of Elektor.

Programming is carried out using the AVR tools, within which the programmer itself is called up. It is essential to select the correct device (ATmega88) and to specify the generated hex object file (LED1.hex): see Figure 9.

The device must be programmed not only with the desired code, but also with the desired fuse settings. Particularly important is the configuration to allow use of the crystal as clock source: as delivered by the manufacturer the device is configured to use its internal oscillator with a divide-by-8 prescaler. Figure 10 shows the correct fuse settings (again using the STK500).

If the programming procedure has been carried out correctly, the result is exactly what one would expect from a quick glance at the Basic program: the LEDs light in turn from right to left at the rate of one step every 100 ms.

A further example BASCOM program is available for free from the project page on the Elektor website, as is the C project for the reaction time tester mentioned at the start of this article, which requires the IAR compiler.

Web Links


Listing 1

Running light (LED1.hex)

's 7 LEDs on PortD
$sregfile = "m88def.dat"
$crystal = 16000000
Config Portd = Output
Dim Leds As Byte
Leds = 1
Do
Leds = Leds * 2
If Leds > 64 Then Leds = 1
Portd = Leds
Waitms 100
Loop

Figure 8. Test board wired up ready for an experiment.

Figure 9. Programming the flash memory.

Figure 10. Configuring the AVR fuses.
Motor Drivers/Controllers

Here are just a few of our controller and driver modules for AC, DC, Unipolar/Bipolar stepper motors and servo motors. See website for full details.

PC / Standalone Unipolar Stepper Motor Driver

Drives any 5, 6 or 8-lead unipolar stepper motor rated up to 6 Amps max. Provides speed and direction control. Operates in stand-alone or PC-controlled mode. Up to six 3179 driver boards can be connected to a single parallel port. Supply: 9Vdc. PCB: 80x50mm.
Kit Order Code: 3179KT - £12.95
Assembled Order Code: AS3179 - £19.95

Bi-Polar Stepper Motor Driver

Drive any bi-polar stepper motor using externally supplied 5V levels for stepping and direction control. These usually come from software running on a computer.
Supply: 8-30Vdc. PCB: 75x85mm.
Kit Order Code: 3158KT - £17.95
Assembled Order Code: AS3158 - £27.95

Bi-Directional DC Motor Controller (v2)

Controls the speed of most common DC motors (rated up to 32Vdc, 10A) in both the forward and reverse direction. The range of control is from fully OFF to fully ON in both directions. The direction and speed are controlled using a single potentiometer.
Screw terminal block for connections.
Kit Order Code: 3166v2KT - £17.95
Assembled Order Code: AS3166v2 - £27.95

DC Motor Speed Controller (100V/7.5A)

Control the speed of almost any common DC motor rated up to 100V/7.5A. Pulse width modulation output for maximum motor torque at all speeds. Supply: 5-15Vdc. Box supplied.
Dimensions (mm): 60Wx100Lx60H.
Kit Order Code: 3067KT - £13.95
Assembled Order Code: AS3067 - £21.95

Controllers & Loggers

Here are just a few of the controller and data acquisition and control units we have. See website for full details. Suitable PSU for all units: Order Code PSU445 £8.95

8-Ch Serial Isolated I/O Relay Module

Computer controlled 8-channel relay board. 5A mains rated relay outputs. 4 isolated digital inputs. Useful in a variety of control and sensing applications. Controlled via serial port for programming our new Windows interface, terminal emulator or batch files. Includes plastic case 130x100x30mm. Power Supply: 12Vdc/500mA.
Kit Order Code: 3108KT - £54.95
Assembled Order Code: AS3108 - £64.95

Computer Temperature Data Logger

4-channel temperature logger for serial port. °C or °F. Continuously logs up to 4 separate sensors located 20m+ from board. Wide range of freeware applications for storing/using data. PCB just 45x45x5mm. Powered by PC. Includes one DS1820 sensor.
Kit Order Code: 3145KT - £17.95
Assembled Order Code: AS3145 - £24.95
Additional DS1820 Sensors - £3.95 each

Rolling Code 4-Channel UHF Remote

State-of-the-Art. High security. 4 channels. Momentary or latching relay output. Range up to 40m. Up to 15 Tx's can be learnt by one Rx (kit includes one Tx but more available separately). 4 indicator LED's: Rx: PCB 77x85mm, 12Vdc/50mA (standby). Two and Ten channel versions also available.
Kit Order Code: 3180KT - £44.95
Assembled Order Code: AS3180 - £54.95

DTMF Telephone Relay Switcher

Call your phone number using a DTMF phone from anywhere in the world and remotely turn on/off any of the 4 relays as desired. User settable Security Password, Anti-Tamper, Rings to Answer, Auto Hang-up and Lockout. Includes plastic case. Not BT approved. 130x110x30mm. Power: 12Vdc.
Kit Order Code: 3140KT - £54.95
Assembled Order Code: AS3140 - £69.95

Infrared RC Relay Board

Individually control 12 on-board relays with included infrared remote control unit. Toggle or memory. 15m+ range. 112x122mm. Supply: 12Vdc. 0.5A.
Kit Order Code: 3142KT - £47.95
Assembled Order Code: AS3142 - £59.95

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We have a wide range of low cost PIC and ATMEL Programmers. Complete range and documentation available from our web site.

Programmer Accessories:
40-pin Wide ZIF socket (ZIF40W) £14.95
18Vdc Power supply (PSU010) £18.95
Leads: Parallel (LDC136) £39.50 / Serial (LDC441) £3.95 / USB (LDC462) £2.95

NEW! USB & Serial Port PIC Programmer

USB/Serial connection. Header cable for ICSP. Free Windows XP software. Wide range of supported PICs - see website for complete listing. ZIF Socket/USB leads not included. Supply: 16-18Vdc.
Kit Order Code: 3149EKT - £39.95
Assembled Order Code: AS3149E - £49.95

NEW! USB 'All-Flash' PIC Programmer

USB PIC programmer for all 'Flash' devices. No external power supply making it truly portable. Supplied with box and Windows Software. ZIF Socket and USB lead not included. Assembled Order Code: AS3128 - £44.95

"PICALL" PIC Programmer


ATMEL 89xxxx Programmer

Uses serial port and any standard terminal comms program. Program/Read/Verify Code Data, Write Fuse/Lock Bits, Erase and Blank Check. 4 LED’s display the status. ZIF sockets not included. Supply: 16-18Vdc.
Kit Order Code: 3123KT - £24.95
Assembled Order Code: AS3123 - £34.95

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The boom in the Internet and rapid evolution of communication techniques and tools have made diffusion of knowledge and projects possible on a massive scale, and allowed work and discussion communities to be created on a global level. New ways of publishing and distributing artistic or technical creations, and contributing to collective projects or works have appeared. When these activities take place within a framework of openness and exchange, we talk about Open Innovation.

This is the case with projects like GNU, Linux, Mozilla, Apache, The GIMP, MySQL, Amarok, OpenOffice, YAMPP or more recently OpenMoko – all referred to as Open Source software or electronic designs. Artists too are taking advantage of this wave and these collaborative tools. Take a look at the Wallpaper project started by Alex Ciccius and The Sambuki Social Crew: 100 artists are creating a 100’ (approximately 32 m) long banner that can be viewed on www.thespacejockeys.com/wallpaper.

The vast quantity of information available on this subject on the Internet is not very user-friendly and is difficult to summarize. The intention of this article is to first give a few historical landmarks and describe open innovation. Then we’ll take a look at a few examples of the different modes of distribution and their viabilities.

We will of course highlight the special character of electronic hardware and describe the development process. There’s no question here of patents or copyright laws, so unfortunately we won’t have the opportunity to discuss the problematic local implementations of EUCD (European Union Copyright Directive). Maybe some other time…

Open Source

The Open Source movement arose in the late seventies at Berkeley University in California, in a development project for an operating system compatible with Unix, called BSD (Berkeley Software Distribution). The publication of the source code, with no restrictions and for the purpose of sharing, allowed this project to develop in a collaborative manner. In the event of collaboration on major projects, many contributors may be involved without their necessarily having known each other at the outset. They work with the same aim in different locations around the globe, and they occasionally organize meetings to define the development plan.

A little later, in 1983, Richard Stallman created the Free Software Foundation to provide a framework for the development of GNU (famously explained as ‘GNU is Not Unix’). Then he drew up the GPL (General Public Licence) in order to distribute the fruits of this labour, ensure its durability, and launch free software. The use of the ambiguous word ‘free’ has caused a lot of misunderstandings. A piece of ‘free’ software isn’t necessarily ‘free of charge’; it may be sold, though this is generally not the case.

The co-operative development of the Linux core, launched by a Finnish student, then its incorporation into GNU (whose operating system was slow in coming), laid the foundations for this form of open innovation. When it involves mainly software, we talk about open source.

There is no definitive definition of open source, nor does it correspond to a particular software licence either. The term ‘open source’ doesn’t even have any inherent legal value in itself. We should also dispel once and for all the confusion between ‘free’ software and ‘open source’ software often perpetuated by the press.
Principal licences

The information published in this inset has no legal value. The sheer amount of information in the licence documents is such that we have to content ourselves with merely extracting a few relevant passages just to give a taste of the subject. We have concentrated on the principal licences used for distributing source code or electronics projects. Readers interested in one particular licence or another will need to look up the corresponding complete document. You will find the texts of these various licences in their many revisions on the Internet via the links available at http://www.elektor.com/UK_open-innovation or directly from the FSF website.

• BSD licence (Berkeley Software Distribution) allows the document it protects to be re-used, in whole or in part and without restriction, in a public or proprietary work.

Unlike the public domain, it does however present a few constraints to be respected when redistributing the document.

It also protects the names of the authors in derivative publications, and releases them from any problems that might arise out of the use of the work.

It is one of the least restrictive.

• GNU GPL licence (GNU General Public License) is certainly the most stringent. It makes the publication of modifications obligatory to the distribution of the software. It is based on the Copyleft principle, which relinquishes reproduction rights to the community (as distinct from Copyright).

However, a document published under GPL belongs in a very real sense to its author, who will decide the appropriate licence for the distribution of later versions of the document, thereby enabling them to change licences.

It has a viral character, as it contaminates (closed) projects in which it is used.

A project published under GPL must be GPL as a whole.

This is certainly the oldest and most popular licence for free software.

• GNU LGPL licence (GNU Lesser General Public License), a toned-down version of the previous one, allows association of code under a GNU GPL licence that is totally free with a resource that is not. In this way, it allows a piece of proprietary software to be written including free resources. It applies principally to software libraries. It’s only really of very limited interest.

• MPL licence (Mozilla Public License) allows combining both proprietary source code (normally unpublished) with free source code within a single project. It then guarantees the openness of the code specified as free. By virtue of its non-viral character, it is regarded by many as freer than the GPL licence. It guarantees the authors that the open character of their work will be preserved, without constraining other contributors (current or future) to doing the same.

• Chronodegradable licences

The free distribution of the source code takes place in a delayed fashion after marketing of the software – in principle when a new commercial version is published. This is the case with ID Software, famous for the success of ‘Doom’, its first 3D game, whose source code it decided to publish at the end of its software’s lifetime, thereby benefiting from external contributions to the storyline.

• IBMPL licence (IBM Public Licence) – used by IBM for distributing certain of its source codes that are regarded as non-strategic – recognized by the OSI. It differs from the GPL in the way it handles managing and distributing patents. It makes the software publisher and distributor responsible, rather than the contributors.

• SCSSL licence (Sun Community Source Licence) is the licence originally used by SUN Microsystems for distributing its JAVA language.

It does not allow the opening up of the JAVA source code and so is not regarded as ‘open’. However, it does allow, on the one hand, acquisition, use, and free redistribution of the JAVA virtual machine (without which it wouldn’t be possible to interpret the code you write), and on the other hand, distribution of free libraries, software, and tools written in JAVA. Since 2005 SUN has introduced new licences in order to increase its openness, though still without publishing its sources.

• Shared Source licence, set up by Microsoft in response to pressure from the free software world, constitutes several licence contracts and is reserved for Microsoft’s largest commercial partners and certain influential institutions (universities, Chinese government, etc.) It mainly lets them consult the source code and allows debugging. Very few have the right to modify.

• Creative Commons licence is flexible and customizable. It offers four distribution options: paternity, no commercial use, no modification, share-alike of the original conditions, which can be combined to create a specific distribution licence.

A refreshing, novel concept that is really starting to take off.

The OSI (open source initiative) open source movement was created in 1998 to respond to the economic and technical realities and defend the freedom of access to software source codes. In a few points, it defined the conditions for a piece of software to be described as open source; what’s more, it has become the official certification body for open source and its diverse publication licences.

Advantages and disadvantages

In his document entitled ‘The Open Source Dynamic’, Robert Visseur lists the advantages and disadvantages of open source. We thought it worthwhile to sum these up here.

• Quality: the stability and performance of open source software like Linux or FreeBSD.

• Reactivity: e.g. updates to software
like Apache or Linux appear very quickly.

- Durability: e.g. loyal users have re-programmed old operating systems like MS-DOS or CP/M.
- Cost.
- Freedom: independence from the developers
- Competition: impossible for a monopoly to take place, by virtue of the source code and communication standards. Stimulates competition between companies, as well as between nations! With open source code, the software can breathe freely and benefits from the support of the entire community. This goes hand-in-hand with the writing and development of real, open, reliable standards where everyone can cast a critical eye.
- Protection of intellectual property: the principal complaint of open source’s adversaries is that secrecy and fierce competition are vital to sustain innovation. To which open source partisans argue that the mixing of ideas and mutual and cross-fertilization favour innovation much more than the fact of appropriation.
- Finish: interfaces have a reputation for being rustic
- Risk of divergence: e.g. BSD gradually split into three projects: FreeBSD (the most widespread and the most user-friendly, favouring performance), OpenBSD (favouring security) and the original branch, NetBSD (which favours adaptation to hardware).
- Brand image: Linux is often poorly-regarded by the hierarchy for professional use.
- Support: Documentation is sometimes lacking. The Wiki script, which came out in the mid-90s and has been made popular recently by the free encyclopedia Wikipedia, is attempting to make up for some of these shortcomings. It offers readers the opportunity to contribute to documentation on line. English is obligatory, despite some laudable translation efforts.

### Contributing to a project

Nothing could be simpler than contributing to an open source project. Contact its author by e-mail or IM, express yourself in the project forum, give your opinion, add a page of documentation or advice to the Wiki.

You can contribute on several levels, from simple encouragement to a small donation. Your general remarks on features or the interface will be appreciated, a bug report, comment, or the review of the source code will be welcomed. And if you have a literary bent, don’t hesitate to participate in the project documentation. If you want to program, prove yourself by sending patches (corrections, improvements) and it won’t be long before you obtain write access to the version manager (CVS, sub version, and so on).

### Launching a project

Launching a project is hardly any more complicated. You have an idea, you think it may be useful to a community, you want to share it. If you aren’t a natural webmaster, open an account at www.sourceforge.net and publish your project, distribute your sources and your work. If you want to keep control of it and host your project website yourself, while benefiting from certain collaborative development tools, create your community space with the help of sourceforge. If not, then a simple website will do…

### Distributing a project

How can the author of free software earn a living, or at least some money from it? Prior to distributing the fruits of your labours on the Internet or simply opening it up to the world, and in order to be able to do so, it’s important to define the legal framework for it that will allow you to be recognized, to protect yourself against possible abusive use, and to share it or not.

Distributing code, circuits, drawings, photos, art, etc. freely and free of charge, while still retaining paternity, can be done by means of a licence (for example, Creative Commons). The inset should help you choose a licence appropriate to your needs, from the fairly stringent open source (free software) licence to the shared source one, via various intermediate nuances.

If your aim is to make money, you’ll need to conform, to a greater or lesser extent, to the economic models, strategy, and marketing that are usual practice in our societies. The OSI is working towards an economy for software with no user licences but based on the sale of services, hardware, and the support needed for rapid deployment.

Several thousands of engineers in Europe are employed by way of this economic model.

### Open Hardware

The concept of open source hardware, or ‘open hardware’, is not all that different. However, it is much easier to copy a piece of software than to reproduce hardware, which requires more advanced skills and knowledge.

Although the open source concept is still quite fuzzy, it is however clearly defined by its licences. The concept of open source hardware, on the other hand, still does not have a definition that is recognized around the world, nor totally accepted.

In an article published in ‘Linux Today’ in 1999, Richard Stallman, founder of the FSF (Free Software Foundation) and author of the GPL (General Public Licence), stated that the GPL licence was not suitable for electronic circuits, as they are difficult to modify or copy. Most of the people involved consider that the same applies to embedded software (firmware), generally stored in Flash memory, but in any event not at all comparable with the volatility of software in a computer’s RAM, at best stored on hard disk.

Users of open source hardware must be able to modify the hardware and distribute it freely. This necessitates making available all the circuits, along with the source code of the components, in particular the HDL (Hardware Description Language) sources of the hardware and the firmware (most often written in C and assembler).
In an Elektor interview with Harald Kipp in Elektor March 2008, the father of the Ethernut said, rather tongue-in-cheek, that “for many people, open source is like communism, in the sense that everyone can take from the community without paying anything.” Kipp added that certain developers also regard open source as like communism, but because they perceive the hierarchy as a dictatorship!

Indeed, we might be tempted to imagine that anarchy reigns in open source, but that’s far from being the case. The organization of open source projects is built on a solid framework, indeed highly hierarchical, most of the time with the owner of the project as incontestable master at the top of the structure.

If he doesn’t like a contribution, he can withdraw it without asking anyone’s opinion. If it’s a developer he doesn’t like, he can send them packing without any other form of trial, and refuse any contribution from them.

For small-scale projects, it’s also the owner who decides when and which version will be published.

Source codes are (in general) freely redistributable, i.e. anybody can proclaim themselves a distributor of free software (as long as the licence conditions are obeyed). If part of the community, or an isolated (and frustrated) developer, thinks they can do better, they are free to take up the source code and branch off into a new project. This branching process is called ‘fork’ (from the name of the instruction in the POSIX standard for duplicating a process in C).

Openness of minds

It’s important for a company to gather malfunction (bug) reports from its users. It may go even further and deploy a public forum where all users can express themselves, criticize any deficiencies in the architecture, or sing its praises. This initiative can turn out to be an uncomfortable one. Allowing anyone to freely study the quality of the source code and the hardware design in order to discuss it openly takes a degree of courage, a lot of getting used to, perseverance, and even a thick skin, such is the extent to which the criticism may turn out to be caustic.

The more judicious criticisms are vital to enable projects to evolve efficiently. Without the pressure of a critical external viewpoint, most design defects will survive the various stages, will become entrenched, and before long an initially elegant concept can turn into a huge, labyrinthine system like MS W****.

Throughout the project, whether in soft- and/or hardware, you must be careful to stay legal and avoid infringing – intentionally or not – this or that patent. Difficult as such infringements are to detect in a ‘closed’ project, they will come to light all the quicker in an open project because the size and diversity of the community. So you’ll need to take appropriate measures to ensure the validity of the copyright for each of the various contributions – no small task!

The community spirit of open projects occasionally forces developers to spot such infringements and to take immediate action.

At the present time, most open hardware and firmware projects are distributed under a BSD licence – less restrictive than the GPL licence – which allows, in particular, distribution of improved firmware without distribution of the corresponding source code. In this way, companies retain control over the publication of certain improvements, while keeping others secret, to protect the added value of the product.

Commercial contribution

So where is the interest for a company in contributing to an open source project, when this is not constrained by a licence? Why would it run the risk of one of its competitors possibly profiting from its work? Doubtless to benefit from the improvements of other contributors, but also because itjudges that before its competitors catch up, the benefits of openness will have enabled it to establish a convincing lead, thanks to better products, better services, and quality that it knows is superior – even if all the competitors are using the same software.

Certain companies will also make ‘late contributions’, initially keeping their improvements secret and only publishing them once their product is well launched (see an example of a chronodegradable licence in the inset).

We would like to thank Harald Kipp for the interview he granted us. To discover this fascinating world in greater depth, come and have a browse at the following address:

www.elektor.com/UK_open-innovation

To your keyboards – happy surfing, and happy development!

Elektor is distributing this article under the creative commons licence with an explicit mention of its paternity, excluding all commercial use, and identical sharing of the original conditions (share-alike). We are keen to open up the source code of our publications, and do so whenever possible. Certain of our authors are still reluctant and unfortunately won’t give us their permission. It’s often a hard choice for Elektor between refusing a very interesting but closed publication, and publishing it anyhow, to allow as many people as possible to benefit from it – but without the pleasure of sharing the source. In the long term, openness pays.

[070348-1]
Ryan Seguine (Cypress Semiconductor Corp.)

With all the excitement about capacitive sensing in the portable media player, laptop PC and mobile handset markets, it is easy to forget that such interface technologies have been actively designed into White Goods applications for years. Significant improvements in sensing algorithms and control circuitry have expanded the suite of applications in which the technology can be implemented.

Designers are seeing the value of capacitive sensing as a mechanical button and membrane switch replacement as well as discovering new, exciting applications such as touchscreens and proximity sensors. A capacitive sensor is constructed of a conductive pad, the surrounding ground, and its connection to a controller. In most applications, the conductive pad is a large copper footprint and the surrounding ground is a poured fill. As illustrated in Figure 1, a native (parasitic) capacitance, $C_P$, exists between these two objects. When a third conductive object, such as a human finger, is brought into proximity with the sensor, the capacitance of the system is increased by the capacitance of that object, $C_F$.

Methods to use

There are several methods for detecting the increase in capacitance caused by the addition of $C_F$.

Field-effect measurement uses an AC voltage divider between a sensor capacitor and a local reference capacitor. Finger detection is achieved by monitoring the change...
in voltage on this divider. Field-effect sensing is a highly-sensitive technique and robust with regard to environmental conditions, however it is implemented with a single ASIC per sensor and does not provide analogue functions.

Charge transfer uses a switched capacitor circuit and a reference bus capacitance with repeated charge transfer steps from the smaller sensor capacitor to the larger bus capacitor. The voltage on the bus capacitor is proportional to the sensor capacitance. The capacitance can be determined by measuring the voltage after a fixed number of steps or by counting the number of steps necessary to reach a threshold voltage. Charge transfer is a low impedance sensing method giving it good noise immunity and is capable of supporting analogue features in capacitive sensors. The direct connection to VDD requires a high-quality, dedicated voltage regulator for the sensor controller.

A relaxation oscillator is a charge time measurement where the charging ramp is determined by the current source (usually fixed) and the sensor capacitance value. Larger sensor capacitors yield longer ramp times, usually measured with a PWM and a timer. The relaxation oscillator is highly flexible and can be implemented in many standard microcontrollers, however the high-impedance inputs can make it susceptible to noise sources without firmware or hardware modifications to filter out such interference.

Successive Approximation
The Successive Approximation method (patents applied for by Cypress Semiconductor) implemented with the PSoC device uses a capacitance-to-voltage converter and single-slope ADC. The capacitance measurement is achieved by converting the capacitance to a voltage, storing this voltage on a capacitor, and then by measuring the stored voltage using an adjustable current source. The low-impedance technique has high immunity to interference and greater sensitivity and analogue characteristics. The current source and the connection scheme allow for more tolerance in voltage regulator quality.

The capacitance-to-voltage converter shown in Figure 2 is implemented with switched capacitor technology. The circuitry brings the sensor capacitor to a voltage relative to the capacitance of the sensor. The switched capacitor is clocked by the PSoC’s internal main oscillator. The sensor capacitor is connected to the analogue MUX bus and is charged via a programmable current output digital-to-analogue converter (iDAC) also connected to the bus. The charge on each bus is given by 

\[ q = CV \]

With the switched capacitor circuit running, the iDAC uses a binary search to determine the value at which the voltage on the bus remains constant. This voltage is a factor of the switching frequency, the sensor capacitance and the iDAC value (current). The bus also functions as a bypass capacitor, stabilizing the resulting voltage. Additional capacitors can be added to the bus and affect performance and timing of the circuit.

The following equations apply:

\[ V_x = \frac{1}{(f_{osc} \times C_x)} \times i_{DAC} \]

\[ V_{BUS} = V_{REF} - V_x \]

The calculated iDAC value is then used to charge the bus again and the time required to take the bus from an initial voltage to the comparator threshold is measured. The initial voltage with no finger present and therefore the charge time is known. A finger on the sensor increases the value of \( C_x \), decreasing the initial voltage and increasing the charge time measurement — see Figure 3.

Building a Sensor: the options
Capacitive sensors have diverse forms and functions and they can use a variety of media. Their implementation ranges from simple to complex. Also, application requirements determine sensor construction and implementation details.
Buttons and sliders are most common. Buttons are large conductive pads connected to the controller. Capacitance is measured and compared against a series of thresholds. Decisions can be made as digital outputs or with more analogue characteristics for activation pressure or finger size. Sliders are linear or radial arrays of conductive pads. Centre-of-mass algorithms determine the position of activation to a resolution far greater than the number of pins used to sense. Most often, simple capacitive sensors like buttons and sliders are deposited onto a printed circuit board using copper (Figure 4). Other substrates and deposition media such as silver ink can be used, however.

Dynamic user interfaces use buttons or activation regions that reconfigure in response to the display itself. These displays are moving the user experience forward by promoting more seamless and intuitive interaction. The construction of these systems is somewhat more complex that simple buttons or sliders. Projected capacitance touchscreens use transparent conductive materials over a display. The conductive surface is deposited onto a substrate such as glass or PET film and connected to the control circuitry. The substrate is then adhered to the overlay and the display. The position of the activation is determined in the same way as a slider. Two sliders, one for each axis are intertwined to provide complete coverage of the display area. Activation is detected on both axes and the position exported as x- and y-data. Because a projected capacitance touchscreen is behind an overlay, it is protected from impact, flexion, and environmental factors that plague traditional resistive touchscreens.

Proximity sensors are essentially large buttons. The object of a proximity sensor is not to detect the exact position of a conductive object; rather the presence. Since the device does not need to know exact position, the response time may be slower (3-4 ms vs. 250 μs). The sensitivity of a proximity sensor is much greater; 30 cm can be achieved in a well constructed design. Since proximity sensors do not need to be associated with any display graphic, their placement on the device is more flexible. A copper ring around the outside of the control circuit board or a wire behind the overlay allow very basic, cost-effective construction of a proximity sensor.

Home appliances and white goods
Usage of capacitive sensors is expanding. The sensors described have created new opportunities for designers to work with such flexible, durable and elegant design elements. Buttons are still used for basic menu navigation and activation. However, analogue characteristics of buttons that are not expensive potentiometers allow easier and less expensive implementation of increased functionality and safety features.

LG’s model LA-N131DR Air Cleaner (Figure 6) uses five capacitive sensors for front panel display menu navigation buttons. These buttons have allowed the designers to implement a seamless chassis design while still realizing the user interface. The capacitive buttons detect the presence of a human finger through four millimetres of glass. The control circuitry is located on the non-sensor side of a two-layer printed circuit board. LG uses the PSoC Mixed-Signal Array to control the sensors and output status to the main device processor.

Proximity sensors allow for reactive backlighting for nighttime operation or for safety features requiring a larger activating element such as an adult hand or metal pot to engage the range-top controls. Figure 5 shows how proximity sensors, buttons, sliders and even touchscreens can be controlled by a single processor using PSoC. Firmware routines allow changes in state based on user inputs or host commands.

Putting It All Together
The PSoC Mixed-Signal Array allows designers to implement buttons, sliders, touchpads, touchscreens, proximity sensors and any combination of all these in a single chip. The pre-defined firmware development modules, reference code and calibration tools make designing a capacitive sensing application fast, easy and effective. Pre-defined firmware development tools include device interconnects, I/O drive modes and APIs. These are created with only a few clicks of the mouse in the PSoC Designer or PSoC Express development tools. Reference code provides a starting point with basic functionality, but the open-source
The nature of the PSoC solution allows for customization and optimization for any project. Calibration tools accelerate development by providing real-time feedback for capacitive inputs. Adjust parameters, increase sensitivity, and calibrate sensors individually through the calibration tool.

PSoC devices are more than just capacitive sensors. Analogue and digital resources are available for a myriad of other applications [1]. Basic digital control is available on all PSoC devices. Drive LEDs, communicate through I2C, SPI and other media, and control a simple 8-bit PWM. Higher-function devices are capable of more digital functions as well as basic analogue. A single PSoC can be configured as a capacitive sensing and a temperature meter or a voltage meter.

Create your capacitive sensing application

The PSoC Mixed Signal Array is a configurable array of digital and analogue resources, flash memory and RAM, an 8-bit microcontroller, and several other features. These features allow PSoC to implement innovative capacitive sensing techniques in its CapSense portfolio. Use PSoC’s intuitive development environment to configure and reconfigure the device to meet design specifications and specification changes. New sensing technologies exhibit improved sensitivity and noise immunity, reduced power consumption, and increased update rate.

Web Links
Frequency Response Sweep Oscillator

50 Hz - 100 kHz range using the Parallax SX28 micro

This project found its origins in a need to see and measure the frequency response of audio filters, tone controls and amplifiers in real time. An SX28 microcontroller module from Parallax turned out to be a really good means of implementing the circuit.

The standard way of measuring frequency response is to use a frequency generator with an oscilloscope or (fast) AC voltmeter and then plot the results on logarithmic graph paper.

This is time consuming especially when dealing with voltage controlled filters which vary their frequency response with a control voltage.

The author developed this circuit as a means of displaying the frequency response of a circuit on a standard oscilloscope. The firmware for the microcontroller core of the test instrument is written in assembly language.

Pluses and specs

There are a number of benefits to using this design:

1. The oscillator has two frequency ranges:
   - 100 Hz to 100 kHz. This allows for the
testing of audio, ultrasonic and infrared communication circuits.

- 50 Hz to 15 kHz. Primarily for higher resolution audio testing.

2. As component values in the circuit under test are changed, the change in frequency response is instantly observable on an oscilloscope screen. This makes it easier to show the difference in frequency response between various types of filter such as low-pass, high pass, bandpass and notch filters. You can even see the difference between filters with Butterworth and Chebychev responses.

3. The display on the scope shows a true logarithmic response and as such volts per decade/octave measurement can be taken directly from the display.

4. There is a facility to show a frequency marker on a second channel of the oscilloscope. A frequency counter (a digital multimeter with a frequency range is adequate) connected to the Marker Frequency Output will then show the frequency at that point, the marker can be moved to any point on the display. This enables the easy measurement of the –3 dB roll off points and Q (quality factor) of any filter.

5. There is a facility for switching between two different frequency sweeps and altering the amplitude of the output signal.

6. The output of the circuit is buffered so that it will not affect the response of the circuit under test. This means that both passive and active (amplifying) circuits can be tested.

### Circuit operation

The circuit is very straightforward, see the schematic in Figure 1. The microcontroller (IC2) generates the 8-bit values that are then sent to the R/2R-based ADC (analogue to digital converter) made from precision (1%) resistors R7 through R30. A dual precision operational amplifier type AD822AN (IC3) provides the buffering needed in the circuit. A pot (P1) and a changeover switch (S8) allow the output signal level of the sweep oscillator to be attenuated as required to match the sensitivity of the circuit under test if it’s ‘active’. The swept-frequency signal fed to the input of the filter or circuit under test is available on connector K2.

The SX28AC/DP micro is clocked at 50 MHz using ceramic oscillator X1. The oscillator pins of the micro also serve to program the device and that’s done via K7, which also provides the necessary ground and +5 V connections.

The micro may be reset by pressing and releasing pushbutton S3. The power supply is conventional, based on a 78M05 regulator (IC1) with its usual set of decoupling capacitors for noise suppression on the supply rails. The unstabilised DC input voltage may be between 8 V and about 15 V from a mains adaptor with 300 mA or so current capacity.

The microcontroller reads five pushbutton switches (S1 through S5) and

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**Figure 1.** Circuit diagram of the sweep oscillator. The heart of the circuit is a Parallax SX28AC/DP microcontroller module.
two on/off switches (S6 and S7) to determine the operation and settings of the sweep oscillator. The switches are read on microcontroller port lines RB0-RB3 and RA0/RA1.

The instrument supplies signals to the oscilloscope and the frequency meter via RB5/K4, RB6/K3 and RB7/K6 with 10 kΩ resistors inserted to protect the micro against short circuits. RB4/K5 is provided for experimental purposes and future expansion. The same applies to SX28 port pins RA2 and RA3.

**Let’s get connected**

The functional connections to the circuit are shown in Figure 2 mainly for those who have never used a sweep oscillator. Although some experienced users will be able to do without it and derive everything from the scope image, the frequency counter is extremely useful as it allows you to see the marker frequency instantly.

**Software & hardware development**

All the hard work is done by the program (‘firmware’) running within the SX28AC, a microcontroller developed by Parallax Inc. and available direct from them or through authorized distributors [1]. Like so many other Parallax products (including their renowned Basic Stamps and recently the Propeller), the SX28 enjoys wide support from Internet communities. The SX28 is cheap by any standard, and lots of free software and documentation is available on the web. Datasheets, compilers, programming examples, simulators, you name it and it can be found — see [2] ‘for starters’.

In terms of hardware development tools, the author used Parallax’s SX-Key™ Rev. F (now an ‘End of Life’ product, to be replaced soon by a USB equivalent). The software developed for the project was written using SX-Key V3.10, also from Parallax. The source code may be obtained as a free download from the Elektor website, the archive file number is 070951-11.zip. We suggest you open it to be able to follow the discussion below.

The main loop of the program outputs a continuous sine wave using a direct digital synthesis (DDS) algorithm to access values in a sinewave lookup table. This is a pretty standard method for creating a sinewave. The clever part comes by using an interrupt serv-
ice routine to alter the value which determines the frequency in the DDS routine. A piece of the routine is shown in Listing 1. There is a facility in this program for two sweep tables. An external switch is read by the program which then changes between the two sets of tables.

Again, SX28 micros come as ‘blank’ ICs so you have to do your own programming. Fortunately, that’s easy using the information found on the Parallax website. If you want to delve into the intricacies of SX28 programming, the publications [3] and [4] are sure to get you hooked on the device. Best of all, Al Williams’s writings on assembly code programming are a free download!

Construct

Elektor Labs have designed a quality printed circuit board for the project. The component layout is shown in Figure 3. The copper track layout is available separately as a free download from the Elektor website. It’s a pdf at true scale you can print directly to a laser printer to make an acetate transparent or ‘direct to copper’ transfer for PCB production on a budget.

IC sockets should be used for the SX28AC micro and the AD822 opamp. The SX28AC micro should be programmed, of course, before it can be used in this circuit (yes there are readers out there inserting blank micros in Elektor circuits and complaining it don’t work). Populating the board should not present problems as the layout is generous and no esoteric or extremely small parts are used. Everyone with a keen eye for detail, some patience and reasonable soldering skills should be able to pull this one off.

BNC sockets should be used for the sweep oscillator analogue output (K2), the Trigger output (K3), Marker Display (K4) and Marker (K6). The BNC sockets are connected to the pinheaders on the PCB using short pieces of thin coax like RG174. The braid of the coax cable goes to Ground!

Operation

The operation of the device is straightforward. Connect up the circuit as shown in Figure 2. Before switching on the power to the sweep oscillator and circuit under test, set the output amplitude pot and the attenuator switch to

### COMPONENTS LIST

<table>
<thead>
<tr>
<th>Resistors</th>
<th>Capacitors</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1 = 1kΩ</td>
<td>C1 = 10μF 40V radial</td>
</tr>
<tr>
<td>R2-R6,R9,R11,R12,R13,R15,R17,R19,R20-R23,R27,R29 = 10kΩ 1%</td>
<td>C2 = 100μF 40V radial</td>
</tr>
<tr>
<td>R7,R8,R10,R14,R16,R18,R24,R28,R30 = 20kΩ 1%</td>
<td>C3-C6 = 100nF</td>
</tr>
<tr>
<td>R25 = 1MΩ</td>
<td>C7 = 100μF 25V radial</td>
</tr>
<tr>
<td>R26 = 110Ω</td>
<td></td>
</tr>
<tr>
<td>P1 = 4k7 potentiometer</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Semiconductors</th>
<th>Miscellaneous</th>
</tr>
</thead>
<tbody>
<tr>
<td>D1 = LED, 3mm, low current</td>
<td>S1-S5 = pushbutton, 1 make contact</td>
</tr>
<tr>
<td>IC1 = 7805</td>
<td>S6, S7 = on/off switch, 1 contact</td>
</tr>
<tr>
<td>IC2 = SX28AC/DP (Parallax), programmed, Elektor Shop # 070951-41</td>
<td>S8 = switch, 1 changeover contact</td>
</tr>
<tr>
<td>IC3 = AD822AN</td>
<td>K2-K6 = BNC socket</td>
</tr>
<tr>
<td>SX28 source and hex files, free download # 070951-11.zip from <a href="http://www.elektor.com">www.elektor.com</a></td>
<td>K7 = 4-way SIL pinheader</td>
</tr>
<tr>
<td>PCB, ref. # 070951-I from <a href="http://www.theppcbshop.com">www.theppcbshop.com</a></td>
<td>X1 = 50MHz ceramic resonator</td>
</tr>
</tbody>
</table>

---

**Listing 1. DDS frequency control**

```c
;-----------------start of 0.2ms interrupt routine---------------------
; Modal register points to sine table on entry
; Modal register must point to sine table on exit
; Value fetched from table is added to frequency register
; This increases the frequency produced by the main output routine.
; At end of sweep everything is reset.
; Marker Buttons are read
; Marker frequency is updated
; Marker pointer is updated
; Trigger is generated

Interrupt
```
their lowest levels, set the frequency range switch (S6) to the desired position (100 kHz or 15 kHz) and the scope time base selection switch to the 5 ms position.

The oscilloscope controls have to be set to the following positions:
• timebase: 5 ms per division;
• external trigger on falling (negative-going) edge.

Connect the power to the circuit under test (CUT) first and then switch on the power to the sweep oscillator. Increase the output amplitude level to provide a usable display on the oscilloscope screen without any clipping of the signal. You should also see the output of the marker display on the second channel (‘2’ or ‘B’). Adjusting the position of this marker using the four pushbutton switches allows you to measure the frequency at this position on the screen using a frequency meter connected to the marker output connector.

Should there be any problems getting the output of the circuit under test to display on the oscilloscope screen (faulty CUT, faulty connections etc.) then connect the output of the sweep oscillator directly to channel 1 (or ‘A’) of the oscilloscope to check that everything is working properly.

There is an option for altering the time-base setting for the 15 kHz frequency range on the sweep oscillator but this is best left switched to the 5 ms setting.

Web Links and Literature
[1] www.parallax.com
NEW

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As a hobbyist you may often be designing a game or an application for your computer. When you’re demonstrating your program or game at a computer fair it seems a shame that people have to use a standard keyboard. It would be much better if their attention was drawn to your creation rather than the computer.

There are various reasons for wanting a Custom Input Device (CID). We can think of the following two examples. What about a pinball game on your computer? When you’ve created a great table or game using Visual Pinball [1], there is nothing so annoying as having to use the keyboard for the plunger and flippers. You want to put your hands on the sides of the table when using the flippers and pull a plunger to launch the ball. A computer keyboard is obviously not suitable for this.

Then there is the game of Rock, Paper, Scissors [2], where two players have to use their hands to show each other a symbol for a rock, paper or a pair of scissors. A rock beats a pair of scissors because the rock blunts the scissors. The scissors beat the paper because the scissors cut the paper. And the paper beats the rock because the paper can wrap round the rock. Instead of playing against another person you can also play against the computer. In that case it’s down to the computer program to ‘guess’ what its human opponent will do. From the Elektor website [3] you can download this game. You can use the following keys for your selection: [r] for rock, [s] for scissors and [p] for paper. This isn’t much fun, however. It would be much more enjoyable if you had a real rock, scissors and paper that you had to hit to make your choice. But how can we turn this bash on a rock or a flipper button into a computer signal? Read on!

**Keyboard**

To build your own Custom Input Device we propose the following method. We’ll use a type of input that is well known and used by everybody: the keyboard. Inside each keyboard is some electronics that converts a key-matrix into a serial signal that can be...
Build your own Custom Input Device

PS2 or USB?

In principle there is no difference between the operation of PS2 and USB keyboards when they’re used to make a Custom Input Device. What could make a difference is if you connect a PS2 keyboard via a PS2 to USB converter to your PC or laptop. In games where timing is important, such as pinball games, you may notice when a short delay occurs in the operation of the Custom Input Device. The question is if the delay is caused by the PS2 to USB converter, the Visual Pinball program, or simply the PC you’re working with or its graphics card.

It has to be said that the author has never found any delay to be a hindrance. The nice thing about USB is that you can connect more than one device at the same time. So you can connect a standard keyboard for normal use, as well as your Custom Input Device. In theory you could connect up to 127 devices to your computer via USB. The PS2 to USB converters will come in very handy here.

used by a computer. Instead of the more than 100 keys that are in a typical keyboard we’ll only use those that are required by the game and connect those to the electronics. In our example for Rock, Paper, Scissors it will only be the [r], [p] and [s] keys.

First you need to find an old, surplus keyboard and take it apart. After removing the screws from the underside we can prise the two halves apart. This exposes a membrane that consists of three layers. The outer layers have tracks on them and the middle layer keeps them apart. The top and bottom layers are connected to a small board of about 10 by 6 cm. This board also has a cable with a PS2 or USB connector at the end. The board should be carefully removed from the keyboard, with a note being made of the connections to the membrane. The two connectors on the board for the membrane connections usually consist of a smaller one with about 8 pins and a larger one with about 21 pins.

Key choices

Now we have to determine which connections are used by a particular key. We place the top of the keyboard onto the membrane and look which contacts are underneath the required key. Next we can find out in two ways which connections are used by this key. The simplest is to follow the tracks from the key to the connector. You’ll have to look carefully and hope that you don’t make a mistake. The second method is more reliable from a technical point of view. Use a multimeter, (who can do without one these days) and put it to its resistance setting. Put one probe on the membrane contact underneath the key and with the other test each of the contacts that connect to the board. When you see a low resistance

Behold the (simple) electronics (this can obviously look different if you have a different keyboard).

The two layers that make up the key matrix are used to determine the correct connections.
of about 60 to 120 Ohm you’ll know you’ve found the right contact. All the other contacts should return an infinite resistance.

Once we’ve determined which connection is used by the key on the layer with the small connector, we have to do the same thing for the layer with the large connector. We’ve then found the point in the matrix for that particular key.

Next we connect two wires to the connections we’ve just found and connect the other ends to our switch. With the keyboard circuit connected to the computer, a press of the switch causes the appropriate keystroke to be detected by the computer.

**CID for Rock, Paper, Scissors**

For the game of Rock, Paper, Scissors we choose the [r], [p] and [s] keys and connected them to some cables. The other ends were connected to three switches that were mounted inside three wooden discs. The discs are mounted on springs and can be pressed down. When that happens a switch closes. On top of the discs we’ve placed images of a rock, paper and scissors. The keyboard electronics are actually fairly attractive to look at. There is a real 40-pin Zilog processor with a few peripheral parts. It would be a pity to hide this circuit out of sight. We’ve therefore put this board in a hollow wooden disc and put a clear plastic panel over the top. In that way everybody can admire the simplicity of the keyboard circuit and our Custom Input Device.

**CID voor Visual Pinball**

In the program for Visual Pinball we can specify which keys operate the flippers and which key launches the ball. We can also interrupt the game with the Esc key. We could use the 1 or 3 key to start a new game, for example. There is also a facility to assign keys to nudge the table in various directions. For all functions that we want to make use of we determine the switch connections on the keyboard circuit and connect them to small switches. We’ve used a sturdy, bash-proof plastic box measuring 40 by 30 by 12 cm for our Visual Pinball CID. When it’s placed sideways on the table it feels comfortable with your hands on it. The two pushbuttons that operate the flippers are mounted on the sides of the case to give a more realistic feel of a pinball table.

The plunger is made from a wooden knob mounted on the end of a 6mm diameter metal rod. On this rod we mount a ring that is normally pulled against a switch (by an elastic band for example), keeping it opened. When we pull the plunger (to launch the ball) the switch closes. And when we let go of the plunger the switch opens again and the ball is launched. In Visual Pinball the time that the switch is closed corresponds to the power of the launch. A short time gives less power and a long time gives more power.

This type of interaction between your CID and the program adds a lot to the enjoyment. If we use a projector to display our Visual Pinball game on a large screen and put the CID some distance away we can imagine that we’re standing in front of a giant pinball machine. The show can begin!

**Web Links**

With a few innovations (elastic band and positioning of the switches) the CID for the pinball table is like the real thing.

The ‘controller’ for the Rock, Paper, Scissors game is exposed to the world in all its glory.
μC Goes Analogue

Cypress PSoC development kit

Paul Goossens

Your average embedded system will be primarily composed of digital components. However, analogue components are also necessary for filtering and amplifying signals, among other things. Cypress PSoCs combine a microcontroller with analogue functional blocks. A development kit such as the CY3270 forms a good starting point for rapid familiarisation with these ICs.

The inputs and outputs of these analogue blocks can be connected to any desired pins of the IC. This also holds true for the digital peripheral components of the chip. This makes designing the PCB layout a lot easier.

Hardware
The hardware in this kit consists of two parts. The first part is the ‘FTPC bridge’, while the second part is the expansion board.

The expansion board holds the PSoC – a CY21434 – that is used to test the provided examples. In addition, this board has an RGB LED, a small speaker, and a thermistor. The PCB also has a pair of copper strips and a connector for inserting the wire included in the kit. The copper strips can be used to make a touch button in combination with the PSoC. The included wire, which extends as a sort of an antenna, can be used to build a proximity sensing circuit. The FTPC bridge provides the communication link between the expansion board and a PC. The USB interface on this board makes connection to a PC easy. This allows the PSoC on the expansion board to be programmed from the PC. In addition, it acts as a USB to I²C bridge and as a USB to SPI bridge. This simplifies debugging of applications that use these interfaces.

Software
The included CD-ROM contains another important part of the kit: the development software and programmer. Incidentally, this software also runs under Windows Vista without any problems. Unfortunately, the programming software included on the CD does not work under Windows Vista. However, a new version that does work with Vista is available on the Cypress website.

What is PSoC?
The abbreviation PSoC stands for ‘programmable system on chip’. A variety of IC makers use this designation. It usually refers to a microcontroller with a large amount of memory and peripheral functions. At Cypress, this name is used for a rather different kind of IC. Beside the microcontroller and some peripheral functions, the Cypress PSoC incorporates several analogue components. These analogue components are configurable. You can thus use them to build a wide variety of analogue amplifiers, filters, modulators, and the like directly in the chip. These blocks allow analogue circuits to be incorporated in an embedded system along with the microcontroller, all in a single chip. This reduces the total number of components required for a given design.

You can buy the CY3270: PSoC First Touch’ starter kit for around £15 (25 euros). It provides a convenient way to discover for yourself what the Cypress PSoCs have to offer. This development kit consists of two hardware modules, a mini-CD, a Quick Start Guide, and a piece of wire (!). All of this is packaged in a plastic box, which you can later use as a handy storage container. The only thing that’s missing is a USB cable – otherwise the kit is complete and ready to use.
The microcontroller can be programmed in C with this software. There is also a built-in simulator. The special feature of this software is the capability of configuring the analogue blocks in the PSoC.

With this software, connecting various types of sensors is very easy. The software also includes a large number of predefined blocks that can be used to connect a wide variety of sensors directly to the IC. The associated C routines for reading these sensors are also included. You can even display typical schematics for the various sensors on the screen. Constructing a circuit effectively amounts to dragging the necessary analogue functions to the design. The properties of these blocks can be adjusted as necessary with a few mouse clicks.

Sample applications
The software is complemented by four sample applications for the expansion card. Using these examples, you can quickly understand how to make a touch sensor that operates on the capacitance principle. Using a piece of wire as a proximity detector is also quite easy, and it’s fun to experiment with adaptations of this design. The light sensor and temperature sensor are also used in the other two examples.

Assessment
The Cypress CY3270 development kit provides a lot of value for relatively little money. The hardware is simple but functional, and the FTPC bridge can be used afterwards as a programming interface for your own projects. Experimenting on the basis of the supplied examples is a pleasant way to spend your time, and it’s bound to inspire you to develop your own creative uses for these PSoCs. The easy-to-use development software, along with the library of handy routines and ready-made sensor interfaces, is especially convenient.

Kit available from:
www.cypress.com/go/elektorFTK

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Elektor Electronics
Jan Buiting, Editor
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Email: editor@elektor.com
In the early days of the personal computer the system could really only be in one of two states: on or off. Putting the machine into standby so it could be restarted more quickly was still unheard of then. There was also the fact that the operating systems in use at that time (DOS and later OS/2 and Windows) weren’t very good at doing several things at the same time. It was better to keep the hardware active all the time (it was well-known that the hard drives in those days didn’t like it if they were continuously turned on and off again). But even then the motherboard manufacturers were hard at work implementing the Advanced Power Management (APM).

APM made it possible to enter a power-saving standby mode via a time-out setting in the BIOS or by pressing a Suspend/Resume button. On detecting this signal the hardware switched into a power-saving mode.

**transformation**

With the advent of newer operating systems such as Windows 95 it became possible to activate this standby mode from within Windows and make better use of it. After all, if the BIOS decides that a device can go into standby mode, but the operating system can’t handle that, then the result will be chaos.

As it was, APM could never be used to its full potential. Much of the functionality could only be used from within the BIOS and was not accessible to the operating system. The support left much to be desired and there were numerous problems with Windows 95 and power management that left many users feeling very frustrated.

**Progress**

The successor to APM is known as the Advanced Configuration and Power Interface (ACPI). With ACPI it is the operating system that makes the decisions regarding the power management. It can put certain parts of the computer into a different state, saving energy. This happens according to the preferences of the user and the programs running at the time. A device that is not used can be turned off or put into an idle state; this is something that can also apply to the whole computer.

The ACPI gives the operating system direct control over the power management and the so-called Plug and Play properties of the computer. You do of course need an operating system that supports the ACPI. Every Windows version from 98SE and NT4 onwards has support for these features. It was very different as far as the alternative operating systems were concerned. It wasn’t that long ago when putting a computer into hibernation would result in a crash and then required thorough check of the hard drive.

Fortunately the open source community doesn’t rest and these days most versions of Linux and FreeBSD make it easy to call the ACPI functions. This is actually quite an achievement since the full ACPI specification is in excess of 600 pages. If it had been left to Microsoft it would have been a closed Windows-only specification.

**How does it work?**

So how does the ACPI work? It would be too much to go through the complete specification, but in a nutshell the ACPI has seven different states, with the power saving varying from none to maximum.

‘G0’ is the normal state in which the computer operates. The operating system and programs run normally and the processor carries out its instructions. In G0 it is possible to turn of a device temporarily while it isn’t required and turn it back on again afterwards. Examples are hard drives and monitors that are turned off after a few minutes if they haven’t been used for that period.

‘G1’ is the sleep state. This state has four sub-states: ‘S1’ to
‘S4’. They effectively determine how quickly the computer can be brought out of its sleep state. In S1 the memory cache is cleared, but the processor(s) and the memory remain powered up. The machine can be brought back to its normal state very quickly. This is also called the ‘POS’ state or Power On Standby. S2 is almost the same as S1. The only difference is that the processor is powered down. The computer therefore takes a little bit longer to wake up again.

S3 is also called ‘Suspend to RAM’ in the BIOS. In the various operating systems it’s called something different again (‘Sleep’ in Vista and OS X, for example). The operating system keeps the memory powered up and stores the system state in it. Because of this the user can get back to work quickly, since storing the system status in RAM requires little effort and you can carry on working where you left off. It takes about as long as powering up the monitor again.

S4 is better known as Suspend To Disk, although the various operating systems again use different descriptions. In OS X it’s called ‘Safe Sleep’ and in the assorted Windows versions it’s known as ‘Hibernate’. In this state the system state is written to the hard drive. The biggest advantage of this is that the computer can be fully turned off once all the information has been written. This is in contrast with S3, where you would lose all the information if there was a loss of power, for example caused by an empty laptop battery.

G2 is also known as S5, but it is not a state that saves more energy than S4, since several parts remain powered up. In this state a press of a key on the keyboard or a signal over the LAN (Wake On LAN) can restart the computer. In this state you wouldn’t be able to change parts either. This can only be done safely and without the loss of data in the G3 state.

G3 is the same as the mechanical off state. The operating system and programs have all been fully shut down and the hardware has been turned off, with just the Real Time Clock (RTC) on the motherboard running from a small lithium battery. In this state it is completely safe to add or replace any hardware. The computer will be in this state when there is a loss of power and usually remains in it when power is re-applied. In some BIOSes this can be changed so that a system will automatically return to the G0 state after a power-cut, and restart. From the G2 and G3 states there obviously has to be a full boot-up procedure before the system becomes operational again.

The success or failure of this functionality obviously depends on the support provided by the underlying hardware. If certain functions are missing it is often impossible for the operating system to implement some power saving functions. When this is the case the state of the system is often called the Legacy mode. The ACPI is not used in this mode and the computer effectively operates in either G0 (on) or G3 (off) mode.

**Choices**

The preference of the author is to use the S4 state on his laptop, as that works well with both Linux and Windows. The biggest disadvantage is the power up time. When restarting from Suspend To Disk the system first has to go through a complete POST (Power-On Self-Test) and then write back the system state into the memory, which takes a while. But as with many things in life, it’s a matter of priorities: do you want to quickly resume with your work or do you want to save energy (from your laptop battery, for example).

Another function of ACPI is used very much in portable computers; running the processor at a lower frequency than it is made for reduces the power consumption, extending the life of batteries. Intel calls this SpeedStep, and AMD uses the terms PowerNow and Cool’n’Quiet.
Lucky Dip

Design it yourself or copy from the Internet?

Thijs Beckers

Like it or loath it, the Internet offers a treasure trove of information. Countless pages magically appear on your computer screen via this digital connection. You only need to know how to find what you’re looking for. But it’s not always that easy. For the electronics enthusiast there are of course all sorts of circuits and ideas waiting to be unearthed — the good, the bad and the ugly! We take a grab at what is on offer.

Do-it-yourself single-chip audio amplifiers with a LM3886 or similar, the so-called ‘Gainclones’ are quite familiar by now. So we won’t talk about those. Perhaps a little less well-known, but still a very popular do-it-yourself subject is the modification of CD players manufactured by Marantz, specifically the CD-63 and the practically identical CD-67. These players have now reached quite a respectable age and can easily be obtained second hand. A large group of audio fanatics [1] knows how to improve this player, with a few modifications, to a level approaching that of high-end.

Audio

A famous website with all kinds of interesting audio projects is Elliott Sound Products [2]. But this is, of course, not the only source for interesting audio circuits. At [3], for example, we find a nice circuit for a USB sound card (Figure 1). Building a simple sound card that connects to the USB port doesn’t require a university degree any more. Using an IC such as the PCM2706 from Texas Instruments you immediately have a headphone amplifier, a digital output (S/PDIF) and a hardware control panel for your media player, without the need to install anything at all when used with Windows XP or MacOS X. You can even download a PCB layout for this from this website [3].

For at home...

...there are naturally also a diverse range of interesting circuits to be found. For example, this doorbell intercom [4]. This handy circuit (see Figure 2) uses the speaker for reproducing as well as picking up sound. The volume can be adjusted with a potentiometer. A switch (indoors) is used to switch the circuit between listening and talking, so that 2-way communication becomes possible. Very handy, of course.

A somewhat older ‘gimmick’, but foremost not necessarily less entertaining, is the lightning bulb [5]. With a simple lamp, a piece of aluminium foil and a high voltage power supply, built from a car ignition coil, it appears that there is an electrical storm inside the glass envelope of the lamp (see Figure 3). It remains fascinating to see how the electrons work their way from one electrode (the filament) through the gas in the lamp to the other electrode (the aluminium foil). Of course, You need to watch out with these types of projects, because they operate at a dangerously high voltage of several kilovolts.

Another thing that would be nice to have at home is a metal detector. In this instructional video [6] you can see how you can, in a few minutes, turn a radio and a calculator into a simple metal detector that you can use, for example, to find wires or pipes in a wall. The ‘circuit’ uses the clock frequency of the pocket calculator.

μC

Very popular as well is the Arduino development board [7]. It is targeted at
artists, designers and hobbyists and everyone who is interested in interactive applications. These little boards are usually based on an Atmel ATmega168 microprocessor (see Figure 4). There are quite a lot of these open-source applications and the number continues to grow. Examples of projects that have been designed with this mini board are drum pads with a MIDI interface (Figure 5), an interactive light system for a bridge and a virtual fish tank.

Microprocessors always need to be programmed of course. One of the many AVR programmers that can be found online is the one from electronics-diy.com [8]. Together with the program called PonyProg [9] it is very straightforward to program hex files in, for example, a 28-pin ATmega8. The circuit is very compact and can be tidily housed inside the shell for the serial connector (see Figure 6). Incidentally, on the PonyProg website you will also find a circuit for a programmer that is suitable for connecting to a parallel port.

PC

If you have poor reception of a WiFi signal you will definitely have to watch this video [10]. This explains how you can make a better antenna for just a few pennies. Just roll up your sleeves for five minutes and you’re done! “Finally a use for that old Windows 95 laptop”, that’s how this website [11] announces the circuit (Figure 7). With three ICs, a dual opamp and a handful of components you can make an excellent 12-bit data logger for less than £10 (€14). A simple Qbasic program does the rest. Qbasic.exe is generally on the original Windows 95 CD (usually in the folder ‘oldmsdos’) or alternatively can be downloaded from [12]. It will probably work with GWbasic as well.

**Web Links** (also on the Elektor website)

[1] www.diyaudio.com


[16] http://home.hccnet.nl/e.vd.logt

[17] www.zen22142.zen.co.uk/Circuits/Power/add-on.html

Robotics

Activating a robot (or something else) with a certain sound signal can be done with this [13] circuit (Figure 8). The IC compares the frequency of the input signal with that from its own frequency generator (adjustable with a resistor and capacitor) and switches its output low when they match. So you can for example, by whistling at a certain frequency have the robot carry out a pre-programmed action (make it come towards you, for instance).

Miscellaneous

A simple parking aid which uses an IR LED and IR photo diode is explained here [14]. Via the home page of this website [15] and the accompanying forum many more interesting projects are waiting to be found.

What has brewing beer got to do with electronics? We find the answer here [16]. On this website we can see the building and brewing process of Emile van de Logt. A genuine PID controller and control with PC software are deployed for this brewing process (Figure 9). With a very small and simple circuit built around a single transistor (Figure 11) you can build a spy microphone that can be received with an FM radio. The website [18] is unfortunately in Czech, but it is easy to understand the circuit without the text. There is even a PCB layout available, although it is rather spacious for a spy microphone.

This was just a random selection of the immense number of circuits on offer. We hope that we have given you a few ideas and in the event that your own searches prove to be fruitless, you can always visit the Elektor website for more than 2,000 circuits on stock.

(070955-I)
My microcontroller doesn’t go…

It is impossible to imagine modern electronics without microcontrollers. What used to be done with combinational or sequential logic is now done with a single IC that runs a program that does exactly what we want it to do. Or perhaps more accurately: should do exactly what we want it to do.

Luc Lemmens

Particularly during the early development phase of the hardware and software, we often run into perplexing problems. The most frustrating of these is when the microcontroller doesn’t do anything at all (or appears not to do anything at all). With older microcontrollers that have external program memory an oscilloscope or logic probe could often give an answer. A measurement on the address or data bus would give a quick indication whether the microcontroller was ‘awake’ or not. But these days all memory is integrated in the IC, in most cases, so only the I/O ports can sometimes provide consolation as to an indication of any sign of life.

Fortunately (?) most controllers still have an external oscillator, so that we at least can check whether the clock is running. However, even this option isn’t available with many small microcontrollers that have an internal oscillator.

The simplest method to ensure that the oscillator is running and that the software, in principle, should be able to work, is to insert a short routine at the beginning of the program that toggles one of the port pins a few times. Preferably a port pin that has an LED connected to it, that gives immediate visual feedback and an oscilloscope is not required.

Don’t make the program wait for some external action (such as a button press, reception of data via the serial link, etc.), but just do ‘something’ on any pin whatsoever. If there is still no indication of any activity (and assuming that very basic checks like measuring the power supply and whether the reset line is at the desired level have already been done), there is a chance of ten to one that something has gone wrong during programming. The configuration fuses of the microcontroller are the main suspects.

As has been mentioned in an earlier ‘LabTalk’ article, modern microcontrollers have a number of bits (fuses) that define the behaviour of the IC. In the scope of this article we first have to look at the settings, if there are any, for the oscillator (internal/external, frequency range). If these settings are wrong then in most cases nothing happens at all. The second suspect is — if present — the watchdog timer (WTD). If this has been turned on when programming and the application does not reset the timer, the microcontroller will repeatedly be reset and often won’t even reach the actual program.

Number three is the setting for the reset circuit. For example, the reset signal for some microcontrollers can be selected to be internal or external. Consult the datasheet for the controller and check the remainder of the circuit to determine the correct settings. It can sometimes take a bit of looking around in the programmer software to find where these settings are hidden — as we already discussed in an earlier story — sometimes they have different names than what you would expect. In final desperation you could try all possible combinations of the fuses in the hope that one of them works. This sounds very awkward, but it will unfortunately be necessary at some point! Fortunately, reprogramming of a microcontroller is not such a time consuming job these days.

A simple start-up indication built into the application saves a lot of time and frustration — at this point you know that the hardware is functioning and that nothing went wrong when programming the memory and fuses. At a later stage of development, you could remove the start-up routine, but only do that if absolutely necessary.
Automatic aquarium feeder

Helmut Schaefer

People come in all shapes and sizes and we all have our own character. You probably know people who are at their best first thing in the morning while others can only get things done when they are burning the midnight oil. The feeding habits of different fish species also show variation; some (such as catfish) are nocturnal feeders while others feed during the day. Unless your own body clock is in sync with the fish in your aquarium you will not be providing them with food when they really need it.

The solution described here is an automatic fish food dispenser. On the mechanical side the apparatus consists of an off-the-shelf DC motor and reduction gear driving an external gearwheel sandwiched between two plates. It is necessary for the spacing between the plates to be greater than the thickness of the fish food pellet (see illustration). A hole in the upper plate is directly beneath a vertical tube (or magazine) which contains a stack of food pellets. The hole in the lower plate is offset and the pellets will eventually drop through here into the aquarium below. In between these holes is the final cog in the gear train which has a hole made in it between the hub and toothed edge of the wheel. The hole must be slightly bigger than the diameter of the food pellet. When the hole is beneath the column of pellets a single pellet drops down into the hole in the gearwheel. At each feed time the pellet over the hole in the lower plate a cam on the output shaft activates a micro-switch. This will ground the ‘clear’ input of IC1B and produce a negative going signal to the clock input of flip-flop IC1A which clocks the state of the J input (Q) through to the Q output to turn off T1 and the motor. The ‘preset’ and ‘clear’ inputs of IC1B are connected directly to the micro-switch output to provide a debounce function ensuring that a single clean clock edge is provided to IC1A. All the other inputs of IC1B related to synchronous operation are unused and tied to ground (logical 0).

Capacitors C2 and C3 should both be ceramic types and although reservoir capacitor C1 is shown as a tantalum normal electrolytic type can be substituted. The motor together with the circuit draws around 35 mA. A 50 mA fuse (F1) is included in the supply to protect the motor and transistor should a food pellet become jammed in the mechanism and stall the motor. A more powerful motor can be used in the design but in this case it will be necessary to reduce the value of R4 to give a greater drive current and swap T1 for a power transistor. The fuse rating will also need to be beefed-up to handle the increased current.

A tip when drilling the plates is to start by making just two holes through the plates and then fitting two pins or bolts through the holes to fix the plates together before drilling the remaining holes that are common to both plates. This ensures that the holes will be properly aligned.

Although the design was developed for feeding fish it could also be adapted fairly easily for other applications that require a programmable momentary mechanical operation.

[Detached diagram]
Ultra-responsive peak detector

Stephen Bernhoeft

The peak detector presented here will respond to amplitude changes of the input signal within one-half of a cycle. Because no ‘bleed’ resistor is required on the output capacitor, droop is only limited by the ‘off’ resistance of a CMOS switch. Note that circuit is more accurately described as an amplitude detector, as the output level is equal to the average of the absolute values of the positive and negative amplitudes. For a sinusoidal input waveform, this corresponds to the peak detect function.

Positive and negative peaks are measured separately. Whilst the positive peak is being acquired, the negative peak is output, or vice versa. At the time a positive-going zero-crossing is detected, the positive peak detector is reset, and similarly for negative signals.

There are two key subcircuits. One is a peak detector, the other is a zero-crossing detector (ZCD). There are two instances of each type, corresponding to the two possible signs of the input signal. Note that all detectors (of both types) give a positive output.

When +ZCD goes high, this causes a brief pulse to reset the positive-peak detector. The reset has no effect on \( V_{\text{OUT}} \), since the high level of the +ZCD means that the negative peak detector is connected to \( V_{\text{OUT}} \) at this time.

During this (positive) half of the input cycle, the +peak detector continuously registers the most positive input signal to date until such a time as it is reset.

Now consider what happens over the negative-going excursion of the input signal. Firstly, +ZCD goes low, then –ZCD goes high. In the short interval that both are low, the output capacitor is isolated. When +ZCD goes low, \( V_{\text{OUT}} \) is removed from the negative peak detector output, and because –ZCD is high, \( V_{\text{OUT}} \) is instead connected to the positive peak detector output. The negative peak detector operates in the same way as described above for the positive one, but because it sees an inverted copy of \( V_{\text{IN}} \), it gives a positive (absolute value) output, as required.

The circuit shown is suitable for low frequencies up to a few kHz. The AD8534 is specified as unity-gain stable for capacitive loads of up to 10 nF. Empirically, it was found that even an ordinary opamp such as the LMC6484 gave no problems when ringing at \( V_{\text{OUT}} \); possibly the ‘on’ resistance of the switch in the 74HC4066 helped to isolate the output capacitor.

The negative peak detector operates in the same way as described above for the positive one. The circuit shown will respond to amplitude changes of the input signal within one-half of a cycle. The ‘on’ resistance of the switch is limited by the ‘off’ resistance of the switch.

Lastly, if desired the inverting opamp stage may be amended to use 100 kΩ resistors.

\[ V_{\text{OUT}} = -V_{\text{PEAK}} \]
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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.

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The closing date is 1 May 2008.

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The solution of the January 2008 puzzle is: 90467.

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Congratulations everybody!
‘Formant’ is without doubt one of the biggest names from the Elektor history. The mega project goes back a good thirty years, was forgotten for about 25, and now halls us through Google and Ebay. Along with Chorosynth, it is one of the vintage instruments presented at the fabulous www.synthmuseum.com [1] website brought to you by Paula Chase and Jay Williston.

The scene: it’s 1970 and ‘groovy’ sounds are heard from Robert A. Moog’s synthesizers like the one used by bands like Yes and Emerson, Lake & Palmer. The Moog synthesizer was the de facto standard at the time, with lots of more or less electronically minded musicians (or musically minded electronics fans) adapting and extending it all the time to create their own flavour of sound. The pitch wheel in particular created sound ‘bends’ that became forever associated with the Hippie age. For a nice history of ‘The Moog’, see (and hear) [2].

The Elektor Formant was originally designed by C. Chapman and the project saw its first publication in the May 1977 issue of Elektor. In an attempt to jump the Moog bandwagon it was announced as “an instrument of advanced specification that bears comparison with many commercially available synthesizers, but at a fraction of the cost”. The article series ended with part 10 (!) in the April 1978 issue. Two Elektor editors, now retired, recalled that the publications got immense acclaim but failed to sell significant numbers of the printed circuit boards. That changed dramatically, at first when the Formant article series were bundled into a book (1980), and a bit later (1981-82) when M. Aigner published follow-up articles (and a book) describing what looks like ‘Formant mk.II’ containing goodies like a Ring Modulator, Sample & Hold, Phase Shifter, Envelope Follower, Mixer, ADSR Controller, VC-LFOs, and other highly desirable sound warping circuitry, some based on Curtis ICs. By contrast, the original Chapman design, although comprehensive by itself, is a conventional Moog-style synth with a classic 1 V/octave characteristic and all the usual modules like VCO, VCF, LFO (made from 3 LFOs), Noise, ADSR, VCA, COM, RFM (not the manual but Resonance Filter Module) and a 24-dB VCF, not forgetting a keyboard and interface and of course a power supply — all DIY, built on Elektor ‘EPS’ printed circuit boards and taking almost 100 pages to describe in great (albeit dry) detail in the magazine.

Formant was rack-able consisting of circuit boards vertically mounted on a backplane with the controls (pots, switches) in bright colours on the front panel. The instrument pictured here is privately owned by my colleague Jan Visser from the Elektor labs who put it at my disposal for photography and sound checking of course! The wooden case was available at the time from electronics retailers advertising in the magazine. It’s an almost fully loaded Formant complete with a keyboard and even a mini-oscilloscope to check the waveforms. With the current revival of seventies things & sounds, I reckon the instrument would fetch some hard cash on Ebay!

The smaller unit pictured here is the Aigner version with a modest complement of dual VCO, VCF, Dual ADSR, LFO and COM. This fine sounding specimen was rescued from the skip and is currently in safe storage at Elektor House. Reportedly the instrument was played ‘live’ several times at electronics exhibitions and shows in France and Germany during the mid 1980s.


Web Links
[2] www.youtube.com/watch?v=TtYkC3NyjM

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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(March 2008)

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Measure it with the PC and the soundcard

Twenty-odd years ago, PCs were so slow no one dreamed of using them for live measurements. By contrast, today's machines happily run RTA (Real Time Analysis) and FFT (Fast Fourier Transformation) maths as a background task. Obviously the options for measurements depend strongly on the software used and that's why we examined a range of relevant products on the market. Also, the quality of the measurements results returned will be determined to a large extent by the sound card used; well it so happens that an Elektor test was planned for these.

Frequency Counter with ATtiny 2313

Only a few low-cost function generators and signal generators we've seen have a frequency display and an accurate frequency adjustment. The module we propose cancels both shortcomings. The core of the circuit is an ATtiny2313 microcontroller and that's about it for special ICs! Frequencies up to 5 MHz can be measured (without a prescaler!) and the LCD can be switched between MHz, kHz and Hz readout.

Mini-display-board with M16C

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