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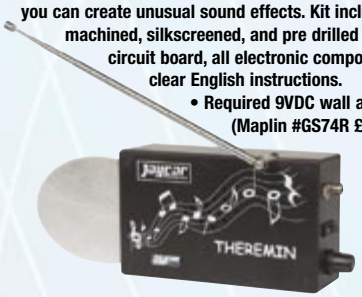

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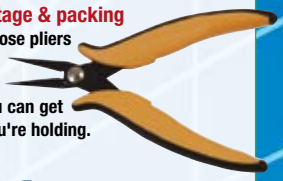

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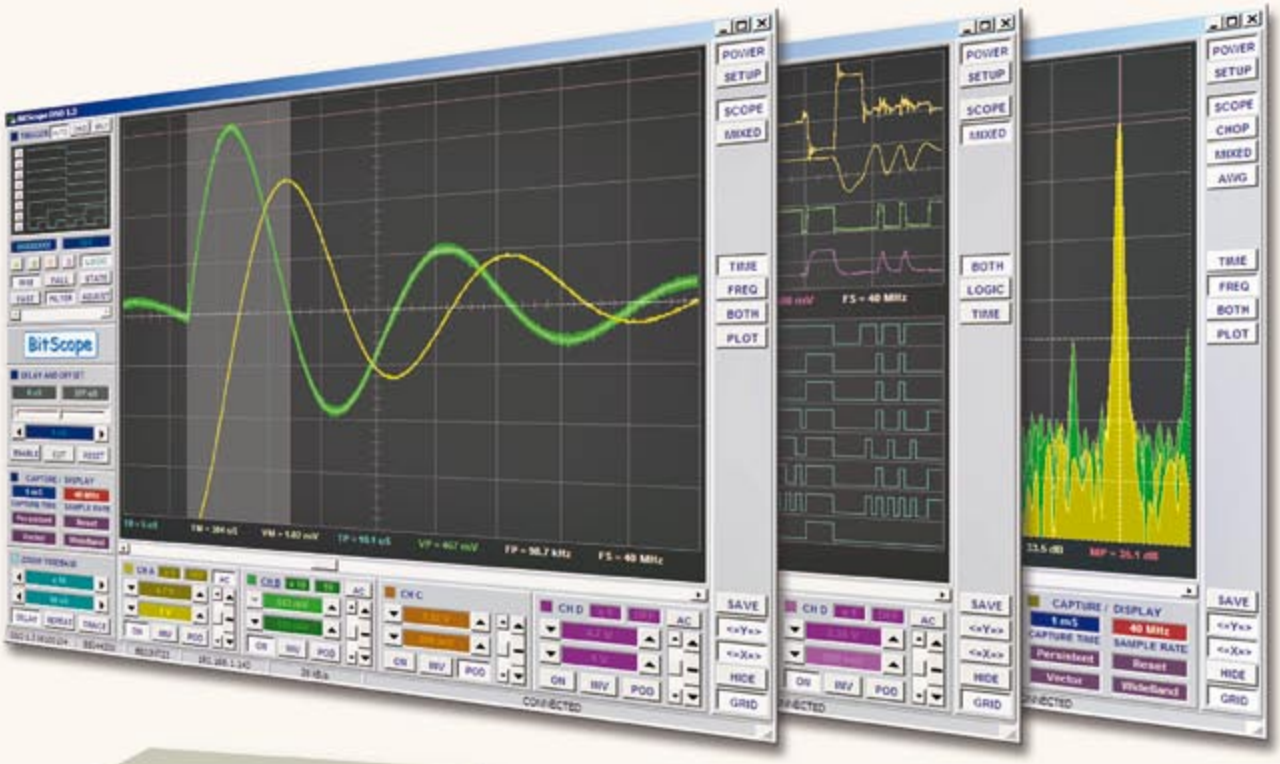

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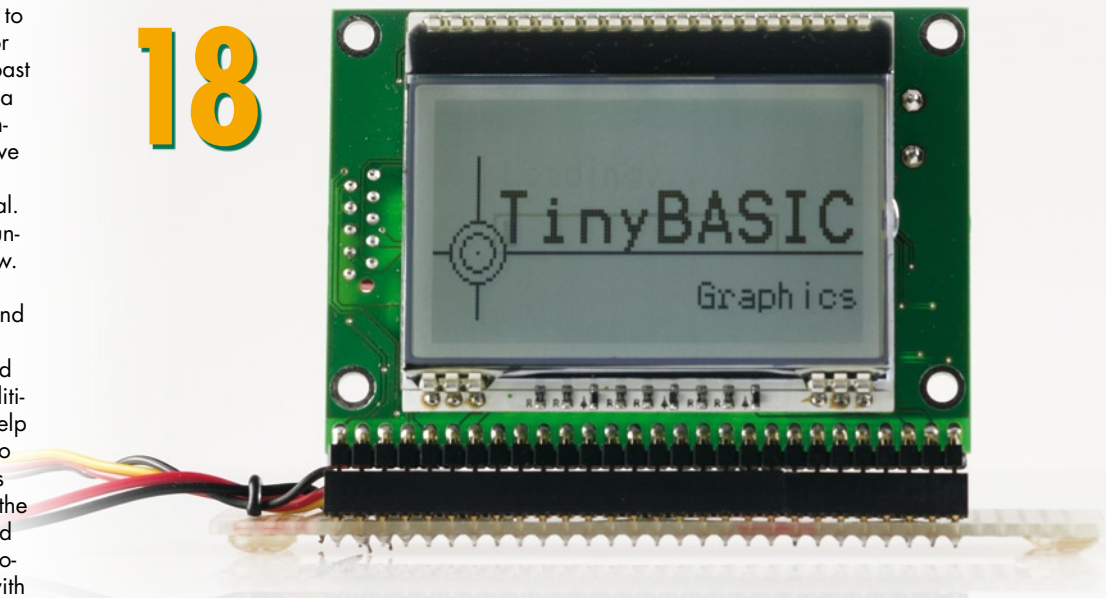
More than just a mag

Most of you will associate 'Elektor' with the printed magazine that's been on circulation in newsstands, bookshops and in electronics retail stores since December 1974. In fact you are reading issue # 377 right now — on paper, and we intend to print quite a few more editions for you to enjoy. However over the past few years Elektor has developed a number of activities that do not involve paper anymore, although we consider them part and parcel of our publishing activities in general. Some of these activities may be unknown to you so I'll mention a few. To start with, there are our PCBs, CDs, books, special issues, kits and modules. Elektor PCBs have been on sale since issue #1 but kits and modules are relatively recent additions. We started selling them to help those individual readers 'dying' to build our more ambitious projects but were either unable to source the components or shamefully ignored by component suppliers moving towards the professional domain with the inherent, awful P&P quotes. Our first 'module' was the legendary GBDSO. Some of our recent kits, like DigiButler (page 26) and last month's Elektor Internet Radio are 'hybrids' in that they contain a PCB that has the SMD components premounted. From reader feedback we learned that many of you still enjoy soldering through-hole parts, hence these are supplied separately with the kit for an hour or so of wielding the old soldering iron (low-power, mind you).
Elektor is also expanding its 'e-vents' portfolio by staging workshops and seminars. Our partners are field leading companies and individuals. Examples include valve workshops and MultiSim10 from (and by) National Instruments EWB. Both were highly successful and got high grades from attendants. Another 'e-vents' activity you may have seen announced is the Elektor-hosted study trip to China.
We have created an Elektor channel on YouTube, provisionally at www.youtube.com/elektorim. We have discovered that short films, however primitively made, on our techno stuff are a great way of pulling in not only newcomers of the MTV generation but also those now in retirement and having discovered Elektor again through successful Googling.

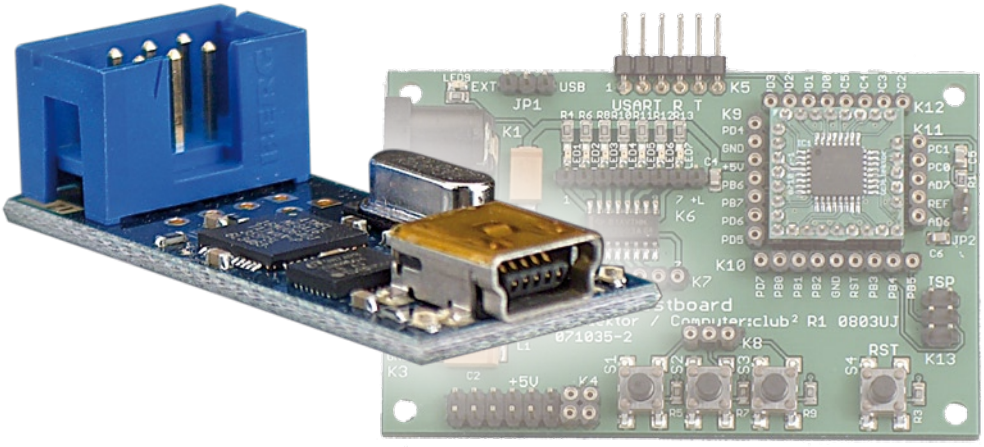
Jan Buiting
Editor

Display Computer 18



Programming a graphic display is distinctly more difficult than programming a text display. Our mini microcontroller board features a new display-on-glass module and a high-performance Renesas M16C microcontroller. The board is available fully assembled, and the microcontroller is pre-loaded with a TinyBasic interpreter to simplify the development of graphics applications – even for novices.

38 Elektor AVRProg



Two events triggered the conception of this AVR programmer: the feedback received on USBprog from Elektor, October 2007 and a series of articles started last month around our ATM18 project. The outcome is a plug-and-play AVRISP mk2-compatible USB programmer for AVR controllers!

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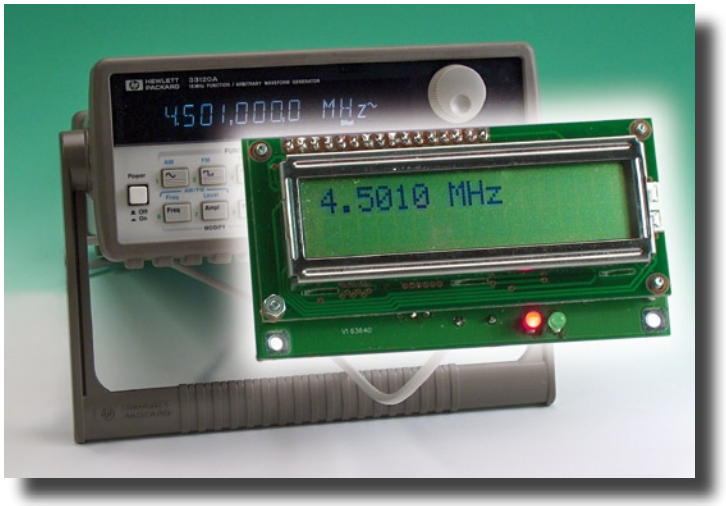
58 Tiny Counter



The tiny frequency counter module described here consists essentially of just an ATtiny2313 microcontroller and an LCD panel. The microcontroller is clocked at 20 MHz, and so the counter module can be used at frequencies of up to 5 MHz without the need for a prescaler.

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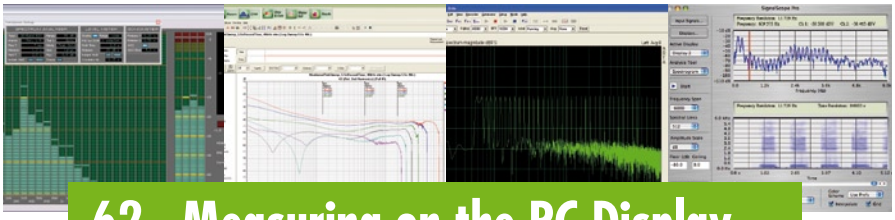
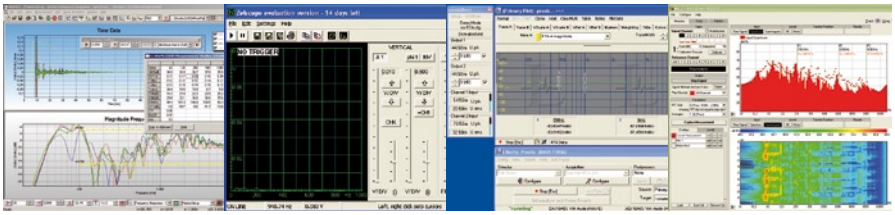
details on page 12



62 Measuring on the PC Display

In addition to its audio uses the soundcard can also be used for measuring purposes. But which software is the most appropriate? In this article we help you get oriented by giving you an overview of what can be found out there.



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Compact Fluorescent lamps

Dear Editor — I liked the article on CF lamps in the January 2008 issue. It gives an insight into the requirements for operation of these miniature fluorescent lamps, but despite the attempts of various governments to inflict these units on the populous, there is still some resistance to their general use. There are many reasons for this. In Britain at least, the cost is relatively high compared to the humble incandescent lamp, although prices have dropped in the last few years. One issue with all CFLs is to know the colour emitted by them. The warm-up time can be a problem in some applications, especially in outdoor units having a short on time such as in IR detector controlled fittings at doorways. In cold weather these can take a few minutes to give a useful light, and by then, the detector is ready to switch off again.

I have used the standard BC fitting replacements for several years now, but current building regulations in the UK demand at least a certain number of low energy fittings in every new build or extension. These must be of a type that cannot accept a standard incandescent bulb as a replacement, effectively ruling out the GLS replacement lamps now becoming widely available here. We are therefore faced with fluorescent fittings, Bi-pin types or square 4D fittings.

Unfortunately, the lamp unit manufacturers have been slow to provide suitable units that are acceptable to the home user. Most of the fittings available that will only accept a none-incandescent type lamp tend to have a somewhat industrial look to them, necessitated by the requirement of providing a ballast of some kind and a place to keep said ballast away from danger. That has to include dissipation of heat in a safe manner, isolation from prying fingers and safety in failure either of lamp or ballast.

There are pendant drops made that will only accept a bi-pin lamp, but they do not readily take a standard shade as the fitting is larger than the old bayonet holder.

Then there is the lamp equivalent problem. How does one relate 18 W = 100 W and pictures of several light bulbs on the packet with the real world? In truth I have seen 5-W CFL lamps that claim to be equivalent to 30 W candle lamps, and yes they are bright, but the light produced has an eerie greenish tinge presumably due to a lack of red in the spectrum produced. By the same token, some CFLs give a stark blue-white light, and these are very bright to the point of being painful, but the quality of the light seems strange. The shadows are harsh and yet the corners of the room seem to be in darkness, despite or perhaps owing to the intensity of the light elsewhere in the room.

It must be said that the more recent spiral and the multi loop lamps are a better colour match to tungsten lamps than they were, although perhaps efficiency has been sacrificed for colour temperature. I modified a fitting to take a 16 W 4D lamp from 2×60 W golf ball bulbs, and for some reason ordered a cool white lamp. It is very bright, but using a 2700° lamp in the same place gives a dismal, gloomy light. It is still 16 watts, but how many incandescent lamps should it have on the pack? It is all a matter of perception.

No-one seems to quote lumen output from GLS lamps (standard household bulbs). These vary enormously dependant on the construction of the filament and the coatings on the lamp in any case. A 60 W rough service lamp has a tough relatively cold filament that gives a yellow light, whilst the mushroom lamps so popular in the 1960s were fragile beyond belief and burned at a high temperature with a coiled coil filament. This gave a very white light compared to its predecessors.

Comparing wattage ratings between GLS, quartz-halogen, CFL, 'normal' fluorescent and other discharge lamps is a bit like comparing fruit, vegetables and bread. It is meaningless without colour temperature and total light output being compared.

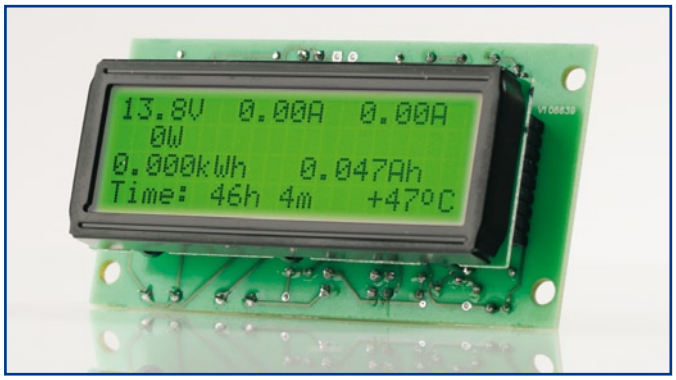
It would be far more helpful to insist on comparison of lumens per circuit watt, which would also include losses in the ballast. One almost unknown loss outside of the electrical fraternity is that suffered in standard iron cored ballasts used for standard fluorescent lamps with switch starters. These can add 15% or more to the tube rating, thus a traditional 40 W 4-foot (1200 mm) fitting actually used a total circuit power of nearer 50 watts, and whist the efficiency was far above that of a tungsten lamp, only recently have HF ballasts become the norm in traditional 'long' fittings.

I recently installed some new lamps in my garage, the tubes being rated at 58 W and the whole fittings claiming to be 59 W. The power factor is also close to 1 and so these are sui-

Power meter revisited

The author of the article on the versatile DC power meter, Oliver Micac, has generated an updated version of the software for the meter. The new version makes it possible to use the meter with 60-mV DIN shunts.

The new firmware is available on the website under the original article (look for item number 070559-11 under 'Versatile DC Power Peter' in the January 2008 issue).



Not a Summer Circuit

Okay — it's not a circuit; it's not even electronic but I think your readers might be interested in my Logic Goats.
http://www.flying-pig.co.uk/pagesv/logicgoat.html
Logic Goats are paper models

table for industrial use as well. They are soft-start, thus reducing inrush currents and have flicker-free start. The mains pollution emitted is low and they also offer possibly longer lamp life. This must be a step forward, but at the cost penalty of about twice that of a switch start unit. Contract electricians will not supply these until they are forced by legislation to use them. For me the cost penalty is not an issue for four units, but if I was supplying four thousand to a site, then offering the switch-start units would make the costing look better to the client.

Unfortunately the lamps are still a five foot long glass tube mounted on a metal box screwed to the ceiling, and we are back to the industrial look again.
What comes next? LEDs are looking promising. They are brighter by the week it seems and can be acceptable for some areas, but once more we are back to perceptions again.
The GU10/GZ10 240 V dichroic type halogen lamp can now be replaced with a CFL version or an LED version. The original tends to be either 35 or 50 watts and produces a typical tungsten light with about 30° spread. The CFL version is too big for most fittings and woefully dim but only rated at 7 or 9 watts. The lack of a realistic reflector makes the light output seem poor. The LED version is an incredibly bright, bluish-white but only offers about a 5° beam. White LEDs tend to have a limited life as well. They are really blue LEDs with a phosphor coating inside, and like fluorescent tubes, rely on this for their final colour. The light output diminishes fairly rapidly and after a year or so, a new white LED is dazzlingly bright compared to one that has been in use for the past 12 months.
All fluorescent lamps, compact or otherwise, use mercury vapour as the principle radiating component in the tube. When a current is passed through the tube the mercury vapour emits a high concentration of UV light. This is sometimes visible if the ends of the tube are not fully coated with phosphor powder, a blue glow can be seen inside the tube itself. The UV excites the phosphors that coat the tube, and cause it to glow. The colour temperature of the light emitted depends on the phosphor mix used, and can be a range of colours from daylight through to red or blue or even UV.
The great efficiency associated with standard fluorescent lamps came from the fact that the light was emitted over an exceptionally large surface compared to a filament lamp. This gave softer shadows, less glare and a greater distribution of light over a given area. The humble tungsten filament lamp, like its predecessor the candle, was effectively a point source. With the CFL we are back to a point source (relatively speaking) so it has to be intensely bright to give a reasonable light output, as do HID lamps. Similar reasoning applies to LEDs as well. Unfortunately this tends to give them a characteristic starkness and glare. Here we go again!
The energy debate will continue no doubt, but what is the environmental effect of the CFL now poised to replace the incandescent lamp? Disposal of large quantities of dead units may be an issue, as they all contain mercury and some exotic phosphors, typically rare earth and metallic phosphor salts. The cathodes (the heater bit that glows in a switch-start fitting) are made from tungsten wire coated with barium, strontium and calcium salts, and are similar in design to an electronic valve (tube) cathode, being designed for optimum thermionic emission at low temperatures. If these things ever do replace the simple GLS lamp, even at five times the life span there will be a lot of undesirable rubbish being dumped into the ground, and no doubt even more regulation will be needed to ensure that the lamps are re-cycled in a safe manner. This cost could be inflicted on the retailer or the manufacturer, putting up the price and making their use less attractive.
There is also the question of energy required to actually make, package and distribute these lamps. They may use one fifth of the energy in their life time, but how much energy is expended making each one in comparison to its more humble cousin?
The glass envelope is far more complex than a single bulb, and the electronics for the CFL ballast inevitably has to be made and built. Despite the maker's claims, the life of the CFL can be depressingly short, especially in the very compact designs that have a cooking hot ballast in the centre of the spiral fitting.

Are we in danger of moving the energy consumption and pollution generation from the end user to the manufacturing and disposal process, or like the electric car, from our cities to the power stations?

Andrew Denham (UK)

of working logic gates but in goat form — you can see a Youtube video of them in action here: www.youtube.com/watch?v=vu3o6JNclRQ
Best wishes

Rob Ives (Flying Pig)

In a word, brilliant! Everyone, put down your soldering irons and get out your scissors and cardboard.

The 'Dekatron' decimal counter valve (1)

Dear Sir — your magazine used to be good, unfortunately it swerves time and again to high-tech subjects. What good are FPGAs and microcontrollers to me when I can't get any use from them? To be able to follow your construction projects you need an academic degree and vast amounts of 'pocket money' to buy special parts and programming tools. That used to be different, and better, in the past.
For example, in your March 2008 issue you present the Dekatron counter valve with a schematic. Where, please, should normal people go to obtain, at a reasonable price, such parts declared obsolete decades ago? Kind of utopian, no? I am not so affluent as to spend my hard earned cash

on this grot. Not my cup of tea and I am cancelling my subscription.
G. Kratzin (Germany)

A bemusing response indicating that Mr Kratzin has missed the point about our Retronics articles entirely, see the footer printed with every instalment.

Anti-Standby Switch — a sequel on safety

Dear Editor —on your green standby switch project (January 2008, *Ed.*), a current transformer MUST always work into a very low impedance load. It is extremely dangerous to not have a low-value load resistor across the secondary, across which a small ac voltage is developed. So dangerous that some commercial current transformer manufacturers install the load resistor within the transformer module. Without such a load, under transient and high current events several thousand volts can be developed across the secondary as it tries to drive its secondary current into a non-existent load.

Without a load a CT looks like a voltage step-up transformer multiplying the 240VAC mains input being pushed through it. Only the saturation of the core limits the energy.
The secondary winding, load resistor and PCB must be rated for the divided down primary load current. For example if the primary is rated for 13 Amps and there is a 1:10 turns ratio then the secondary must be designed for a steady state current of 1.3 Amps and a peak current of say 5 Amps (typical domestic 0.2 second fault current is 50 Amps). Obviously with a low impedance load and suitable conductors the power dissipation is very small.

(name withheld at request of correspondent)

The designer, Thomas Scherer, replies

Dear Jan — I thank the correspondent for being so concerned about security issues. But in my eyes he is too concerned about this and misses the point in some way. Specifically, the rule he mentions is no law of nature. In fact this is pure theory which doesn't match the real circumstances. Especially transients may happen with every inductive load, with coils and ordinary transformers too. This is nothing special. But they do not occur at the high energy levels he mentions. Therefore this never is as dangerous as you believe — otherwise a big part of commercially produced electronic devices would be dangerous. What he has not considered really is the amount of energy a pulse can have which is provided by this little current transformer. Like you said: this energy is limited by the core of this transformer and therefore is not insignificant. Second, there is no 'no load' condition. Connected to the secondary coil of the current transformer is found a 10-k resistor in series with a 100-nF capacitor which has nearly zero ohms for transients. A transient pulse of 1 kV peak should produce a current of 0.1 A which equals a peak power of about 100 W (for some µs). This little transformer is never able to produce such a peak power. And if you still believe in your theory: I measured the voltages which occur at the secondary windings of the current transformer during shutting off currents of 10 A on the primary side. The result is that the maximum measured pulse peaks do not reach 20 V. Is this dangerous? Not even for the following opamp, I believe, because the voltage at the 100-nF capacitor never exceeds 1 V.
Lastly the correspondent is completely wrong in thinking that the parts at the secondary winding of the current transformer need to withstand 5 A peaks. This really really never will happen. This is a practical case of impossibility ;-) So I am really sure the PCB is totally safe and nobody can be killed but your theory of unsafety....
Dr. Thomas Scherer

The original correspondent replies

Dear Jan — as your contributor Thomas points out it is all a matter of coupling. The CTs I was working with were designed to accurately measure (to within a percent or so) the primary current (typically 300 A) and in that application had many thousands of secondary turns to scale the primary current down to an electronics-friendly few milliamps using a substantial core. I have seen capacitors and ICs explode off the board when a load of 1 ohm was inadvertently omitted and in once case a senior engineer was thrown the length of the test bay when a technician

perhaps deliberately removed the working load.
In this application the CT is mostly sensing any significant primary current. I do not fully accept that the capacitor is a load since its contribution would be out of phase. The transient I am concerned about is the switch-on surge of the connected appliance, which with modern switch mode power supplies can sometimes be as much as 50 A for the first cycle.
So-called power factor corrected PSUs sometimes have a lower in-rush current. Providing the core saturates at the odd amp or so the energy fed into the secondary is relatively small. Even so the 10 k resistor becomes a safety item, should this fail, downstream electronics would probably be damaged.
At one time we considered putting voltage limiters across the CT secondary but our Safety Committee could not resolve a satisfactory fail-to-safe mechanism and concluded that the reliability of a quality ohmic load was such that it far less likely to fail than the protection components proposed to protect the system should it fail. Every component was subject to such analysis which sometimes took weeks and sometimes needed experiments on live systems with induced failures.
Perhaps Elektor should publish a follow-up advising readers only to use the specified core and winding specification and not to substitute a genuine current transformer which is likely to have a very significantly higher coupling efficiency. Current transformers are very weird components that few readers are likely to have had experience of. Although I never had a shock or caused others to have a shock off them, what I have seen has made me very wary of such an innocent looking device!

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DEVELOPMENT TOOLS | COMPILERS | BOOKS

EasyPIC5 Development Board

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

Following tradition of its predecessor EasyPIC4 as one of the best PIC development systems on the market, EasyPIC5 has more new features for the same price. The system supports 8-, 14, 18, 20, 28 and 40 pin PIC microcontrollers (it comes with a PIC16F877A). **USB 2.0** on-board programmer with **mikroICD** (In-Circuit Debugger) enables very efficient debugging and faster prototype development. Examples in **C**, **BASIC** and **Pascal** language are provided with the board. **Touch screen** controller with connector is available on-board.

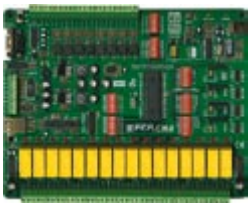
LV24-33 Development Board

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

System supports 64, 80 and 100 pins **PIC24F/24H/dsPIC33F** microcontrollers (it comes with PIC24FJ96GA010 - PIC24 16-bit Microcontroller, 96 KB Flash Memory, 8 KB RAM in 100 Pin Package). Examples in BASIC, PASCAL and C are included with(in) the system. You can choose between USB and External Power supply. **LV 24-33** has many features that make your development easy. **USB 2.0** on-board programmer with **mikroICD** (In-Circuit Debugger) enables very efficient debugging and faster prototype development.

PICPLC16B Development Board

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



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

EasyAVR5 Development Board

with on-board USB 2.0 programmer

The system supports **8, 14, 20, 28 and 40 pin** microcontrollers (it comes with ATMEGA16). Each jumper, element and pin is clearly marked on the board. It is possible to test the most of industrial needs on the system: temperature controllers, counters, timers etc. **EasyAVR5** is an easy-to-use Atmel AVR development system.On-board USB 2.0 programmer makes your development easy. Examples in **BASIC** and **Pascal** language are provided with the board.

EasyPSoC3 Development Board

with on-board USB 2.0 programmer

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

Uni-DS 3 Development Board

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

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

EasydsPIC4 Development Board

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

The system supports **18**, **28** and **40** pin microcontrollers (it comes with dsPIC30F4013 general purpose microcontroller with internal 12-bit ADC). **EasydsPIC4** has many features that make your development easy. Many of these already made examples in C, BASIC and PASCAL language guarantee successful use of the system. Ultra fast **USB 2.0** on-board programmer and **mikroICD** (In-circuit Debugger) enables very efficient debugging and faster prototype developing.

EasyARM Development Board

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

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

BIGAVR Development Board

with on-board USB 2.0 programmer

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

Easy8051B Development Board

with on-board USB 2.0 programmer

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

LV 18FJ Development Board

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

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

dsPICPRO 3 Development Board

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

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

BIGPIC5 Development Board

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

System supports the latest (**64**) and **80-pin** PIC microcontrollers (it is delivered with PIC18F8520). Many of these already made examples in **C**, **BASIC** and **Pascal** language guarantee successful use of the system. **Touch screen** controller with connector is available on-board. This development board has an on-board ultra fast on-board **USB 2.0** programmer, **mikroICD** (In-circuit Debugger) and integrated connectors for MMC/SD memory cards, 2 x RS232 port, RS485, CAN, on-board RTC, PS/2 connector, DAC etc...

mikroElektronika Compilers

Pascal, Basic and C Compilers for various microcontrollers

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

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

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

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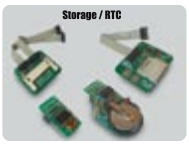
CAN-1 Board - Interface CAN via MCP2551.

CANSPI Board - Make CAN network with SPI interface.

RS485 Board - Connect devices into RS-485 network

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

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



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

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

EEPROM Board - Serial EEPROM board via I2C interface.

RTC Board - PCF8583 RTC with battery backup.

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

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

Keypad 4x4 Board - Add keypad to your application.

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

PICFlash

with mikroICD support

PICFlash programmer – an ultra fast USB 2.0 programmer for the PIC microcontrollers. Continuing its tradition as one of the fastest PIC programmer on the market, a new PICFlash with mikroICD now supports more PIC MCUs giving developer a wider choice of PIC MCU for further prototype development.
mikroICD debugger enables you to execute mikroC / mikroPascal / mikroBasic programs on the host PIC microcontroller and view variable values, Special Function Registers (SFR), memory and EEPROM while the program is running.

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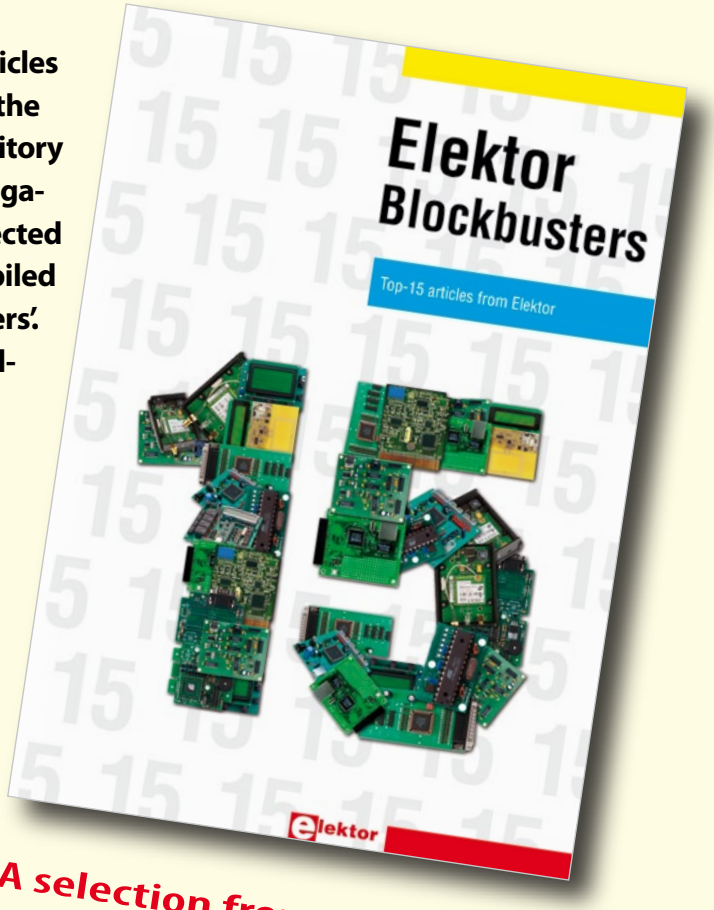
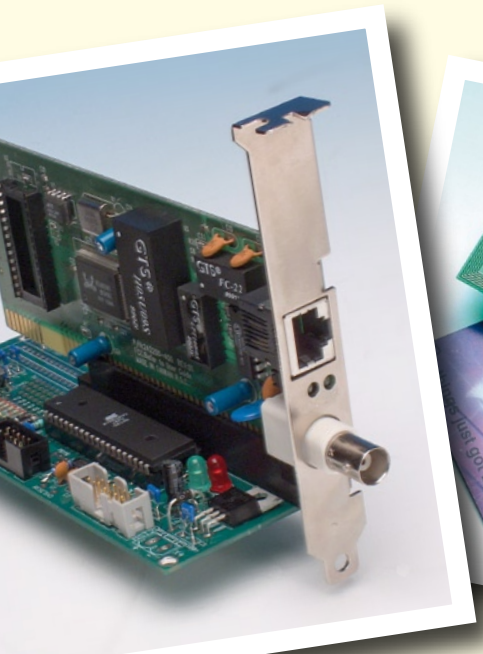


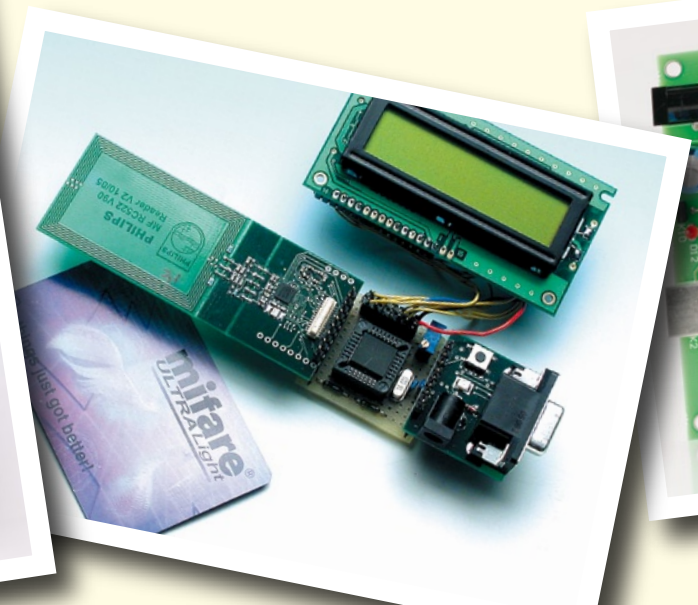
Elektor likes to do a little extra for its readers, like a CAD software CD-ROM or the 24-page 'tinker-away' i-TRIXX supplement in the centre of the December issue. Our subscribers enjoy the additional luxury of receiving, via the address carrier, advice on exclusive offers and discounts that together can add up to considerable savings. Now, we add a free e-book for all readers: '15 Elektor Blockbusters' — an exclusive collection of top ranking articles from recent Elektor issues.

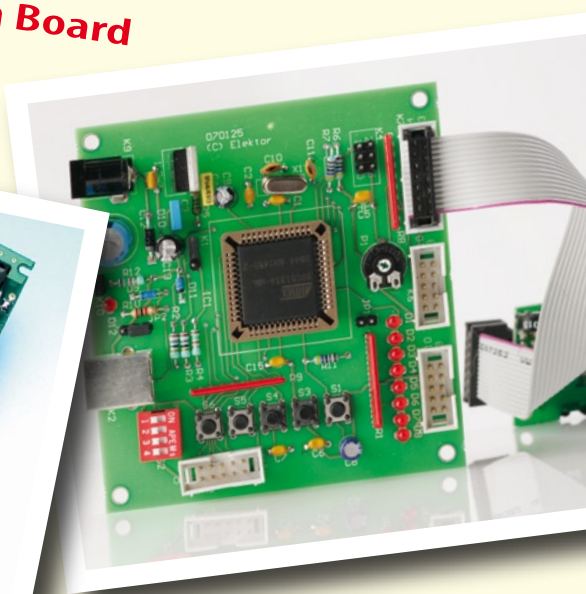
Getting your copy of the e-book is easy, fire up your Internet browser and go to www.elektor.com/ebook. As a registered user of the Elektor website you are just one click away from'15 Elektor Blockbusters'. No problem if you are not yet a registered user of our website. After a few easy steps you will receive your personal login data and then '15 Elektor Blockbusters' is also available to you for downloading.

A selection from the contents

- **Elektor RFID Reader**
- **Software Defined Radio**
- **Micro Webserver**
- **USB Flash Board**







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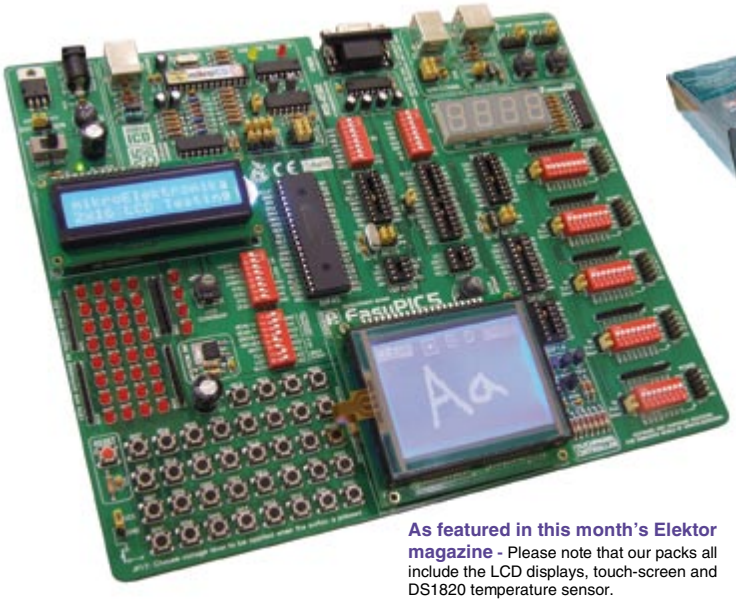
EasyPIC5 Starter Packs—everything needed to learn about and develop with PIC microcontrollers from only £99



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

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

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

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

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

UNI-DS3 Universal Development System

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

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

dsPICPRO3 Development System

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

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

PICPLC16B Control System

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

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

PoScope Multi-Function Instrument

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

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

LAP-16128U Logic Analyser

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

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

Leaper-48 Universal Device Programmer

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

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

Robo-PICA Robot Experiment Pack

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

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

NX-51 V2 Microcontroller Trainer

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

Other training systems available for microcontroller and electronics teaching.

IDL Series Circuit Labs

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

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USB Digitisers & Digital Multimeter

National Instruments has announced the release of the NI USB-5132/5133 digitisers and the NI USB-4065 6½-digit digital multimeter (DMM). These small, lightweight instruments feature bus-powered and plug-and-play operation, which makes them ideal for portable, benchtop and OEM applications. They are also shipped with NI LabVIEW SignalExpress LE, an interactive measurement workbench for quickly acquiring, analysing and presenting data, with no programming required.
The USB-5132/5133 50 MS/s and 100 MS/s digitisers offer two simultaneously sampled channels with 8-bit resolution. These USB digitisers feature 10 input ranges from 40 mV to 40 V and programmable DC offset, and come standard with 4 MB/ch of onboard memory for measurements requiring extended data captures. The USB-4065 DMM offers 6½ digits of resolution at up to 10 readings per second and up 4 MB/ch of onboard memory for measurements requiring extended data captures. The USB-4065 DMM offers 6½ digits of resolution at up to 10 readings per second and up to 3,000 readings per second at lower resolutions. With ±300 V of isolation, current measurements up to 3 A and 2- or 4-wire resistance measurements, the USB-4065 offers a complete multimeter solution for portable 6½-digit measurement needs.
Each of these instruments includes its own soft front panel, which provides an interactive, familiar interface to get up and running quickly. For data logging applications, engineers can easily combine the USB-5132/5133 digitisers or the USB-4065 6 ½-digit DMM with LabVIEW SignalExpress measurement software. Together, this intuitive software and the bus-powered architecture of these new instruments are extending the ease-of-use and performance of portable measurements.

www.ni.com/modularinstruments/usb

(080073-VII)

Verotec strengthens direct sales route and technical support

Verotec, the successor company to Vero Electronics and APW, announce that a new online shop will be launched on March 1st 2008. Well-known APW / VERO products such as KM6-II Subracks & Front Panels, Diplomat, LBX & Verotec Cases, Fan Trays, 19" rack cases and many others can now be purchased either directly or through the new on-line shop. Selected sizes from all ranges are also available from the leading pan-European catalogue distributors Farnell and RS Components.
Verotec standard products are available direct on short lead times with many popular items being available ex-stock. Customisation is a very common requirement for all types of sub rack and enclosure; Verotec's experienced technical support team are available to advise on the best product for any particular application and to provide quotations for custom versions. The intrinsic experience, knowledge base, tooling and production equipment availability normally means that Verotec is able to offer the most competitive price and lowest time to market for any standard enclosure configured to meet the project needs.
For 50 years, the name VERO has been synonymous with high quality electronics packaging. The majority of Verotec employees are ex VERO and APW; they have extensive knowledge and experience of the design, engineering, manufacturing and customisation of all the products. The traditionally high quality, fit and finish associated with the VERO name is being maintained and bettered; in-house technical and commercial departments provide support on all aspects of the product range.

www.verotecshop.co.uk

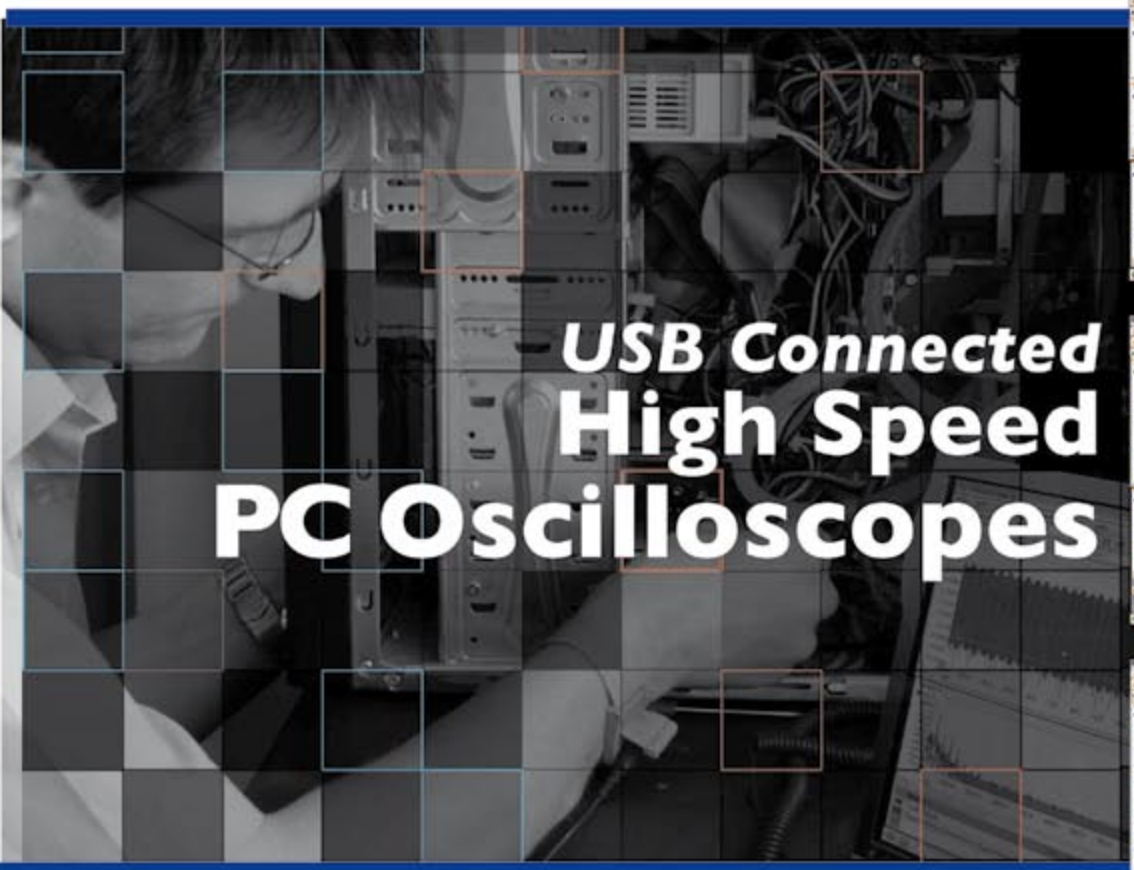
(080087-IX)

PS-900 soldering system

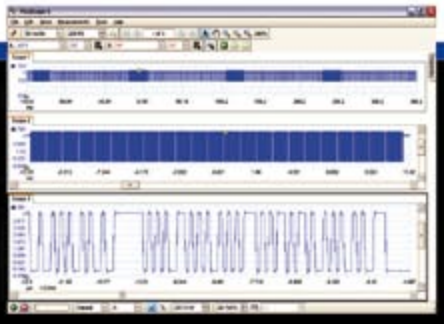
OK International has introduced the PS-900 Soldering System. Controlled and powered by SmartHeat® Technology, the PS-900 provides users with exceptional capability to solder high thermal demand applications including lead-free solders, multi-layer boards, and large mass components.
The PS-900 is a fixed temperature system that varies power to match the thermal demand of the device being soldered. SmartHeat® Technology provides an exceptionally fast response when under load while eliminating the potential for thermal overshoot. The result is a high quality solder joint formed at safe, controlled temperatures.
The PS-900 has a compact footprint power supply in a rugged, lightweight cast aluminum housing. The system includes an ergonomic soldering handpiece, an Auto-sleep Workstand for the soldering iron, and a temperature resistant tip removal pad.
Over 30 tip geometries are available in dimensions as small as 0.4 mm (.016") to 5 mm (.197"). This range of tips allows users to perform a wide variety of applications including single point soldering of through-hole and SMD leads, drag soldering SMD leads, touch-up and pad clean-up. All PS-900 tips employ the use of high plating thickness. This feature protects the tip from flux attack, therefore, prolonging tip life and lowering operating costs.
The Auto -Sleep workstand, which is unique to OK International, automatically reduces the tip temperature during idle periods, providing increased tip life. Moreover, with SmartHeat® Technology, the PS-900 does not require calibration. This eliminates costly down-time typically associated with conventional soldering systems.

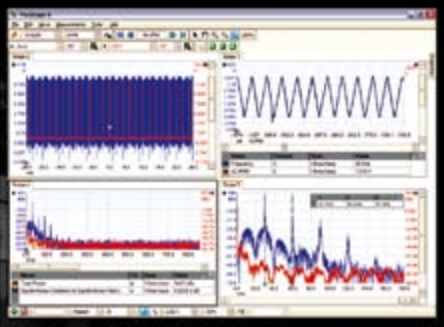
http://www.okinternational.com

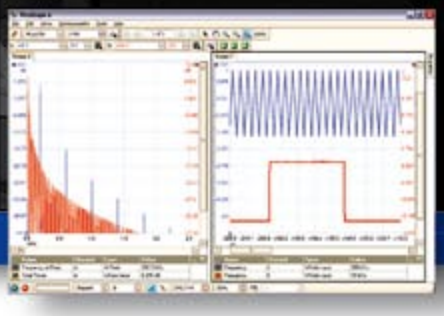
(080073-X)



USB Connected High Speed PC Oscilloscopes







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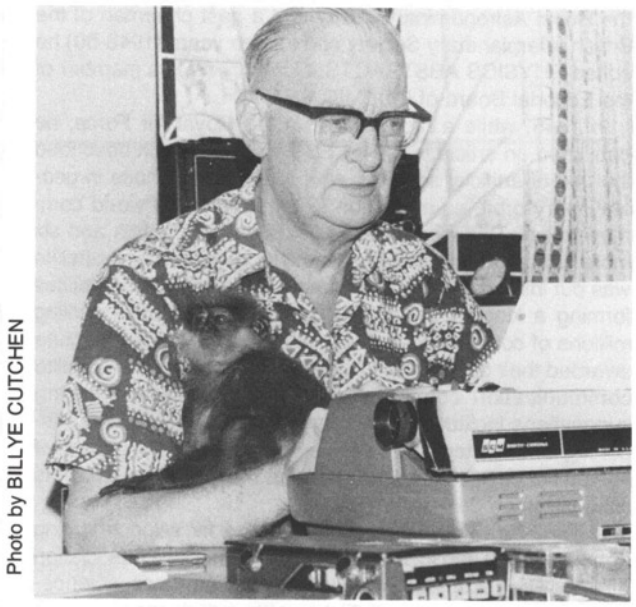
Remembering Sir Arthur C. Clarke

source: ITU News

Science fiction writer and visionary Sir Arthur C. Clarke died on 19 March 2008 in Colombo, Sri Lanka, at the age of 90. He was born on 16 December 1917 in Minehead, Somerset in the United Kingdom and moved to Sri Lanka; then called Ceylon, in 1956.

The international telecommunication community will remember Sir Arthur for making popular the concept of using the geostationary orbit for communications. In October 1945, Clarke published in the British magazine *Wireless World* a technical paper entitled „Extra-terrestrial Relays — Can Rocket Stations Give World-wide Radio Coverage?" The paper established the feasibility of artificial satellites as relay stations for Earth-based communications. Clarke predicted that one day communications around the world would be possible via a network of three geostationary satellites spaced at equal intervals around the Earth's equator.

Nearly two decades later, in 1964, Syncom 3 became the first geostationary satellite to finally fulfil Clarke's prediction. Later that year, Syncom 3 was used to relay television coverage of the Summer Olympic Games in Tokyo to the United States — the first television transmission over the Pacific Ocean. Now, there are hundreds of satellites in orbit and providing communications to millions of people around the globe. In 1954, Clarke had also proposed using satellites in meteorology. Today, we cannot imagine predicting the weather without using dedicated meteorological satellites.



Clarke and friend.

Looking back on these developments, in his book *How the World Was One — Beyond the Global Village*, published in 1992, Clarke wrote: „Sometimes I'm afraid that you people down on Earth take the space stations for granted, forgetting the skill and science and courage that went to make them. How, often do you stop to think that all your long-distance phone calls, and most of your TV programmes are routed through one or the other of the satellites? And how often do you give any credit to the meteorologists for the fact that weather forecasts are no longer the joke they were to our grandfathers, but are dead accurate ninety-nine percent of the time?"

Clarke wrote more than 80 books involving science, and science fiction. His short story *The Sentinel* served as the basis for Stanley Kubrick's 1968 film *2001: A Space Odyssey*. His other famous works include *The Exploration of Space*, *The Promise of Space*, *The Fountains of Paradise*, his semi-autobiographical novel *Glide Path*, and *Childhood's End*. Before his death, Clarke had just reviewed the manuscript of his latest novel, *The Last Theorem*.

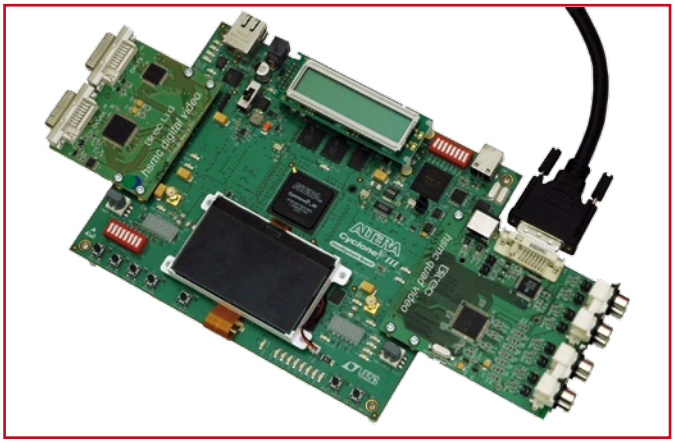
(080144-IX)

Altera & Bitec: next-generation video system development

Altera and Bitec Ltd. jointly announced the availability of a video development kit that enables designers to rapidly develop and prototype high-performance, cost-sensitive video applications. At the heart of the kit are Altera's Cyclone® III FPGAs, which are an ideal video processing platform given the device's large parallel processing capabilities with up to 288 multipliers, 4-Mbit embedded memory blocks, and low power consumption. The kit supports multiple video I/O formats, allowing video application developers to quickly develop, debug, and prototype designs using their lab video signals and displays.

The video development kit features a Cyclone III development board with two high-speed Mezzanine Connector (HSMC)-based video interface daughtercards developed by Bitec. The kit supports composite, S-video, DVI and RGB video and contains:

- Cyclone III EP3C120F780 development board
- Quad-Video HSMC daughtercard (8 composite or 4 S-Video inputs)
- DVI HSMC daughtercard and DVI cable
- Quartus® II Web Edition software
- Access to Altera® OpenCore Plus evaluation intellectual property (IP) megafunctions including the Video and Image Processing (VIP) Suite
- A CD-ROM with a video mosaic reference design developed by Bitec



The Cyclone III FPGA-based video development kit is currently available exclusively through Bitec. Interested customers can find additional information about the kit and general technology at the websites below.

www.bitec.ltd.uk/ciii_video_dev_kit.html.
www.altera.com/devkits
www.altera.com/products/ip/dsp/image_video_processing/m-alt-vipsuite.html

(080144-VI)

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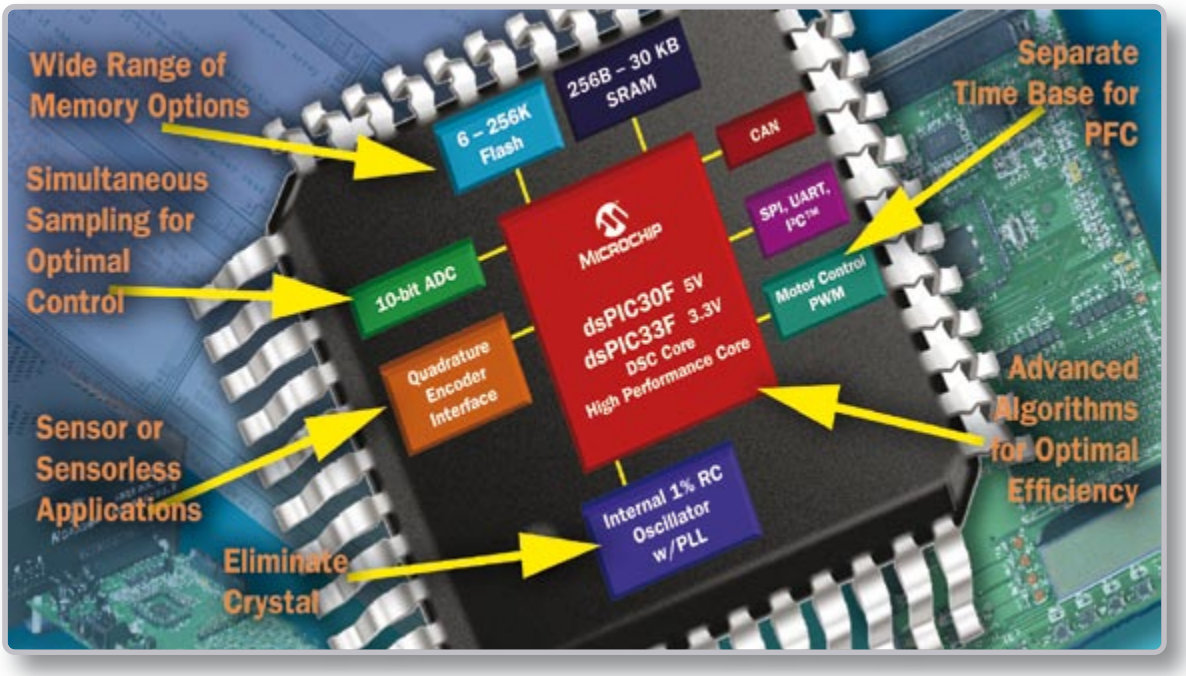

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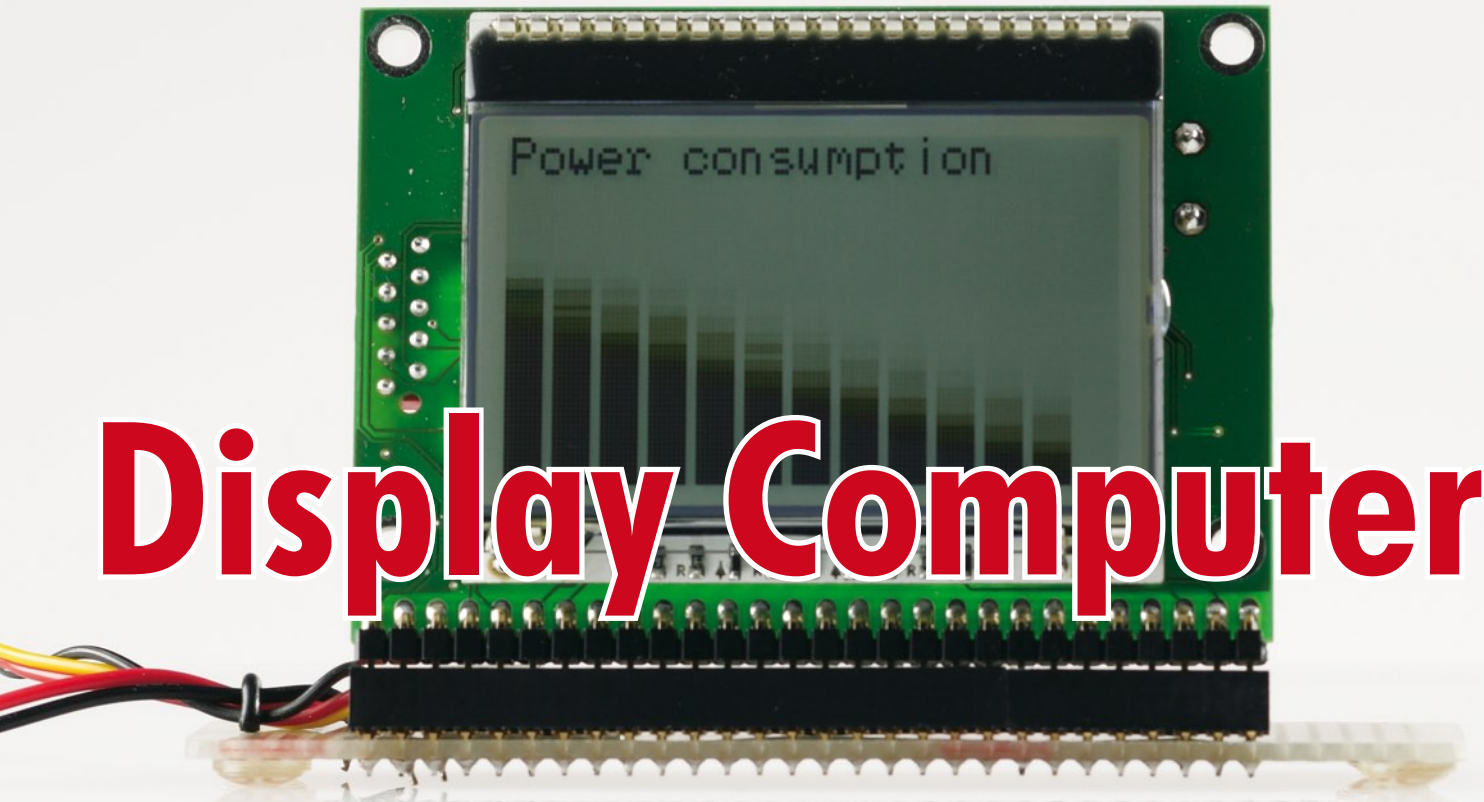


Display Computer

M16C mini board with graphics, programmable in C and Basic

The prices of graphic displays are dropping, which makes them increasingly attractive for many applications. However, programming a graphic display is distinctly more difficult than programming a text display. Our mini microcontroller board features a new display-on-glass module and a high-performance Renesas M16C microcontroller. The board is available fully assembled, and the microcontroller is pre-loaded with a TinyBasic interpreter to simplify the development of graphics applications – even for novices.

Dr Uwe Altenburg

There are countless applications for a stand-alone microcontroller board with a graphic display – everything from model railways or regulating the temperature in your home or conservatory to robotics.

However, driving the display and programming the associated microcontroller are tasks that exceed the skills of quite a few beginners. For this reason, in this article we present a ready-made board equipped with a display, a high-performance 16-bit microcontroller, and even a Basic interpreter [1].

The powerful M16C – the big brother of the R8C, which is well known to many of our readers – can also be programmed in C just like any other microcontroller, so advanced users have plenty of opportunity to develop their own applications. In any case, you can take advantage of features such as 128 kB of flash memory, a 10-bit ADC, PWM signal generation and much more, which make this mini board a truly versatile module.

Display

Electronic Assembly has released a novel 'display on glass' module with the part number EA-DOGM128, which is driven via an SPI interface [2]. This interface can be clocked at up to 20 MHz, so data transmission is not a significant bottleneck. Data is only transmitted in one direction here (from the microcon-

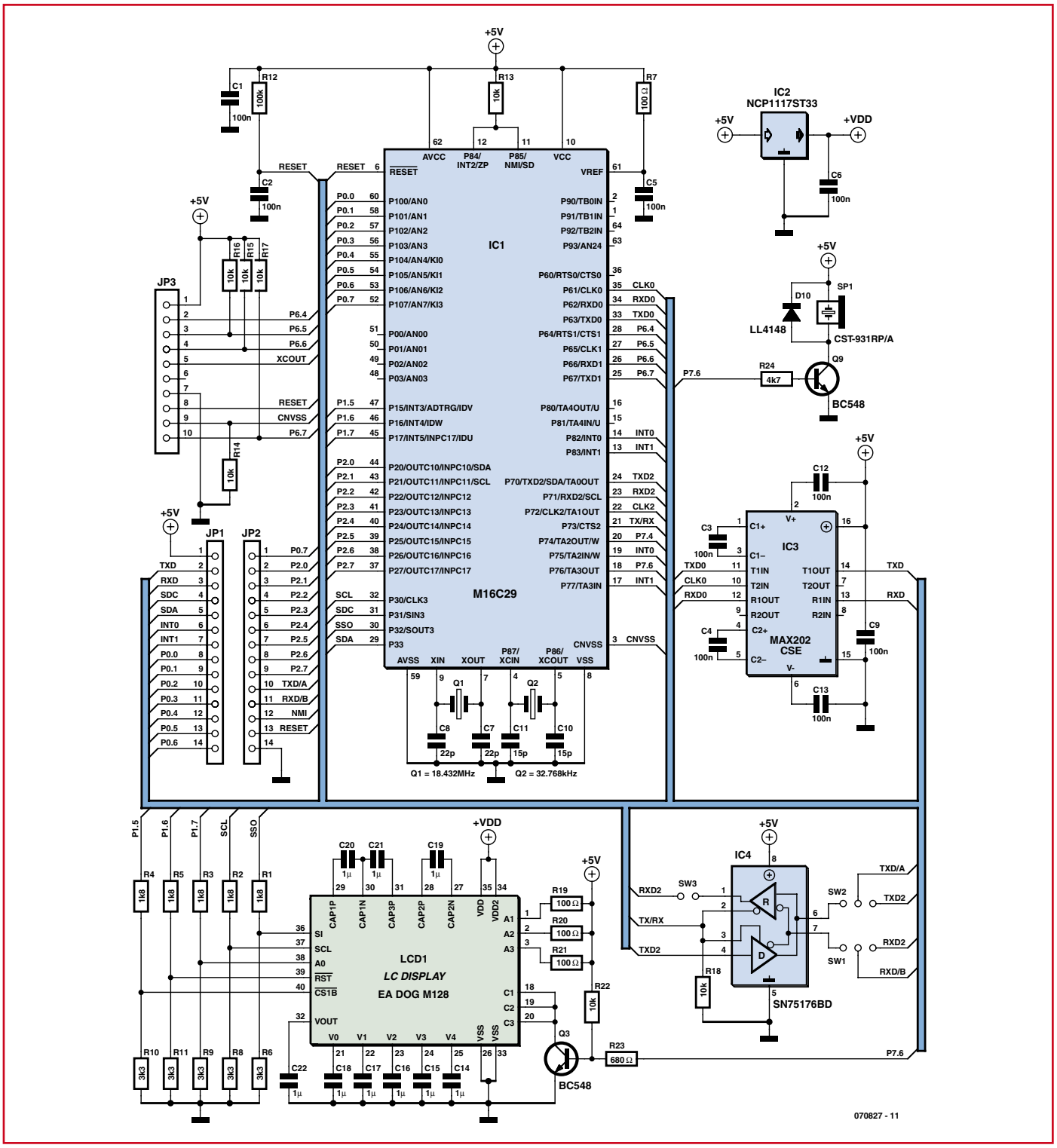


Figure 1. The circuitry around the M16C is relatively uncomplicated.

troller to the display), so only two signal lines are necessary. All in all, only five microcontroller I/O pins are needed – two for the data lines and three for the control lines (RESET, /CS and DATA). The display also features a very low profile of only 5.8 mm. The integrated LED backlight and automatic contrast adjustment ensure good legibility under all conditions, combined with low current consumption. Thanks to its pin-header contacts spaced at 2.54 mm, the module is easy to fit on a PCB. And on top of all this, it is available in several colour combinations (e.g. from Reichelt Germany [3]).

Microcontroller

Our search for a suitable microcontroller led us to choose the Renesas M16C28/29 [4]. This 16-bit machine has an impressive array of features. With 128 kB of flash program memory, 4 kB of flash data memory and 12 kB of RAM, it is generously endowed with storage capacity. Although the display has its own graphic memory, the data for the display must still be assembled in the microcontroller. A monochrome display with a resolution of 128 × 64 pixels requires an image memory of 1 kB in the microcontroller for this purpose (128 × 64 ÷ 8). The M16C28/29 has two DMA channels, so data can be copied directly from the image memory to the display without imposing any significant load on the microcontroller.

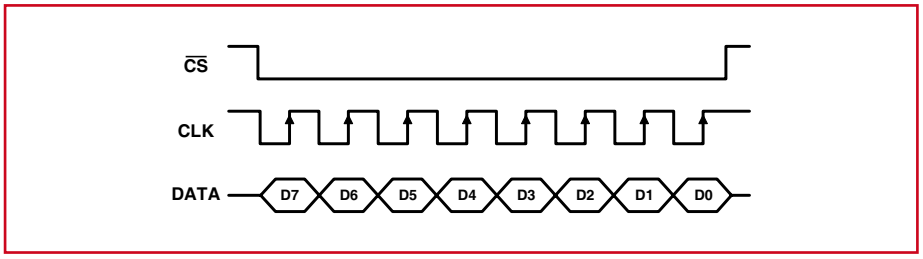


Figure 2. The data transferred via the SPI link is clocked into the display on the rising clock edge.

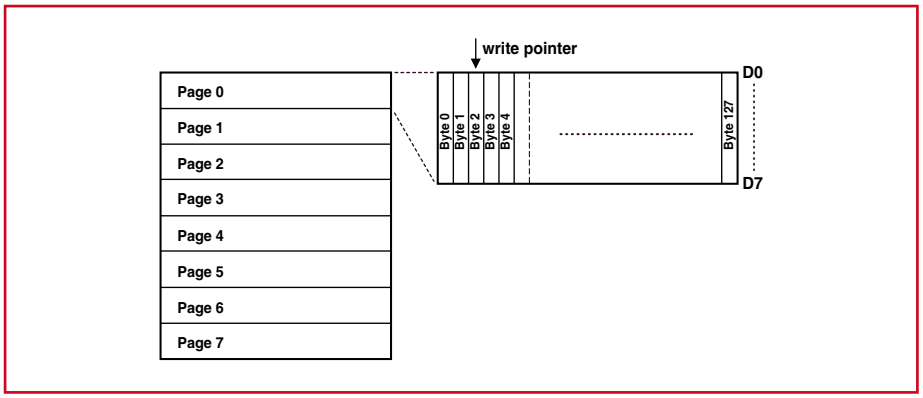
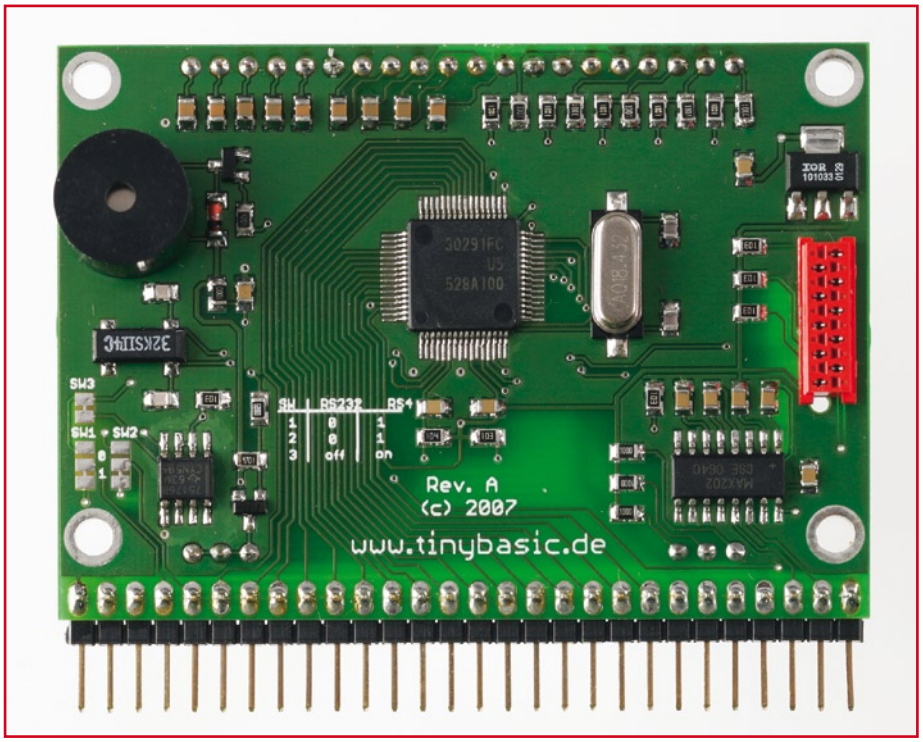


Figure 3. The image memory structure of the display.

Naturally, this little powerhouse in its 64-lead P-LQPFP package also has a lot more to offer. Along with a 10-bit ADC with 16 input channels, it has several timer units, one of which can generate up to eight PWM signals with a resolution of 16 bits. There is an SPI interface for the display (of course), as well as two UARTs available for user-defined functions. A third UART is used for the ISP/debug interface.

Without wishing to revive the old debate on the relative merits of RISC and CISC architectures, we can simply mention here that the instruction set of this CISC processor is extremely efficient. The instruction execution time is only 50 ns with a 20 MHz clock. Several registers can be saved on the stack at the same time with a single assembly-language instruction when an interrupt routine is called. This results in extremely short interrupt response times. For information on other features, such as clock generation using a PLL, we suggest that you consult the datasheet.



Circuit

The schematic diagram of the circuit (**Figure 1**) is relatively uncomplicated. It is built around an M16C29 microcontroller (IC1) with a minimum of peripheral components. The Reset input manages nicely with a simple RC network (R12/C2). The primary clock signal is generated using an 18.432-MHz crystal (Q1). The microcontroller has a specified maximum clock frequency of 20 MHz. Given the capabilities of the internal dividers and the requirement to have the serial interfaces support all standard baud rates from 300 to 115,200 baud, the maximum clock frequency that can be used is 18.432 MHz. However, the SMD crystal used here is a standard component.

In the interest of maintaining a low profile, the display is soldered flush against the surface of the circuit board. All other components are mounted on the solder side. This means that SMD components must be used (with a few exceptions). This applies to the second crystal as well (Q2), which operates at 32.768 MHz to provide a secondary clock signal. There are essentially two situations in which the secondary clock can play a role. The first is when a timer is programmed to act as a real-time clock, for instance in order to trigger a low-priority interrupt once per second. Alternatively, the secondary clock can be used in place of the primary clock in order to operate the microcontroller with the lowest possible power consumption.

A 10-way MicroMatch connector is used for programming and debugging the microcontroller. The signals available on this connector correspond to the signals needed by the Renesas E8 emulator for this type of microcontroller. The Renesas emulator is available from Reichelt [3], among other sources, but it can also be obtained from Rutronik or Glyn along with an evaluation board. The emulator is accompanied by a very good C compiler, which

can handle a code size of up to 64 kB in the free version.
But that's not all: for the C fans among our readers, the next issue of *Elektor* will have an article describing a small circuit that lets you program the microcontroller without using purchased hardware. All you actually need to flash into the M16C is a serial interface and a few freely downloadable tools (for example, from Renesas), and many readers are probably already familiar with them from the R8C 'Tom Thumb' project.

Display power

The display (LCD1) requires only a single supply voltage of 3.3 V. The microcontroller can be operated at 3.3 V or 5 V. As the display module is intended to be used in other circuits, we decided on a supply voltage of 5 V.

A supplementary low-drop 3.3-V voltage regulator (IC2) generates the supply voltage for the display. Simple voltage dividers (R1–R10) are used to adjust the levels of the signals from the microcontroller to the levels required by the display. Here the fact that the display is driven by only five lines, and only in one direction, is a distinct advantage. It keeps the amount of hardware necessary for level adjustment within reasonable limits.
The display microcontroller (an ST7565) needs higher internal voltages to drive the LCD segments. For this purpose, a set of external capacitors (C14–C21) must be connected to its integrated charge pump circuit.

The LEDs for the display backlight are driven via series resistors R19, R20 and R21 and a simple transistor stage (Q3). The display illumination is always on unless it is programmed otherwise. In the simplest case, the illumination can be switched on and off under software control. However, the I/O pin used for this purpose (P7.4) can also be programmed as a PWM output to provide a conveniently adjustable brightness level under software control.
One of the two free serial interfaces is connected to one of the 14-way headers via an RS232 level converter (IC3, a MAX202). This interface can be used for connection to a PC or a modem. The TinyBasic interpreter, which is described later on in this article, also uses this interface for downloading program code. (Note: if you're not afraid of a bit of soldering work, you can tap off another V24 signal from the T2OUT pin of the MAX202 – see the schematic diagram.)
The second serial interface can be connected to the header either directly or indirectly via an RS485 level converter by suitable configuration of jumpers SW1, SW2 and SW3. This means that the module can also be connected to a network and share a bus with other microcontrollers.

Listing 1. Display initialisation
(Data types used: BYTE = 8 bits unsigned, WORD = 16 bits unsigned, INT8 = 8 bits with sign, INT = 16 bits with sign, LONG = 32 bits with sign)

```
// --- Init sequence ---
const BYTE InitList[] =
{
        0x40,                                   // start line
        0xA1,                                   // normal layout
        0xC0,                                   // normal COM0..63
        0xA6,                                   // normal display
        0xA2,                                   // set bias 1/9
        0x2F,                                   // booster regulator on
        0xF8,0x00,                              // booster to 4x
        0x27,0x81,0x16,                         // set contrast
        0xAC,0x00,                              // no indicator
        0xAF                                    // display on
};

// --- Init display ---
void InitDisplay()
{
        BYTE nCmd;

        LCD_CS = 1;                             // no chip select
        LCD_RES = 0;
        Sleep(50);                              // 50ms reset delay
        LCD_RES = 1;
        Sleep(50);                              // 50ms power-up delay

        LCD_MODE = 0;                           // command mode
        for (nCmd = 0; nCmd < sizeof(InitList); nCmd++)
        {
                SPISend(InitList[nCmd]);        // send cmd
                Sleep(1);                       // wait 1ms
        }
}
```

Drive logic

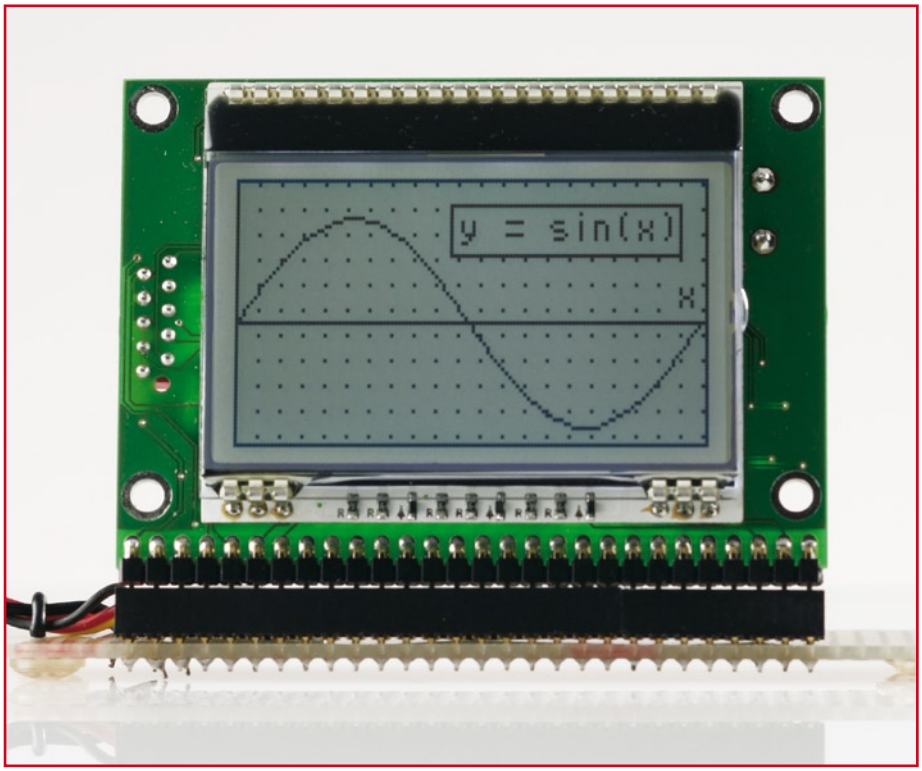
Now let's turn our attention to the graphic display. The SPI interface is

Listing 2. Page copying

```
// --- Copy a single page ---
void CopyPage(BYTE nPage)
{
        BYTE nPos;

        LCD_MODE = 0;                           // command mode
        SPISend(0x40);                          // memory base
        SPISend(0xB0 + nPage);                  // select page
        SPISend(0x00);                          // col low
        SPISend(0x10);                          // col high

        LCD_MODE = 1;                           // data mode
        for (nPos = 0; nPos < 128; nPos++)      // copy page
                SPISend(Pixels[nPage][nPos]); // send byte

        LCD_MODE = 0;                           // command mode
        SPISend(0xE3);                          // send nop
}
```

operated in Mode 0, which means that the data is clocked into the display on the rising edge of the clock. The timing diagram for this is shown in **Figure 2**. The individual data bytes are transferred to the display sequentially using this clocking scheme. In the code examples, the SPISend() routine is called for this purpose (see **Listing 1**).
The display must be initialised before any image data is sent to it. The routine that does this is called InitDisplay(). This routine sends several commands after the Reset pulse and a short startup time delay. The A0 line of the display must be held low while the commands are being transferred. Consult the data sheet for the display microcontroller (ST7565) for the specific functions of the individual commands. The sequence of commands shown in Listing 1 is designed to initialise the display to an operational state.
The next question is how to send image data to the display. To answer this question, you first have to understand how the image memory of the display is organised. The EA-DOGM128 is divided into eight sections called 'pages'. Each page consists of a 128×8 array of pixels. This means that each page needs 128 bytes. The top left pixel corresponds to bit 0 of the first byte of the top page.

The display has a write pointer in addition to the image memory (see **Figure 3**). The write pointer can be set to a specific position in a page by sending commands to the display. All data bytes sent after this are written to the image memory starting from this position. The write pointer is incremented automatically during this process.
Naturally, each data byte modifies eight pixels at the same time. Modifying a single pixel is thus not possible, and it would anyhow not be especially efficient. Instead, a copy of the image memory is maintained in the microcontroller, and it is also organised in pages. This can be achieved by declaring a suitable variable: BYTE Pixels[8][128]. All drawing operations are performed directly on this internal image memory. This simplifies the graphics routines, and it is significantly faster.
Of course, the internal image memory must be copied periodically to the display. In the simplest case, this can be done by an interrupt routine that copies only one page at a time to the display. The CopyPage() routine first sends several commands to the display to set the write pointer to the start of the page to be copied. After this, the page data is sent to the display, and the process is terminated by a NOP command (see **Listing 2**).
At a data rate of 1 Mbit/s, the copy process takes approximately 1.1 ms.



Listing 3. Pixel setting

```
// --- Set a single pixel ---
void SetPixel(BYTE x,BYTE y)
{
        if (x < 128 && y < 64)                  // clip
        {
                BYTE nPage = y / 8;             // calc page
                BYTE nMask = 1 << y % 8;        // calc mask

                Pixels[nPage][x] |= nMask;      // set pixel
        }
}
```

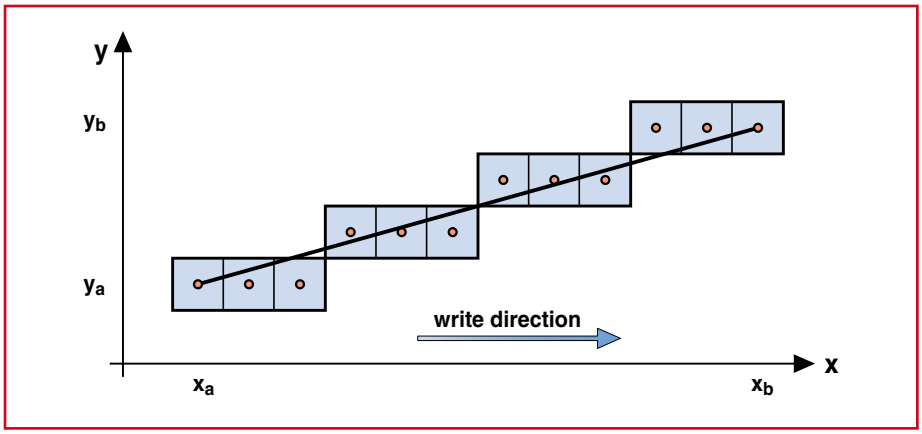


Figure 4. The Bresenham algorithm constructs lines as sequences of adjacent pixels. Here three steps in a straight line are followed by a diagonal step (see Listing 4).

If the interrupt routine is called every 10 ms, it takes around 80 ms to transfer a full image. Naturally, it is only necessary to copy the pages where changes have actually occurred. For this purpose, a 'Dirty' flag is maintained for each page. It is set by the graphics routines. The alternative 'high-end' solution is to use a DMA channel for the page data.

Listing 4. Line from point A(ax,ay) to point B(bx,by)

```
// --- Draw a line ---
void DrawLine(BYTE ax,BYTE ay,BYTE bx,BYTE by)
{
        INT  x  = (INT)ax;                      // start
        INT  y  = (INT)ay;
        INT  dx = (INT)bx - ax;                 // distance
        INT  dy = (INT)by - ay;
        INT8 sx = 1;                            // step width
        INT8 sy = 1;

        if (dx < 0)                             // x orientation
        {
                sx = -1;
                dx = -dx;
        }

        if (dy < 0)                             // y orientation
        {
                sy = -1;
                dy = -dy;
        }

        if (dy <= dx)                           // select direction
        {
                INT c = 2 * dx;
                INT m = 2 * dy;
                INT d = 0;

                while (x != bx)                 // draw in x direction
                {
                        SetPixel(x,y);          // set pixel

                        x += sx;                // step x
                        d += m;

                        if (d > dx)
                        {
                                y += sy;
                                d -= c;
                        }
                }
        }
        else

        {
                INT c = 2 * dy;
                INT m = 2 * dx;
                INT d = 0;

                while (y != by)                 // draw in y direction
                {
                        SetPixel(x,y);          // set pixel

                        y += sy;                // step y
                        d += m;

                        if (d > dy)
                        {
                                x += sx;
                                d -= c;
                        }
                }
        }
}
```

Graphics programming

Now that you know how to connect and program the EA-DOGM128, you might think that you're all set – but in fact you're just getting started. Here we want to talk about drawing line and circles, which is not as simple as it seems.
Of course, the first thing you need is a routine for setting the values of individual pixels, which goes by the name SetPixel(x,y) – see **Listing 3**. As the image memory is virtually located in the RAM of the microcontroller, the routine only has to set the right bit. One of the most important tasks in this connection is range checking, as otherwise it would easily be possible to set bits that have nothing at all to do with the image.

When you hear the term 'straight line', you may well recall the standard algebraic formula for a straight line: $y = ax + b$. It can be used to calculate the y value of a straight line for all possible values of x. This is a good initial approach, but it requires very precise calculation of the factors, in particular the slope a ($\Delta y/\Delta x$), and even with a precise calculation the formula for a straight line results in a broken line if the slope is steep, due to the quantisation of the x values.
Avoiding the need for floating-point arithmetic another is another factor that makes revisiting the 'stone age' of computer technology worthwhile. At that time, clever approaches were often devised to compensate for low processing power – something that seems to neglected more and more these days. In the 1960s, Jack Bresenham was working at IBM on graphic output for plotters, and around 1962 he developed an algorithm that bears his name: the Bresenham algorithm [5a][5b] – see **Figure 4** and **Listing 4**. Even now, 40 years later, this algorithm is just as important as ever.

Lines and circles

The Bresenham algorithm first considers only straight lines with slope $0 < a < 1$ (first octant). The line is drawn by processing the x coordinates incrementally starting from the initial point and deciding for each point

whether the *y* coordinate should be increased. The *y* coordinate is increased if the error relative to the straight line is greater than half a pixel.
The error is calculated for each step in a manner that only requires an integer comparison. Finally, the algorithm can be applied to the other seven octants by mirroring or by reversing the direction of drawing. This yields a very fast and exact line-drawing algorithm. The Bresenham algorithm can also be used to draw circles and ellipses, which avoids the need to calculate sine and cosine values. A suitable listing can be downloaded from the Elektor website [6].

TinyBasic interpreter

As mentioned above, the microcontroller used here has enormous potential, including a relatively large memory capacity, analogue inputs, and a variety of interfaces. It would be a sin to use this potential for nothing more than driving the display. To make it even easier for novice programmers to create their own graphic applications, the author has developed a Basic interpreter.

Programs can be generated using a convenient PC-based text editor that highlights keywords in colour (**Figure 5**). The program code can then be downloaded directly to the flash memory of the microcontroller, where it will be launched immediately when the module is switched on.
An overview of the language and the available commands is available online [1]. Naturally, it supports conditional branching and loop commands, as well as mathematical functions such as SIN(), COS(), EXP() and LOG(). There are also commands for graphic output (PLOT, MOVE, DRAW, COLOR, FRAME, CIRCLE, PICTURE, BARGRAPH) and for accessing the hardware (POKE, PAUSE, SOUND, SETCOM, SETPWM, SETPORT, SETCLOCK, SETDRIVE, SETKEYPAD, SETDISPLAY, SETNETWORK, SETCOUNTER, SEND, RECV, I2CIN, I2COUT, and SPISHIFT).
As an example, up to eight R/C servos could be connected to the module, which is enough for a small walking robot with facial expressions and gestures.

A sample application…

As a sample application to get you started, here we describe how to use

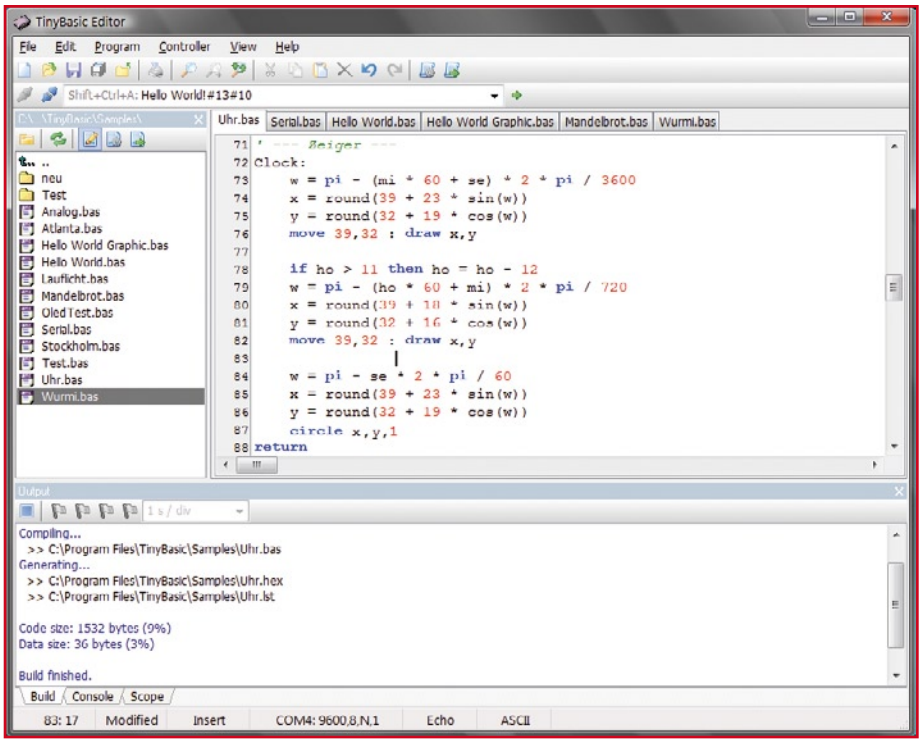


Figure 5. The PC-based text editor provides a convenient development environment for Basic programs.

Listing 5. Analogue clock in TinyBasic (excerpt)

```
' --- Definitions ---
#define BTN1_PRESSED   (port0.5 = 0)          ' Button 1
#define BTN2_PRESSED   (port0.6 = 0)          ' Button 2
#define BTN3_PRESSED   (port0.7 = 0)          ' Button 3
#define BACKLIGHT       port7.4               ' LCD backlight
#define T20SEC          20000                 ' Backlight time

' --- Hardware ---
setdisplay LCD_DOGM128x64                     ' Display type
setclock REAL_CLOCK                           ' Real-time clock
setport 7,$10                                 ' Backlight output
setport 0,0,$E0                               ' PB switch pull-ups

' --- Variables ---
float w,t0,t1
byte  ho,mi,se,da,mo,ye,x,y
byte  Icon[18]

' --- Init ---
BACKLIGHT = 1                                 ' Backlight on
Timer0 = T20SEC                               ' Start timer

gosub Scale                                   ' Draw clock face

' --- Main loop ---
do
        if BTN1_PRESSED or BTN2_PRESSED or BTN3_PRESSED then
                Timer0 = T20SEC               ' Start timer
                BACKLIGHT = 1                 ' Backlight on
        elsif Timer0 = 0 then
                BACKLIGHT = 0                 ' Backlight off
        endif

        if Time.Second <> se then             ' New second
                gosub UpdateTime              ' Update time
                gosub UpdateTemp              ' Display temperature
        endif
```

the module to make an analogue clock with an integrated display of the indoor and outdoor temperature. This requires a small amount of additional circuitry for measuring the temperature in a suitable manner.
A temperature-dependent current source, such as the AD592, can be used as the temperature sensor. The advantage of this sensor is that it has a linear characteristic. You only have to connect a 10-kΩ resistor in series with the sensor in order to covert the current into a temperature-dependent voltage with a scale factor of 10 mV/K (see **Figure 6**). Unfortunately, this sensor is relatively expensive. As an alternative, you could construct a similar circuit using the more economical LM344 sensor.

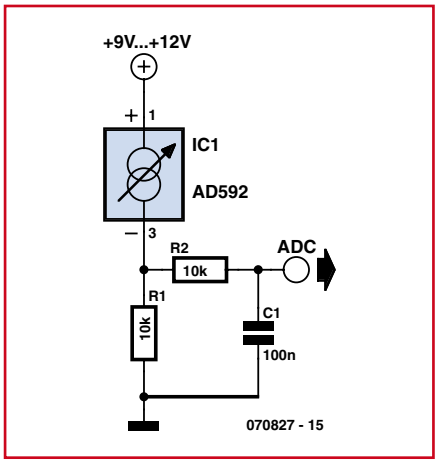


Figure 6. This additional circuitry can be used for temperature measurement.

The AD592 supplies a current of 273 μA at a temperature of 0 °C. This results in a voltage of 2.73 V across the resistor. The analogue inputs (in this case P0.0 and P0.1) have a resolution of 10 bits, which means they supply values in the range of 0 to 1023. The currently measured temperature can be calculated using the simple formula 'temp = (analogue_value – 559) ÷ 2.04'.
Naturally, the previously described routines for lines and circles can be used for the analogue clock display. The sin() and cos() functions must be used to calculate the positions of the hands. TinyBasic provides these trigonometric functions (and others) – see **Listing 5**. As this is supposed to be an analogue clock, the hands should of course move smoothly. For this reason, the positions of the hour and minute hands are interpolated. This gives the impression of continuous motion. The second hand is represented by a small circle, which is more a question of design than necessity.

…and your own applications

If you buy the display board from the Elektor Shop, you receive a fully assembled and tested module. The TinyBasic interpreter is already installed in the microcontroller. The Basic development environment can be downloaded from the Elektor website [6] free of charge, along with additional examples and listings.

For beginners, we have also put together a step-by-step guide that describes how to install the necessary software on the PC and how to download your own application.

(070827-1)

```
loop

' --- Clock face ---
Scale:
        frame 0,0,127,63                        ' Draw frame
        circle 39,32,29,25                      ' Draw clock

        for w = 0 to 2 * pi step 2 * pi / 12
                x = round(39 + 25 * sin(w))
                y = round(32 - 22 * cos(w))
                plot x,y
        next

        for w = 0 to 2 * pi step 2 * pi / 4
                x = round(39 + 26 * sin(w))
                y = round(32 - 23 * cos(w))
                plot x,y
        next
return

' --- Hands ---
Clock:
        ' Hour hand...
        w = pi - (mi * 60 + se) * 2 * pi / 3600
        x = round(39 + 23 * sin(w))
        y = round(32 + 19 * cos(w))
        move 39,32 : draw x,y

        ' Minute hand...
        if ho > 11 then ho = ho - 12
        w = pi - (ho * 60 + mi) * 2 * pi / 720
        x = round(39 + 18 * sin(w))
        y = round(32 + 16 * cos(w))
        move 39,32 : draw x,y

        ' Second hand...
        w = pi - se * 2 * pi / 60
        x = round(39 + 23 * sin(w))
        y = round(32 + 19 * cos(w))
        circle x,y,1
return
```

Web Links

[1] www.tinybasic.de/

[2] www.electronic-assembly.de/deu/dog/dog.htm

[3] www.reichelt.de/ (in German)

[4] www.m16c.de/

[5a] http://en.wikipedia.org/wiki/Bresenham_algorithm

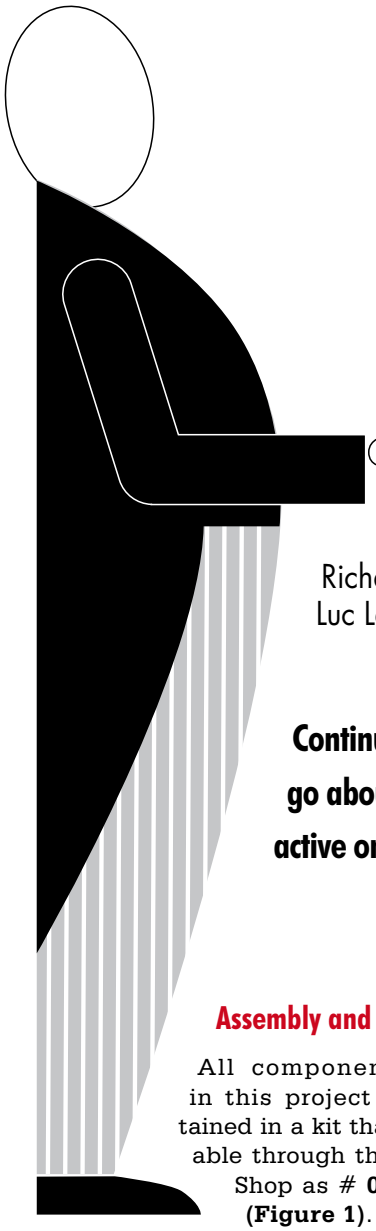
[5b] http://www-lehre.inf.uos.de/~cg/2002/skript/node30.html (in German)

[6] www.elektor.com

Component availability notice

Ready assembled and tested board including display and pre-programmed microcontroller (bootloader and Basic Interpreter) available from the Elektor Shop, order code 070827-91.

Bare PCB, ref. 070827-1 available from www.thepcbshop.com.



assembly, test and software

DigiButler (2)

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

Continuing on from the April 2008 issue, in this the second and final part of the article we go about assembling the kit and connecting up the hardware and software to get DigiButler active on the web and in control of an electrical appliance in your home or office.

Assembly and test

All components used in this project are contained in a kit that's available through the Elektor Shop as # **071102-71** **(Figure 1)**. The PCB contained in the kit comes with all but six SMD components ready-soldered and the Coldfire micro ready programmed with the DigiButler firmware. This makes building the project a matter of soldering three dozen or so through-hole components and six relatively large SMD parts including the Ethernet transformer T1.

The component mounting plan of the DigiButler board is shown at true size in **Figure 2**. The associated parts list clearly indicates which parts are prestuffed on the board you get, and which ones have to be soldered.

Assembly of the board should be straightforward using the parts from the kit. Solder the SMD components first and follow with the through-hole components. The SMD parts you have to solder yourself are:

- capacitors C20, C21 (both 4.7µF solid) located at the underside of the board;
- capacitor C15 (4µF7 solid) located between J11 and J12 located at the top side of the board;
- transformer T1 (H1102NL) located at the top side of the board. Triangle marker on the PCB overlay to register with the white dot printed on the device;
- quartz crystal Y1 (25 MHz) located at the top side of the board;
- voltage regulator U2 (LD29080DT33R) located at the top side of the board.

If you use a fine-tipped solder iron and the usual care and precision then mounting these parts should not cause problems. Give the mounting of T1 a thorough visual inspection to make sure no adjacent pins are short-

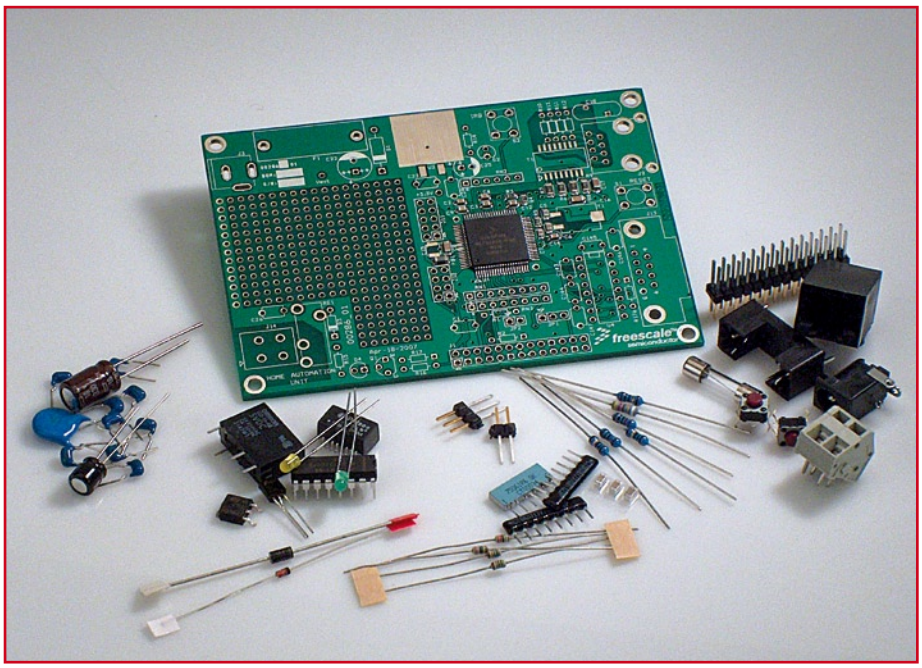


Figure 1. The DigiButler kit ready to be assembled, complete with the SMD-prestuffed PCB. The project is an hour's worth of careful soldering. (packaging not shown; actual parts supplied may differ from photograph)

Exercise extreme caution if using this board to switch power to an AC mains powered load as dangerous voltages will exist on the pins of J14 and RE1. The maximum current switched by the relay contacts is 2 A. If in doubt consult an experienced professional.

circuited by solder blobs.
Now, on with the soldering of the leaded parts from the kit. Voltage regulator U2 has a thermal pad on the underside of the device, the tip of which should be soldered to the nearby copper square on the PCB. The centre pin is not used — the metal pad establishes the ground connection.
The connectors, fuseholder and relay should be assembled last. Pay special attention to J14 and RE1 which should be placed on the board together before being soldered.
The 'pin-1' marker printed on resistor networks RN1, RN2 and RN3 should register with the respective little circles on the PCB overlay. Watch the polarity of radial electrolytics C22 and C25, LEDs D2 and D4, diodes D1 and D3, and finally U4, the MAX3232ECPE.
When placing the assembled PCB directly onto a hard surface, take care to avoid damage to the passive surface mount components at the underside of the PCB. Four 5 mm high PCB pillars secured with M3 nuts will take care of the problem.
The base of RS232 socket J13 may be secured to the board using two M3 screws and bolts. RJ45 socket J2 has two plastic studs that snap secure into the 3 mm holes on the board.
Do not install jumper JP2 (BDM_ENable) and set JP1 (BDM_SEL0) the right-hand position (2-3).
Check the board carefully before applying power. Ensure that all solder joints are good and that there are no shorts. Connect power to the board using either an unregulated or a regulated DC supply with an output voltage of 5-8 V. LED D2 should light up.

I can do it cheaper

Be our guest, although you'll find the price of the DigiButler kit hard to beat. Especially for those among you who insist on sourcing their components locally and doing the microcontroller programming all by themselves we also supply the same SMD-prestuffed PCB with an **empty microcontroller** as Elektor Shop # **071102-1**. 'Empty' means no firmware in the MCF52231, so you will also need the TBLCF hardware and software, or a professional equivalent from Freescale or a third party.

TBLCF hardware

For completeness' sake we recall that the PCB design and construction notes for Daniel Malik's Turbo BDM Light Coldfire Interface (TBLCF) may be found at [7] referenced in Part 1 of this article (April 2008). PCBs for the TBLCF are supplied through the Elektor Shop as # **071102-2**. The bare board is shown in **Figure 3**. You will need TBLCF if you want to make changes to the DigiButler firmware, or use the hardware as a Coldfire development system.
Remember the 'free samples' trick we showed in last year's 3-Axis Accelerometer article? Use the Freescale website again to get a free MC908JB16JDWE chip for the TBLCF programmer. For the project name, enter: 'Elektor DigiButler'. Caution: the supply of free samples is strictly at the discretion of Freescale Semiconductors Inc. Look in Elektor's forum topics on

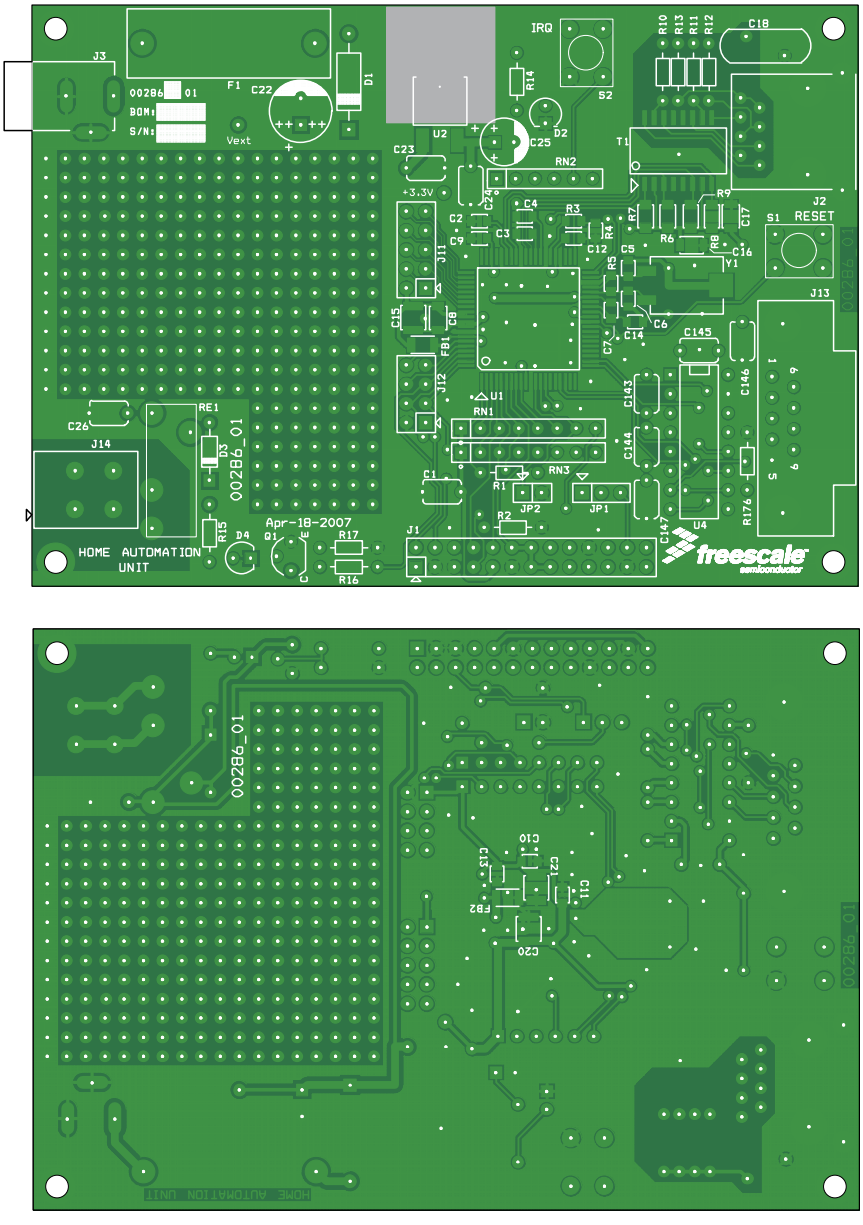


Figure 2. DigiButler board layout. The board comes with all but six SMD parts premounted

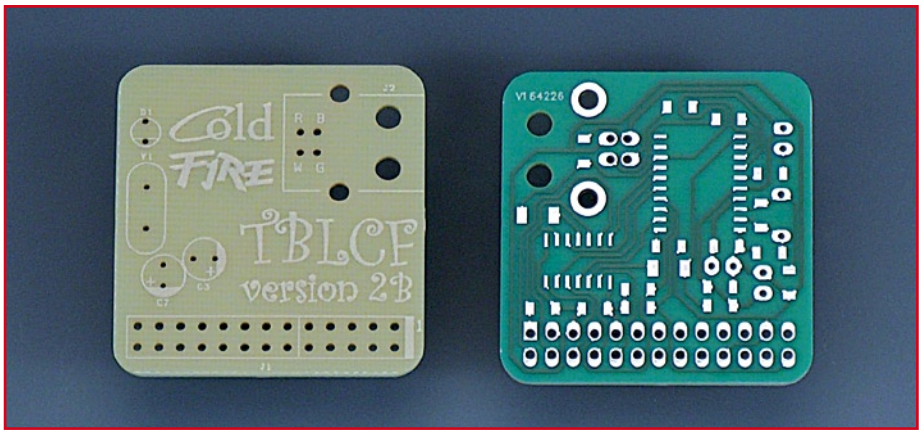


Figure 3. TBCLF board, unstuffed.

the SpYder and Accelerometer projects how others did it.
TBLCF is programmed from the ground up as described in its extensive manual.

Compilation and programming

Code (re)compilation and device (re)programming is only necessary if you

1. have an unprogrammed board # 071102-1 and/or

2. want to make changes to the existing firmware.

The project software including the full C source code is available from the Elektor website as a free download — you'll find it as archive file # **071102-11.zip**. Unpack it into an appropriate directory.

Compilation and (re)flashing the MCF52231 requires **CodeWarrior Development Studio for Coldfire Architectures, v. 6.3**. CodeWarrior is an integrated development environment which includes a project manager, editor, compiler and debugger. Version 6.3 is a free download. At ref. [1] it's marked as "Updates and Patches" but Elektor has 'inside information' that it's actually a full install version! The download is about 140 MB. Type 'Elektor DigiButler' when you are asked for the project name.
At the time of writing, the 'Special Edition: CodeWarrior for ColdFire Architectures' (v. 7.0) revealed some issues with the MCF52231 micro we're using. An update/patch or service pack for 7.0 has been announced by Freescale. It should be well worth the wait considering that the suite can compile up to 128 k of code in 'C' and unlimited assembly code. The Special Edition can be downloaded at [1] too — sit back & relax for 270 MB or so.
Programming and debugging also needs a background debug pod such as TBLCF or the USB-ML-CFE [2] from P&E Micro. A detailed procedure to do the firmware flashing is given in the **'(re-)Flashing your board'** inset.

Network connection

The most important part of the project is connecting DigiButler to a network, and for this we need an IP address for the board. An IP address is similar to a telephone number and allows the board to be identified by other devices on the network. By default, the board software is configured to request an IP address from a DHCP server, although it can be reconfigured to have a fixed, or static, IP address. Most home cable or DSL modem routers have built in DHCP server functionality and are able to provide local IP addresses.
To link to your network, connect the DigiButler board to your router using a standard RJ45 cable. Next, connect the

COMPONENTS LIST

1. Components pre-fitted on board

Resistors
R3 = 12kΩ, SMD 0805
R4 = 390Ω, SMD 0805
R5 = 10MΩ, SMD 0805
R6,R7,R8,R9 = 51Ω, SMD 1206

Capacitors
C2,C3,C4,C12,C13,C14 = 220nF ceramic, SMD 0805
C9,C10,C11 = 100nF ceramic, SMD 0805
C17 = 220nF ceramic, SMD 1206
C5,C6 = 22pF ceramic, SMD 0805
C7 = 1nF ceramic, SMD 0805
C8 = 100nF ceramic, SMD 1206
C16 = 10nF ceramic, SMD 1206

Inductors
FB1,FB2 = BLM31PG601SN1 ferrite bead, SMD 1206

Semiconductors
U1 = MCF52231CAF6 (Freescale)*

2. Components to fit on board

Resistors
R1 = 22Ω SFR16S
R2,R17,R176 = 10kΩ SFR16s
R15 = 470Ω
R10-R13 = 75Ω SFR16S
R14 = 270Ω
R16 = 1kΩ SFR16S
RN1 = 7-way 4kΩ7 SIL
RN2 = 5-way 10kΩ SIL
RN3 = 7-way 10kΩ SIL

Capacitors
C1,C23,C24, C26,C143,C144-C147 = 100nF ceramic, lead pitch 5mm
C15,C20,C21 = 4µF7, solid, SMD1206
C18 = 2nF2 1000V ceramic (TDK)
C22 = 330µF 16V, electrolytic, radial
C25 = 220µF 6.3V, electrolytic, radial

Semiconductors
D1 = 1N4004
D2 = LED, 3mm, green
D3 = 1N4148
D4 = LED, yellow, 3mm
Q1 = BC546B
U2 = LD29080DT33R (STMicro)
U4 = MAX3232ECPE

Miscellaneous
F1 = 0.5A slow, 5x20mm
J1 = 26-way double-row pinheader
J2 = RJ45 socket, PCB mount
J3 = DC adaptor socket, PCB mount
J11 = 10-way double-row pinheader
J12 = 8-way double-row pinheader
J13 = 9-way sub-D socket (female), angled pins, PCB mount
J14 = 2-way terminal block, 5mm lead pitch
JP1 = 3-way pinheader with jumper
JP2 = 2-way pinheader with jumper
RE1 = G6D-1A-ASI-DC5 (Omron)
S1,S2 = pushbutton, EVQ-PAE05R Panasonic)
T1 = H1102 Ethernet transformer (Pulse)
Y1 = 25MHz quartz crystal
Fuse holder, PCB mount
Kit of parts, Elektor Shop # **071102-71**, contains all parts and SMD-prestuffed circuit board (see text)
PCB, Elektor Shop # **071102,** available separately. Marking: 00286_01 "HOME AUTOMATION UNIT"
PCB for TBCLF, Elektor Shop # **071102-2** **

* ready-programmed on PCB in kit 071102-71; blank on PCB 071102-1.

** optional, see text.

board to a PC's COM port using a regular RS232 cable. USB-to-RS232 adapters are often problematic so an (older) machine with a real serial port (COM) is preferred. If necessary, borrow the kiddies PC.
Start up a terminal session such as Minicom for Linux or HyperTerminal or TeraTerm for Microsoft Windows.
The communication settings are

- 115,200 databits/second
- 8 data bits
- no parity
- 1 stop bit
- no flow control

Power up the board and push switch S1 to reset it. This will cause the application software to communicate with the DHCP server in the router to acquire an IP address for the board. On the PC screen, the terminal window will display the board IP address, like **F 4,** indicating connection to the network and ability to be accessed remotely. Note that it takes a few seconds for the board to obtain an IP and include it in the message sent to the terminal. Got the complete message? Congratulations, your hardware is working.
If you just want to connect the board direct to a PC, you will need a **crossover RJ45 cable** and a **fixed IP address** in the application software.

Ethernet setup and access security

We have assumed so far that DigiButler will be connected to the Internet via an Ethernet router. A router allows many computers on a local network to share the same internet connection. It also prevents unwanted Internet visitors accessing those same computers unless authorised.
Preventing access to your private DigiButler could be a problem if it were not for a router feature called Port Redirection or Port Forwarding, see **Figure 5** for a typical example.Port Forwarding lets through Internet traffic destined for a given IP address and port and then sends it to a computer or other device on your local network. Let's say the local IP address of the server is 192.168.0.2 and the address of your router – given to you by your Internet Service Provider (ISP) — is 86.131.222.120. Login to the administration pages of the router and change the router settings to forward any incoming traffic destined for port 80 to DigiButler at address 192.168.0.2. Anyone who now enters http://86.131.222.120 in their web browser will be taken to your DigiButler board.
Be aware that you probably won't be able to see the server if you try this from a PC on the same local network. Instead you will have to use http://192.168.0.2.
Another important point to note is that each port can only be forwarded once. It's not possible to have port 80 forwarded to multiple IP addresses so you won't be able to run a web server on a local network and also run DigiButler as they both use port 80.

The end result: network, web and WAP

The home automation server is ready for access over a network as soon as the Coldfire device has been programmed and the network cable is

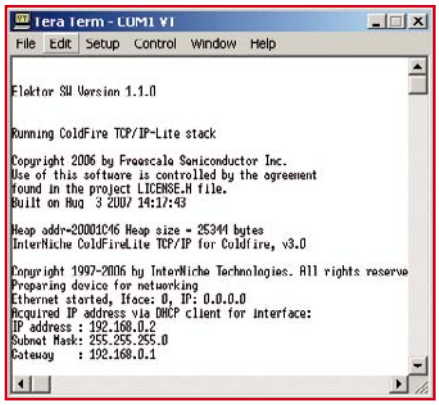
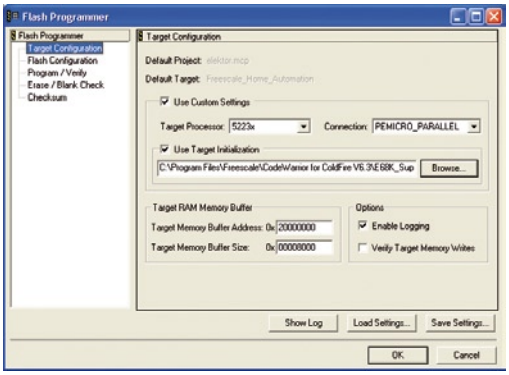


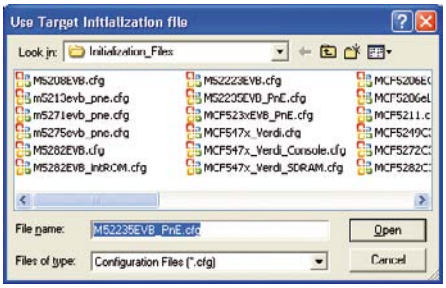
Figure 4. "It's alive Jim!"
Output from serial port after DigiButler is reset.

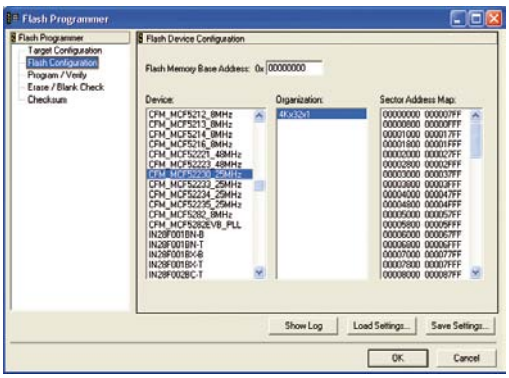
(re-)Flashing your board

The following procedure was recorded with a PE Micro parallel programmer / debugger pod connected to J1 on the DigiButler board, a laptop PC running Windows XP and a downloaded version of CodeWarrior 6.3. TBCLF may require different jumper settings and steps, please consult the TBCLF documentation. Updates to this procedure may become available at www.elektor.com/digibutler_en.



1. Fit jumper JP2 and set jumper JP1 to the right-hand position (2-3).
2. Start the CodeWarrior IDE, open the project 'elektor.mcp' using the File→Open command in the IDE menu bar. Connect the debug pod to connector J1 and apply power to the board.
3. Use Tools→Flash Programmer to bring up the Flash Programmer dialogue box.
4. In the Target Configuration menu, Browse to the Target Initialization files and there select and Open: M52235EVB_Pne.cfg
5. In the Flash Configuration menu, select: CFM_MCF52230 25 MHz.
6. Go to the Erase /Blank Check menu and run an Erase action. This is useful to check if the connection to the target is okay. If erasure is successful, the comms are okay. Click on Save Settings.
7. Now go to Program/Verify and browse to the file 'web_coordinator' (without an extension). This is a precompiled binary image, included for those who do not wish to recompile the source code.
8. Program the device! With the device programmed, the board is ready to be used.





connected to either a router or a PC. Remember that when connecting directly to a PC, the network cable must be a crossover type. Enter DigiButler's IP address in the web browser of a PC on the same network and an authorisation dialog box will be presented (**Figure 6**). The default user name is 'user' and the password is '1234567'. If required, both can be changed in the project source code.

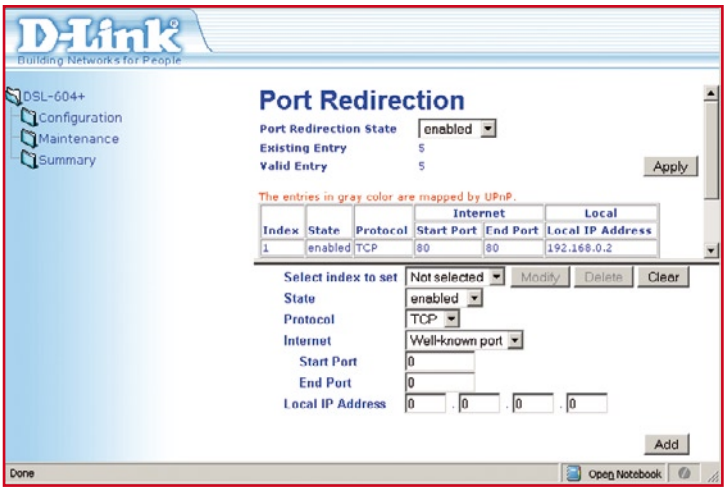


Figure 5. Most routers support port redirection or port forwarding. Setting the IP address and port number allows Internet users to access DigiButler on a local network.

Successful authentication brings up the default main web page, *index.htm*. As illustrated in **Figure 7**, a graphic image on the example default web page shows the status of the relay. The project source code allows you to substitute your own image! A dark image signifies that the relay (RE1) (lamp) is off, while a bright image shows that the relay (lamp) is on. The relay can be switched on and off remotely using Light ON / Light OFF button on the web page. Application note AN3455 (ref. [2] in part 1) gives an in depth description of an alternative method of switching the relay on and off using web page variables in a browser address bar. From the same web page it is also possible to set a timer for when the relay should switch on or off, this function making use of the Coldfire's real time clock. And lastly, the example page allows the user password to be changed if desired.

The process for talking to DigiButler over the Internet is exactly the same. Entering the router IP address in the browser of an Internet connected PC gives the same results, but only if the router has been set up for forwarding port 80 to the DigiButler's local IP address. In our example, the router address is 86.131.22.120. Be aware that it might not be possible to access the server from a PC within a local network, if you use the router IP address.If you are having difficulty remembering the IP address, NO-IP [3] offers a free service which maps the IP address to an easy to remember sub domain name.

Finding an Internet connected PC is not always possible or safe, so WAP phone access is also supported. Nearly all modern mobile phones have WAP, but the service is subject to what your provider is offering you. DigiButler's default WAP page is *wap.wml*. Entering our example URL,

http://86.131.22.120/wap.wml

from the browser of a WAP enabled phone, gives similar results as before but without the images. The WAP pages have been tested using Nokia and Samsung mobiles, but may need to be changed to support other manufacturers' handsets.

Creating and uploading web pages

A neat feature of the software is its support for dynamic uploading of new web pages. The following is intended for those having some experience in programming web-connected devices.

By implementing an Ethernet writeable FLASH based file system, it's possible to update web pages remotely without reprogramming the Coldfire device. Two files systems are actually implemented — a static compile time system and the dynamic writable system. Both can be used to store web pages, graphics files and other content and both allow directory structures and file names up to 255 characters. Since the application looks in the writable system for a requested file before searching the compile time file system, it's possible to override the compiled files. For example, if an image file exists in both file systems with the same name, then the file in the writeable system will be used and the one resulting from the compile will be ignored.

Figure 6. The first access in a web session requires the user to enter a username and password before access is granted to the main page of the home automation server.

Example web pages and Ethernet loading utilities can be found in the *web_page* directory of the project. The files required to upload new web content to the automation server are *make.bat*, *filelist.txt*, *emg_dynamic_ffs.exe* and *emg_web_uploader.exe*.

The batch file *make.bat* conveniently calls the necessary utilities to compress and upload the web-resultant content image file using the files listed in *filelist.txt*. Before executing *make.bat*, change the IP address in the line

```
emg_web_uploader 10.171.88.63 dynamic.ffs joshua
```

in *make.bat* to the board's IP address as shown in the terminal window. The parameter *dynamic.ffs* is the name of the compressed file image generated by compression utility *emg_dynamic_ffs.exe*. This compresses the files in *filelist.txt* into a single image. The parameter *joshua* is the upload security key, used to prevent unauthorized upload of web content. DigiButler will verify the supplied security key with the version in memory and upload only if both match. The security key can be changed in the server source code if required.

An example of the contents of *filelist.txt* is shown below. These files will be compressed into one image for upload to the server. The last line in the file must be a blank line with only a CRLF (i.e. hit Enter in the last blank line).

```
* This is a list of the files stored in the bin file.
```

```
* The files are arranged
in the order they are
listed here.

index.htm
kitchen.jpg
black.jpg
main.js
pot_data.txt
fsllogo.gif
variables.htm
wap.wml
wap1.wml
wap2.wml
wap_main.wml
incorrect.wml
```

Overcoming firewalls

Both FTP or TFTP protocols are commonly used to upload files to webservers. However, many firewalls and routers consider these protocols as dangerous and block the transfer, which causes a problem if trying to upload new content to the automation server. To overcome this, the utility *emg_web_uploader.exe* uses TCP and port 80 thereby getting around the problem.

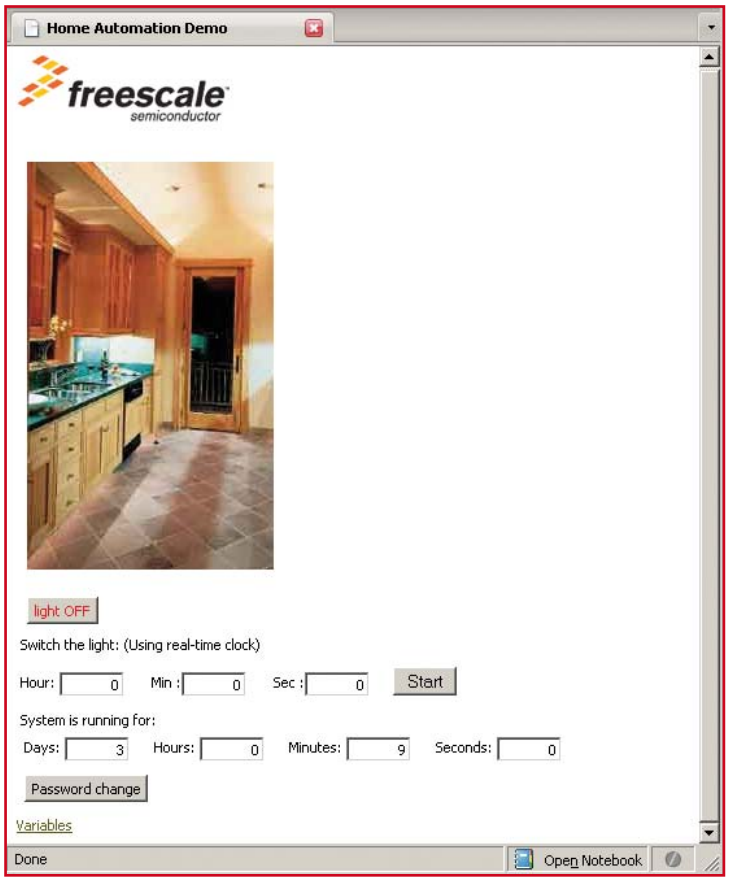


Figure 7. The first web page the user sees when accessing DigiButler from a PC web browser. You can switch the kitchen lighting on and off.

Enhancements and your contributions

DigiButler opens up many exciting opportunities for controlling devices remotely and for remote real time data measurement. Analogue and digital signals can be captured, measured and subsequently analysed from a web browser. For example, a sensor could be added to the DigiButler analogue inputs and be read remotely using the HTML VARS function described in AN3455. With some modification to the software, images could be captured using a VGA camera module such as the C328-7640 [4].

The prototyping area on the board allows you build your own extension circuits. Many signals to and from the microcontroller are conveniently found on J11 and J12, while the V_{ext} pin close to the fuse may help to power the extension(s). The same for the +3.3 V rail which can be 'tapped' near J11 (but watch the extra current consumption of your extension circuit). If you duplicate the existing relay circuit for the control of a second 230 VAC load, be sure to observe electrical safety precautions.

The authors look forward to seeing your applications and extensions as the project was designed and published with the open-source concept in mind. A dedicated web page will be 'at your service' at www.elektor.com/digibutler_en.

(071102-1)

Web Links

[1] www.freescale.com/webapp/sps/site/prod_summary.jsp?code=CWS-MCF-STDED-CX&nodeId=01272694012E704080&fpsp=1&tab=Design_Tools_Tab

[2] www.pemicro.com/products/product_viewDetails.cfm?product_id=163&menu_id=details&CFID=1032336&CFTOKEN=52342289

[3] www.no-ip.com/services/managed_dns/free_dynamic_dns.html

[4] VGA camera module www.electronics123.com/s.nl/it.A/id.2027/.f?sc=8&category=233

Changing the IP address

You may wish to use a fixed IP address instead of having an IP address assigned by the router's DHCP server functionality. This is possible by making two simple code changes. The first is to switch off the DHCP functionality by commenting out the line

```
#define DHCP_CLIENT     1  /* include DHCP client code */
```

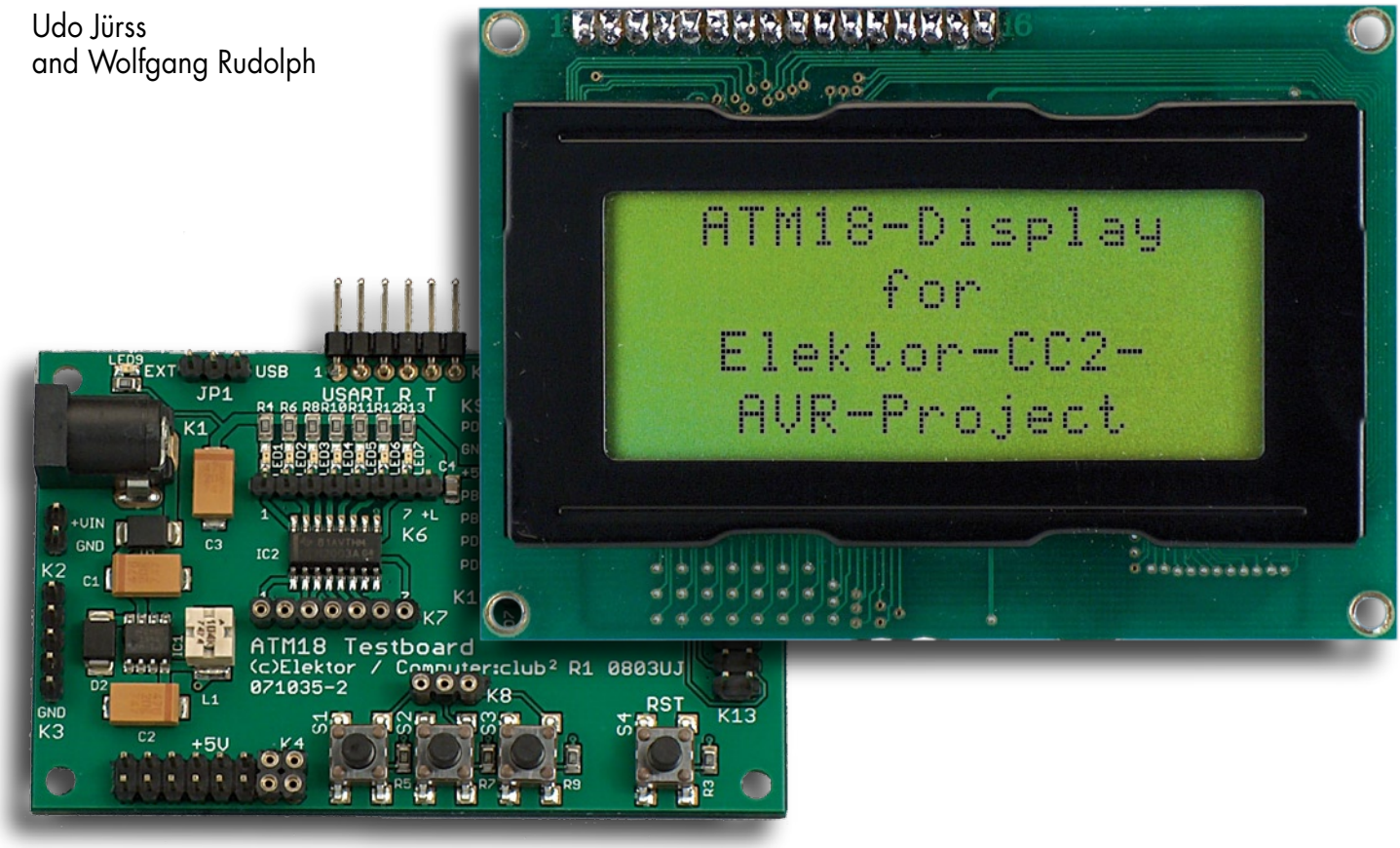
in the file 'ipport.h'. The second is to set the IP and gateway addresses and subnet mask. Example values for these parameters are included in file 'main.c'. Change them according to your setup and remember to change the #if 0 statement to #if 1.

```
#if 0
IP_ADDRESS(213,194,223,49);
DEF_GATEWAY(213,194,223,1);
SUBN_MASK(255,255,255,128);
```

Two-wire LCD

ATM18 display for the Elektor AVR project

Udo Jürss
and Wolfgang Rudolph



This LCD expansion module for the ATM18 test board opens up a huge range of applications. Although the design might look like a standard interface between microcontroller and LCD panel, there is an elegant technical detail: in order to minimise the number of port pins required, a special two-wire interface has been developed.

An ordinary LCD panel can be driven from a microcontroller using either four or eight data wires. In addition to these, an RS signal is needed to distinguish data from commands, and an E signal is needed to clock the data into the panel. This large total number of connections is unfortunate in our application because it ties up a number of port pins that could be used for other purposes.

Data transfer

All ordinary LCD panels are connected using 14 wires, plus any connections needed for the backlight. It is here

that models differ, as the manufacturers are not consistent as to whether the backlight supply should be located next to pin 1 or next to pin 14. Our printed circuit board is designed for displays where the backlight connections are on pins 15 and 16, and two pads are provided to which the backlight power supply can be soldered. If a different display is used it is simplest to use just the 14 main connections and leave the backlight unconnected. The display we used has the following pinout:

Pins 14 down to 7: data bus

Pin 6:E (enable signal), active high

Pin 5: R/W, 0 = write, 1 = read

Pin 4: RS, 0 = command, 1 = data

Pin 3: V0, contrast adjustment from 0 V to 2 V

Pin 2: VDD, +5 V

Pin 1: VSS, 0 V

The direction of data transfer is specified by the level on the R/W signal. Here we only use write mode, and so the pin is connected permanently to ground in the circuit (**Figure 1**). The internal registers of the display controller are selected using the RS signal, which is used to distinguish between data and commands.

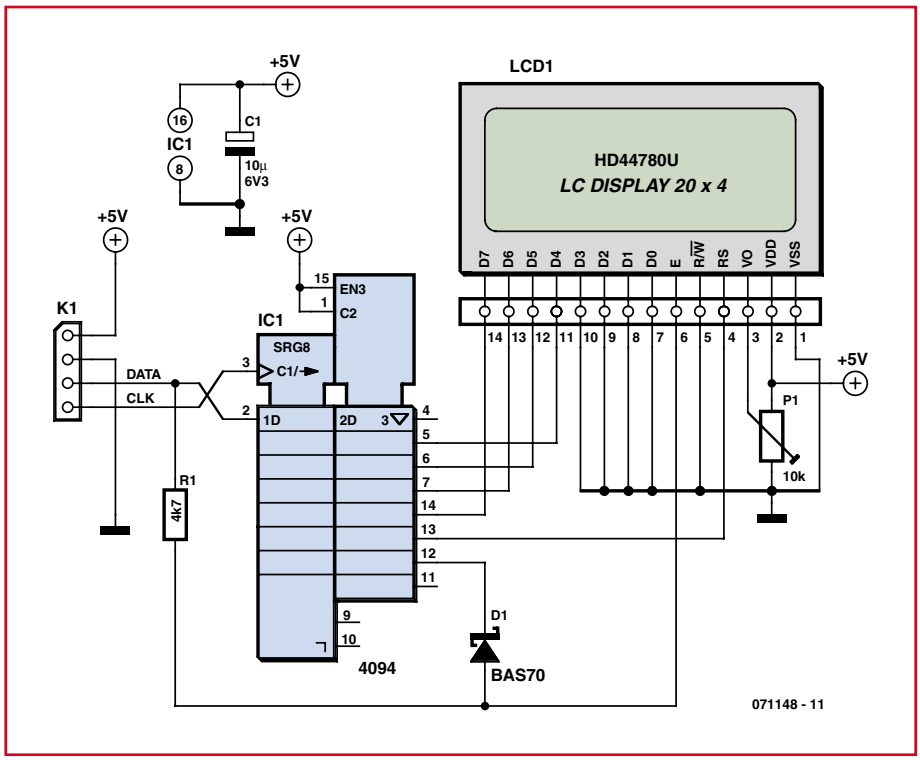


Figure 1. The LCD interface is built around a shift register.

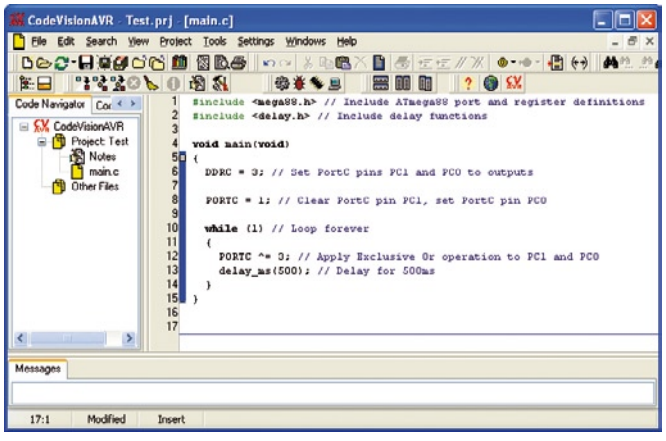
Two-wire interface

The circuit is based around a port expander that uses two port bits. A natural choice for such a design would be the I²C bus, but we have chosen a faster and cheaper approach. All that we need is a type 4094 shift register (see Figure 1). This allows clock rates of sev-

C compiler

Advanced C programmers who wish to control an LCD using the expansion module described here can take advantage of two example programs available for download from the Elektor website. One example is for use with WinAVR (GCC) and the other is for use with CodeVision.

Software house HPInfoTech has produced a special free-of-charge version of their popular 'CodeVisionAVR' compiler for this Elektor project. The compiler supports the ATmega48, ATmega88, ATmega168 and ATmega328 with a maximum object code size of 4 kB.



CodeVisionAVR in use

A version limited to 16 kB code size costs around fifty pounds and a 32 kB version is around sixty pounds, within the reach of many hobbyists.

The compiler produces very efficient code and includes a so-called 'smart linker' that only includes in the final object file functions that are actually called. It is therefore possible to use comprehensive libraries without having to tailor them to each application.

CodeVision makes setting up a project very straightforward. The integrated 'CodeWizard' automatic program generator generates a complete skeleton for your program. Beginners in particular will find it helpful to use this as a model for their programs in the same way as they can learn from our example programs. Automatic generation of libraries and selection between application and bootloader code, as well as code templates for frequently wanted program functions, make it easier to get started. Built-in drivers for all current programming adaptors allow devices to be programmed directly from within CodeVision. Internal EEPROM and fuse bits can also be programmed, and there is a built-in terminal with file transfer and hexadecimal debugging output. The compiler offers powerful optimisation features for advanced users including global register allocation and freely-programmable ISR entry and exit code, comprehensive help (also available on-line) and a debugging interface to AVR Studio.

eral MHz rather than the 400 kHz maximum that can be achieved using I²C.
At first sight things might look a little complicated. First we have to send the data bits D4 to D7 and RS, and then we have to generate an enable pulse on the E wire. To achieve this, the data input to the shift register is logically ANDed with output Q7 using a resistor and a diode.
Only when Q7 is high will a pulse on the data input be transmitted to the LCD as a pulse on its E input. To make sure that no spurious E pulses are generated, the following sequence must be observed.

1. Clock eight zero bits into the shift register by setting the data signal low and generating eight clock pulses. The bits are clocked in on each rising clock edge. Now all the Q outputs of the shift register are low, and in particular no E signal can be generated.

2. Now send seven data bits. The first bit must be high and will ultimately appear on Q7, where it will allow an E pulse to be generated. The second bit is destined for the RS signal on Q6; the next four bits are data. The final bit is zero, ensuring that the data signal is left low. After a total of seven clock pulses the data bits will appear as required on the Q outputs, and in particular Q7 will be high.

3. Now we emit a pulse on the data signal, which in turn generates a pulse on the E line because Q7 is high.

The above procedure must be carried out twice, once for the high data nibble (bits D4 to D7) and once for the low data nibble (bits D0 to D3). **Listing 1** shows an excerpt from the BASCOM example program that can be downloaded from the *Elektor* website. Data can be written to the LCD (with RS being set high) using Lcd_write_data, while commands can be sent (RS low) using Lcd_write_ctrl, for example when initialising the display controller.

Listing 1

Data transfer using the shift register

```
Sub Lcd_write_data(byval D As Byte )
  Rs = 1
  Low_nibble = D And 15
  High_nibble = D / 16
  Lcd_write_nibble High_nibble
  Lcd_write_nibble Low_nibble
End Sub

Sub Lcd_write_ctrl(byval D As Byte )
  Rs = 0
  Low_nibble = D And 15
  High_nibble = D / 16
  Lcd_write_nibble High_nibble
  Lcd_write_nibble Low_nibble
End Sub

Sub Lcd_write_nibble(byval D As Byte )
  Pe_clock = 0
  Pe_data = 0
  'Clear all stages of shift register
  For N = 1 To 8
    Pe_clock = 1
    Pe_clock = 0
  Next N
  'Set E level at Q7
  Pe_data = 1
  Pe_clock = 1
  Pe_clock = 0
  'Set level for RS at Q6
  Pe_data = Rs
  Pe_clock = 1
  Pe_clock = 0
  'Shift in 4 bits
  Mask = 8
  For N = 1 To 4
    State = D And Mask
    If State = 0 Then
      Pe_data = 0
    Else
      Pe_data = 1
    End If
    'Clock in data with rising edge
    Pe_clock = 1
    Pe_clock = 0
    Shift Mask , Right
  Next N
  'Shift in zero bit
  Pe_data = 0
  Pe_clock = 1
  Pe_clock = 0
  'Set E
  Pe_data = 1
  Pe_data = 0
End Sub
```

Initialisation

The display recognises a large number of commands, all of which are sent with RS set low. The commands are grouped into families according to the number of zeros that appear in the high-order bits of the command byte (see **Table 1**).
The display also includes an internal cursor register that points to an individual character position on the display. In the case of a two-by-sixteen display we have:

Row 1: addresses 00h to 0Fh
Row 2: addresses 40h to 4Fh

while for a four-line display with 20 characters per line we have:

Row 1: addresses 00h to 13h
Row 2: addresses 40h to 53h
Row 3: addresses 14h to 27h
Row 4: addresses 54h to 67h

The cursor advances automatically as each character is written, or the address can be set directly in order to write to any desired position.
On power-up a number of initialisation commands must be written to the command register. **Listing 2** shows an example of how an LCD can be initialised

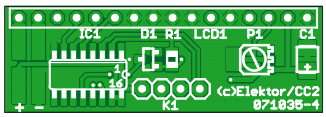


Figure 2. Printed circuit board for the LCD expansion module.

COMPONENTS LIST

Resistors
R1 = 10kΩ (SMD 805)
P1 = 10kΩ preset (SMD)

Capacitors
C1 = 10µF 6.3V (SMD)

Semiconductors
D1 = BAS70 (SMD)
IC1 = 4094 (SMD SO16)

Miscellaneous
K1 = 4-way SIL pinheader
LCD1 = LC Display 4x20 characters (HD44780 compatible)
14-way SIL pinheader
PCB with SMDs premounted, incl. all parts and 4x20 LCD; Elektor Shop # **071035-93**

Table 1. Display commands

Function	7	6	5	4	3	2	1	0
Clear display	0	0	0	0	0	0	0	1
Cursor home	0	0	0	0	0	0	1	x
Entry mode	0	0	0	0	0	1	ID	S
(ID=1/0: right/left, S=1/0: without/with scroll)								
Display, Cursor	0	0	0	0	1	D	C	B
(D,C,B=1/0: display, cursor, blink on/off)								
Scroll	0	0	0	1	SC	RL	x	x
(SC=1/0: scroll/cursor moves to RL=1/0: right/left)								
Initialisation	0	0	1	DL	N	x	x	x
(DL=1/0: 8-/4-bit bus, N=1/0: two lines/one line)								
User-defined character memory	0	1	Character			Column		
Display memory	1	Memory address						

over its four-bit data bus.

Text output

In order to display text at a defined position we must first set the cursor address. It is convenient to express the position in terms of the column (x-coordinate) and row (y-coordinate). Then a call to Lcd_pos will move the cursor as

Listing 2

Initialisation

```
Sub Lcd_init
  Waitms 50
  Lcd_write_ctrl &H20
  Waitms 50
  Lcd_write_ctrl &H20
  Waitms 50
  Lcd_write_ctrl &H28
  Waitms 50
  Lcd_write_ctrl &H0C
  Waitms 50
  Lcd_write_ctrl &H01
  Waitms 50
End Sub
```

Listing 3

Text output

```
Sub Lcd_pos(byval X As Byte , Byval Y As Byte )
  D = 127 + X
  If Y = 2 Then D = D + 64
  Lcd_write_ctrl D
End Sub

Sub Lcd_text(byval Text As String )
  J = Len(text)
  For I = 1 To J
    Char = Mid(text , I , 1 )
    D = Asc(char)
    Lcd_write_data D
  Next I
End Sub
```

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required. For example, Lcd_pos 1,1 will move the cursor to the leftmost column of the first row. Then Lcd_text can be used to write a string of characters, as illustrated in **Listing 3**.

Printed circuit board

The interface circuit can be constructed on the compact printed circuit board shown in **Figure 2**, which uses SMD components. Those wary of soldering SMDs can purchase ready-populated boards from the Elektor shop, with just the external connections left to be soldered by hand. The four-way connection to the ATM18 test board is best fitted with a header socket so that temporary connections can be made for test purposes using lengths of solid-core wire.

The 16-way connection can also be fitted with a socket or plug to mate with a connector on the LCD, or direct connection can be made using header pins or a ribbon cable. The four connections to the microcontroller are V_{CC}, GND, data and clock. Data and clock can be connected to any two port pins: the example software uses port B.1 for clock and port B.2 for data.

In use

Using the display module is very easy. **Listing 4** shows a simple example program that displays a measured voltage on analogue input ADC(0). The analogue-to-digital converter is configured to use the external 5 V reference, and the 10-bit conversion result, in the range 0 to 1023, is written to the display. The complete example program is available for free download from the *Elektor* website at www.elektor.com.

(071148-I)

Listing 4

Outputting a measured value

```
Config Adc = Single , Prescaler = 64 , Reference = Off
Start Adc

Lcd_init

Lcd_pos 2 , 1
Lcd_text „adc(0)="

Do
  Lcd_pos 2 , 2
  Value = Getadc(0)
  Text = Str(value)
  Lcd_text Text
  Waitms 500
Loop
```

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Assembled Order Code: AS3179 - **£19.95**

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Kit Order Code: 3158KT - **£17.95**
Assembled Order Code: AS3158 - **£27.95**

Bi-Directional DC Motor Controller (v2)

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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.
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Assembled Order Code: AS3180 - **£54.95**

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Assembled Order Code: AS3140 - **£69.95**

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Assembled Order Code: AS3142 - **£59.95**

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Leads: Parallel (LDC136) £395 / Serial (LDC441) £3.95 / USB (LDC644) £2.95

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USB/Serial connection. Header cable for ICSP. Free Windows XP software. Wide range of supported PICs - see website for complete listing. ZIF Socket/USB lead not included. Supply: 16-18Vdc.
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Assembled Order Code: AS3117 - **£24.95**

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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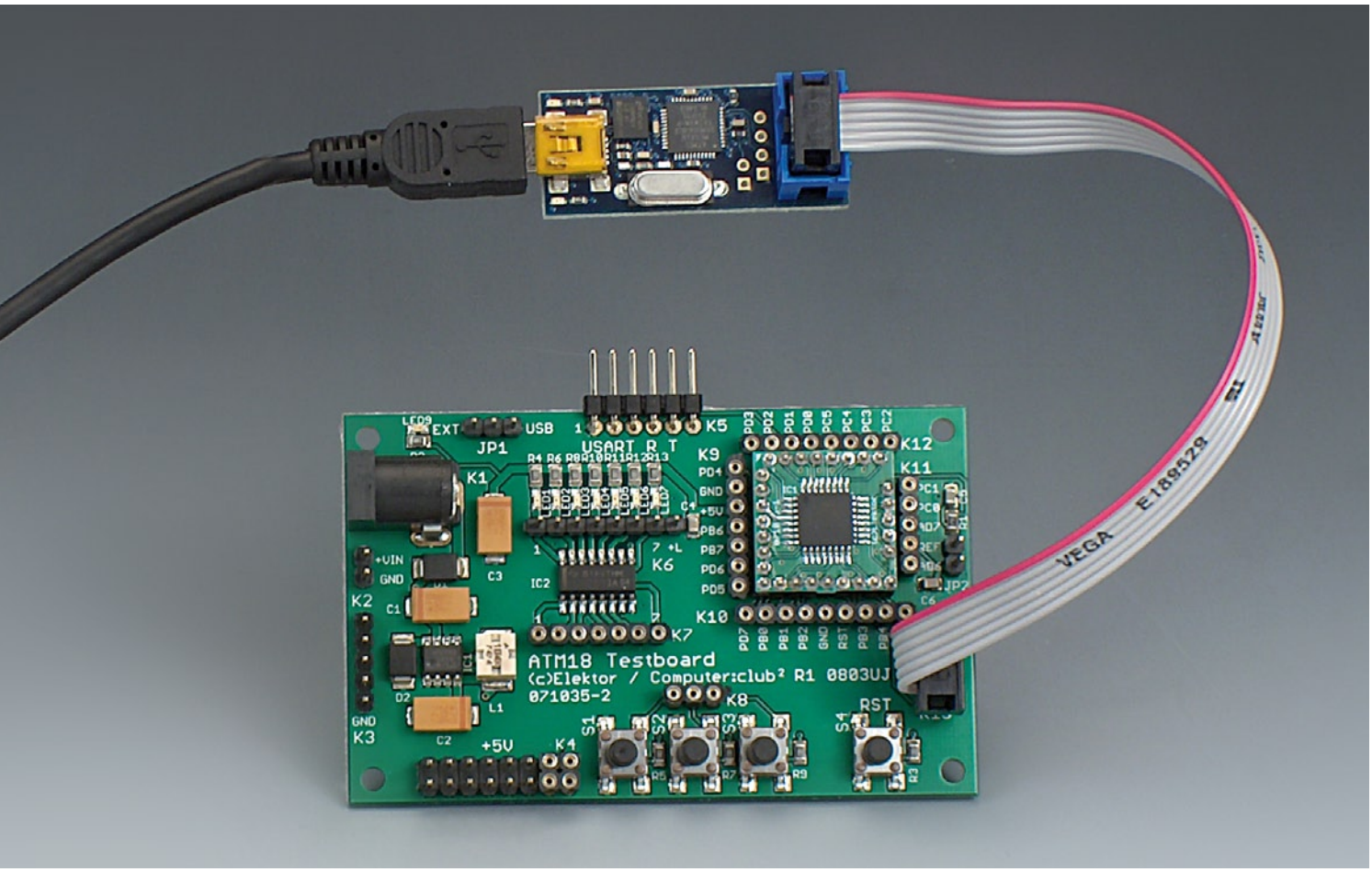
Elektor AVRprog

Benedikt Sauter and Dr. Thomas Scherer

Two events triggered the conception of this AVR programmer: the feedback received on USBprog from Elektor, October 2007 and a series of articles started last month around our ATM18 project. The outcome is a plug-and-play AVRISP mk2-compatible USB programmer for AVR controllers!



Since the launch of USBprog in October 2007 [6] many readers have explored Benedikt Sauter's website [1] and discovered his amazing open source circuit, on a par with the all-in-one animal of mythology that provided mankind with eggs, wool, milk and meat. This little printed circuit board (PCB) has aroused deserved admiration and to the extent that it fulfilled the requirements of a number of *Elektor* readers it was certainly a success story. All the same, feedback from other readers indicated that the capabilities offered in Benedikt's solution (USB-serial converter and ARM programmer for instance) were not exactly top of their wants list. They were mainly interested in using the device as a straightforward AVRISP mk2-compatible programmer for deploying with a diverse range of software applications.

Simple solution

A sample wish list for a new programmer would include the phrases 'simple to construct', 'user-friendly' and 'inexpensive' (OK, let's be honest — 'cheap'). A quick opinion poll indicated that reinventing the wheel was not what people wanted, so Mr Sauter got on with slimming down the circuit of USBprog to produce a kind of dedicated programmer for AVR controllers with a user outlay that would be a whole lot cheaper than the more complex circuits already available.

Doing without a bootloader and other technical frills in this programmer made it possible to employ an ATmega16 instead of an ATmega32. The cir-

Simple AVR universal programmer with USB

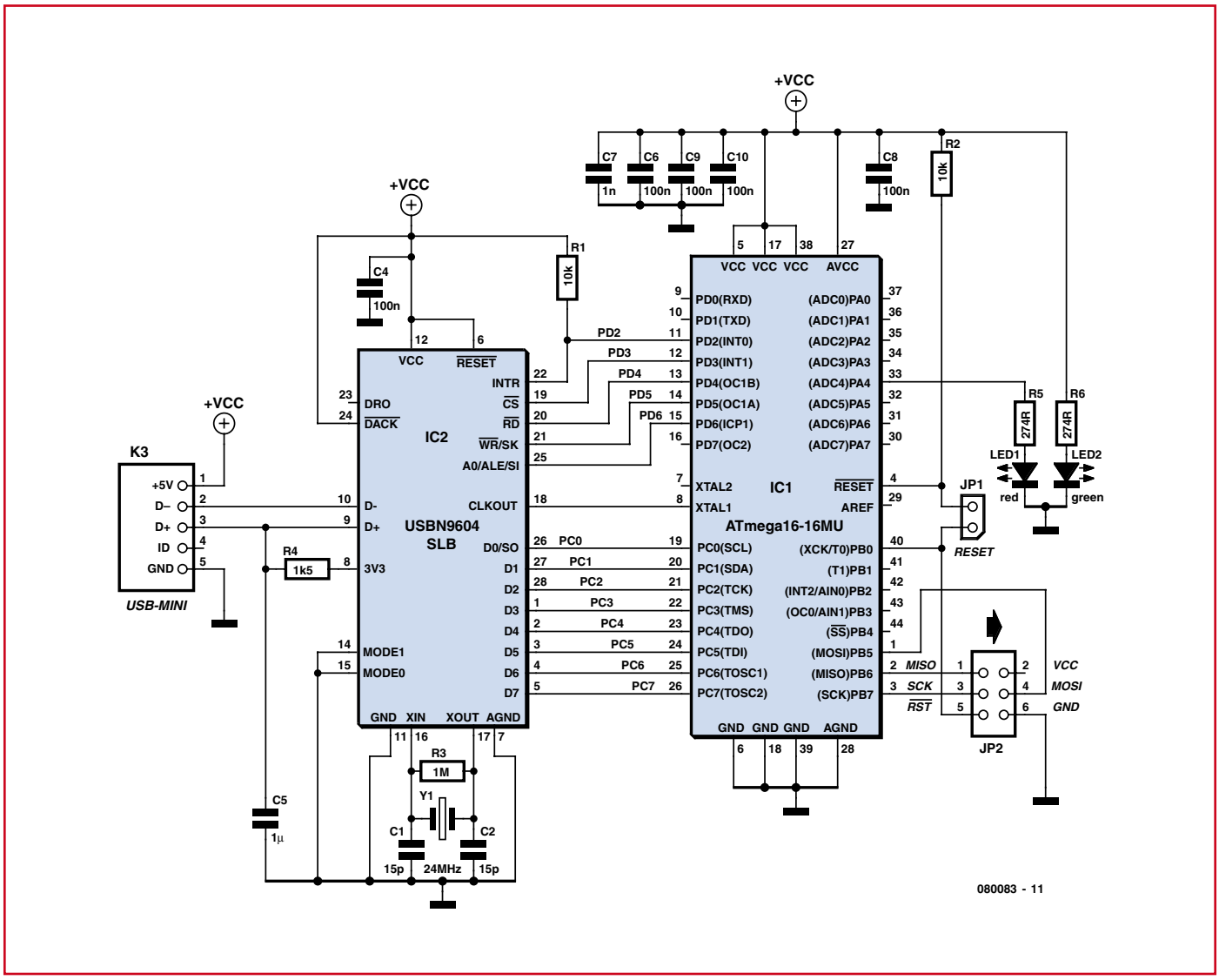


Figure 1. The circuit of the Elektor AVRprog has much in common with its predecessor, USBprog, published in Elektor, October 2007. A USB bridge and a microcontroller are the only other components.

cuit of the Elektor AVRprog is little altered from the source design, as you can see in **Figure 1**. Space on the PCB is optimised by using a miniature USB connector and a 6-pin (instead of 10-pin) ISP interface. The resulting PCB is commendably petite, measuring just 4.0 x 1.7 cm (**Figure 2**).

We decided against offering this programmer in semi-kit form as a part-populated board; not everybody feels comfortable soldering microscopic surface-mount components in confined spaces. It seemed more logical to provide the ready-programmed ATmega16 along with the remaining electronics and PCB as a ready-to-use module that readers could employ without fiddling about. So that's what we decided to produce: a remarkably cheap AVR programmer for instant use, supplied complete with a matching USB cable and the necessary 6-way ISP cable.

Software

As an AVRISP mkii clone the Elektor AVRprog is usable with a broad range of software—effectively every program that supports this variant of AVRISP. That said, even the best USB hardware will achieve precious little without suitable drivers. The program AVR Studio 4 [2] from Atmel solves this problem at a single stroke; simply installing AVR Studio as shown in **Figure 3** with its own integrated drivers does everything necessary. Once this is done, you can plug the Elektor AVRprog into your PC straightaway.

Under Windows the new hardware is recognised automatically, using the

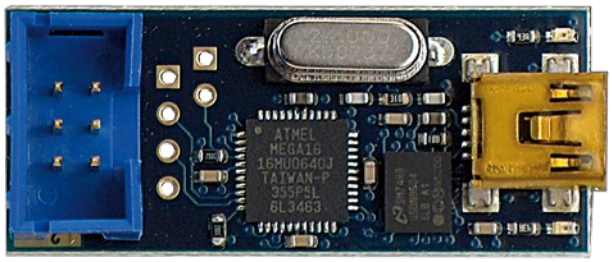


Figure 2. This is how the module looks when complete. A Mini USB connector and a 6-pin ISP interface help ensure its extremely compact dimensions.

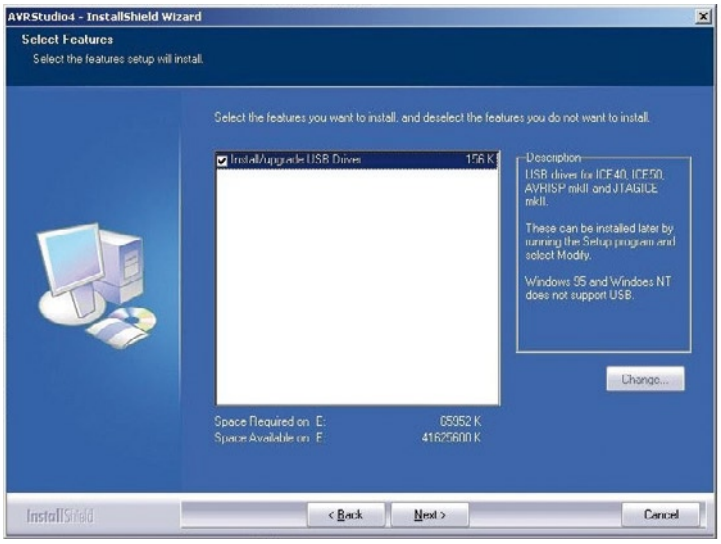


Figure 3. A screenshot taken during installation of AVR Studio 4 by Atmel. Once the software and drivers are installed, the Elektor AVRprog is usable without further ado.

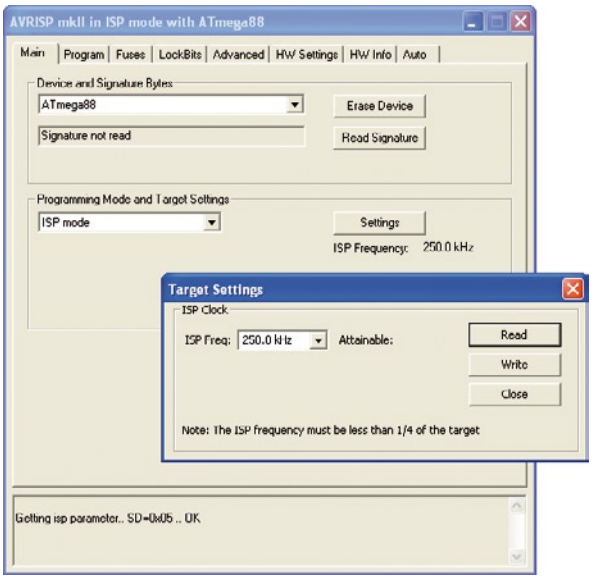


Figure 4. In this dialogue with AVR Studio (version 4.13) the so-called ISP frequency is being entered under 'Settings'.

dedicated driver. On many Windows XP installations, a false error message can occur at this stage, with the file 'libusb0.sys' not found and the user asked to indicate where the computer should look for it. Simply ignore this and click on 'Cancel'. The driver will in fact be found — assuming it is actually present — and installed without any further problems.

With the driver now installed you can deploy your Elektor AVRprog with a variety of software. For example, you can program it direct from CodeVisionAVR [3], but currently not directly from BASCOM [4] owing to a lack of AVRISP mkii protocols.

The Elektor AVRprog will also work with non-Windows computers. For Linux you have plenty of choice (search Google for Linux + AVRISP mkii + software), whilst the popular Open Source program AVRDUDE [5] is a stand-out solution for both Linux and Mac OS X. The command line interface of this program may be unfamiliar for Mac users, which is why the Elektor website has a PDF file explaining how to integrate AVRDUDE into a 'normal' graphical interface.

Warning: speed trap!

AVR microcontrollers cannot be programmed at any frequency you might desire. The 'bitrate' for programming must be set no higher than a quarter of the clock frequency of the controller being used. If the controller's clock frequency is 8 MHz, the frequency you set in Elektor AVRprog must not exceed 2 MHz. This is the top limit feasible with this programmer. The lower limit is a rather tranquil 249 Hz. In truth this value is largely theoretical and not actually practicable. In any case AVR Studio version 4.13 will not allow you to program frequencies below 5 kHz. To see how you set this so-called ISP Frequency in AVR Studio take a look at **Figure 4**.

The programmer is, as already mentioned, an Open Source project. Among other things this means that not absolutely 100 per cent of AVRs are fully supported. No problems should arise with the usual types, however. Nevertheless, if something nasty crops up then it's worth taking a look at reference [1] to see if newer firmware exists. Although it may not be obvious, it is in fact possible to change firmware on the Elektor AVRprog. For this you need to link the two holes directly next to the crystal (it might be better to sol-

COMPONENTS LIST

Resistors
R1,R2 = 10kΩ, SMD 0603
R3 = 1MΩ, SMD 0603
R4 = 1kΩ5, SMD 0603
R5,R6 = 274Ω, SMD 0603

Capacitors
C1,C2 = 15pF, SMD 0603
C4,C6,C8,C9,C10 = 100nF, SMD 0603
C5,C7 = 1µF, SMD 0603

Semiconductors
IC1 = Atmega16-16MU, MLF44
IC2 = USBN9604SLB
D1 = LED red, SMD 0603
D1 = LED green, SMD 0603

Miscellaneous
Y1 = 24 MHz quartz crystal, HC49/4 case
K3 = Mini USB socket type A-USBB-M5/SMD
JP2 = 6-way boxheader
Ready-assembled and tested module, incl. USB and ISP cable, order code **080083-71** from Elektor Shop

About the lead author

Benedikt Sauter is a passionate Open Source hardware and software developer and keeps himself busy with his website where he documents the Open Source applications he has developed.

der a small two-pin header and insert a jumper). Then, using a second programmer connected via the 6-pin ISP connector, you can introduce new firmware 'backwards' so to speak.
Bear in mind too that the Elektor AVR-prog is designed to operate on 5 V. If the target chip is powered with 3.3 V or less during programming, the operation may fail under some circumstances. In this case the target controller should be powered with 5 V and 'transplanted' onto a small experimenter board if necessary.

(080083-I)

Web Links and Literature

[1] Project page:
www.embedded-projects.net/usbprog

[2] AVR Studio 4:
www.atmel.com/avrstudio

[3] CodeVisionAVR:
www.codevision.be

[4] BASCOM:
www.mcselec.com

[5] AVRDUDE:
www.nongnu.org/avrdude

[6] USBprog,
Elektor, October 2007.

Advertisement

Soldering SMDs with

Simple job thanks to comprehensive

Harry Baggen

The latest version of The Elektor DIY SMD oven, which goes by the name of 'Reflow Control', makes easy work of doing your own soldering of SMD parts on printed circuit boards, using a simple little electric oven. We already introduced the electronics for this project in last December's issue. There is now a comprehensive kit available for this project, which allows even electronics enthusiasts with two left hands (do they exist even?) to easily build such an SMD oven.

Since more and more electronics components are now available from their manufacturers only in SMD versions it is as a designer impossible to avoid using SMD parts. But making a single circuit or a small run of a few boards does not justify (certainly for use at home!) the purchase of a real SMD oven, which is necessary to mount all those little, leadless parts on the board. Can't we think of a simpler solution?

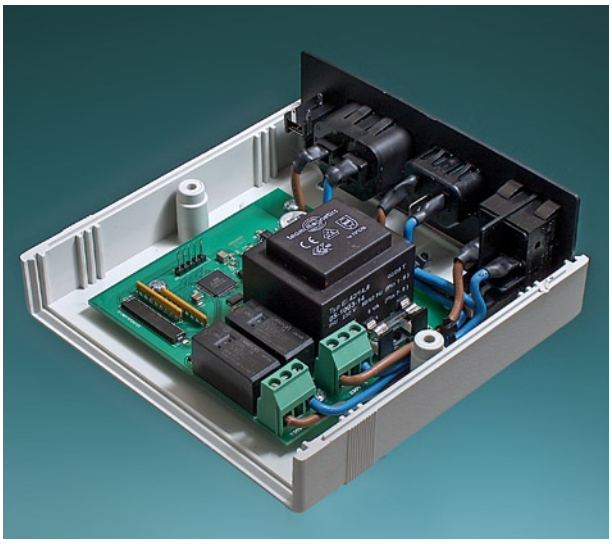
Yes, of course we can! As we already wrote in the December 2007 article, with a special control circuit you can transform an ordinary kitchen oven into a handy SMD baking station. The control circuit that is required for this is now available from Elektor as a kit, so that there is no chicken and egg problem. To solder the SMD parts on the PCB you really need a reflow oven. But this is not ready yet because you need this board for that... etcetera. Now, that is no longer a problem because of this handy kit.

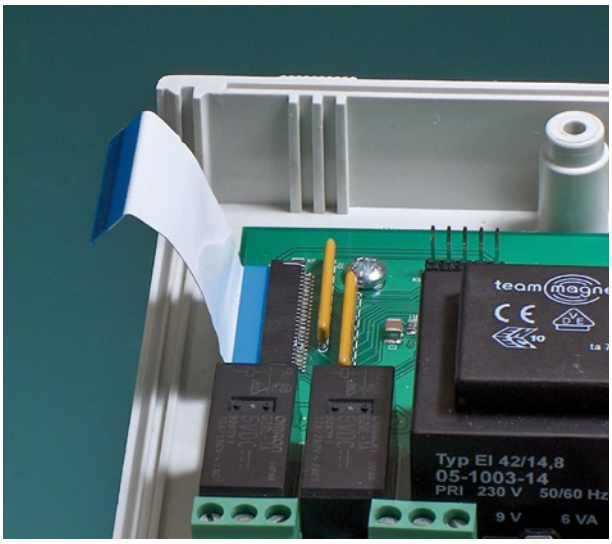
Simple job

The kit available in the Elektor Shop under part number **060234** contains all the parts for building the controller section. The only other thing you need is a cheap electric oven that you can buy from any appliance store.

A quick recap of the requirements for this oven. Use a simple analogue type, that is fitted with a mechanical thermostat and a mechanical clock. The temperature has to be adjustable to at least 225 ºC and preferably a little higher still.

It is also beneficial if the volume of the oven is as small as possible. This allows the temperature of the oven to increase rapidly. A power rating of 1.5 kW is usually enough.
There is no need to make any changes to the oven itself.





Reflow Control kit

The plug on the end of the standard power cord is replaced with the appliance connector that is included in the kit. The thermocouple from the kit is attached inside the oven.

Contents of the kit

The kit for the Reflow Control circuit contains a completely assembled main board, a display and control panel board, and an enclosure with pre-milled front and rear panels. Plus of course all the other required little bits and pieces such as thermocouple, sockets, nuts, cables, cable ties, self-adhesive feet, mains switch, IEC connectors and a mains cable.

You only need to mount the boards in the case and make a few connections between the PCBs and the sockets/switch on the rear of the box.

The kit includes a clear construction manual which gives a step-by-step description of what you have to do. Even without electronics knowledge it is easily assembled within an hour. A separate operating manual describes how to use the Reflow Control circuit. This manual also discusses the calibration, the changing of the temperature profile and drying of components ('baking') using the oven.

With this kit you can build a very handy SMD oven in no time at all. A very useful device that quite possibly you may end up using more often than your ordinary soldering iron.

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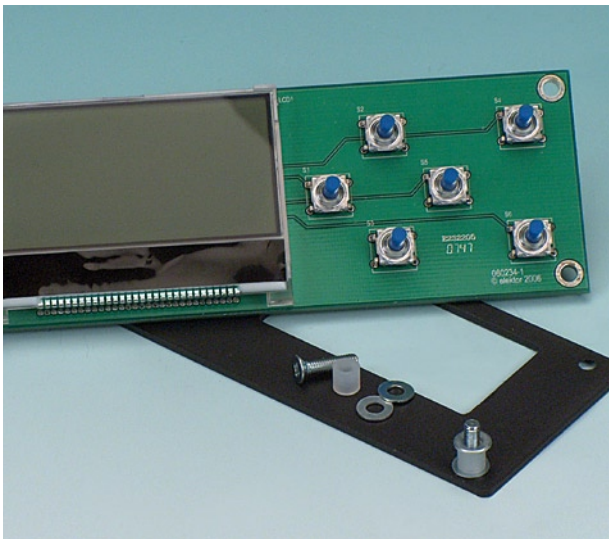
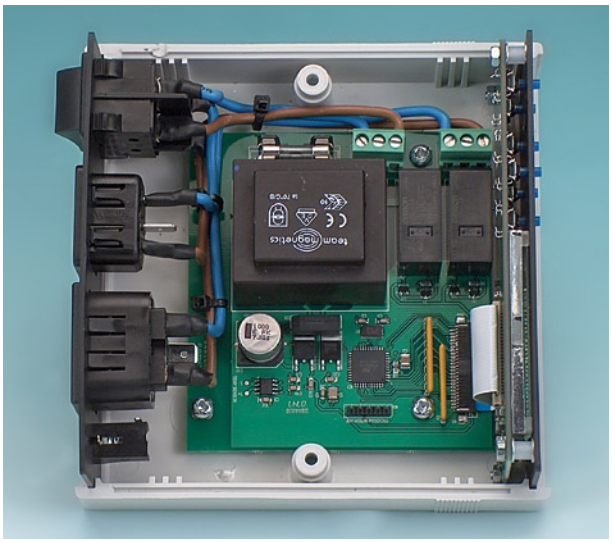
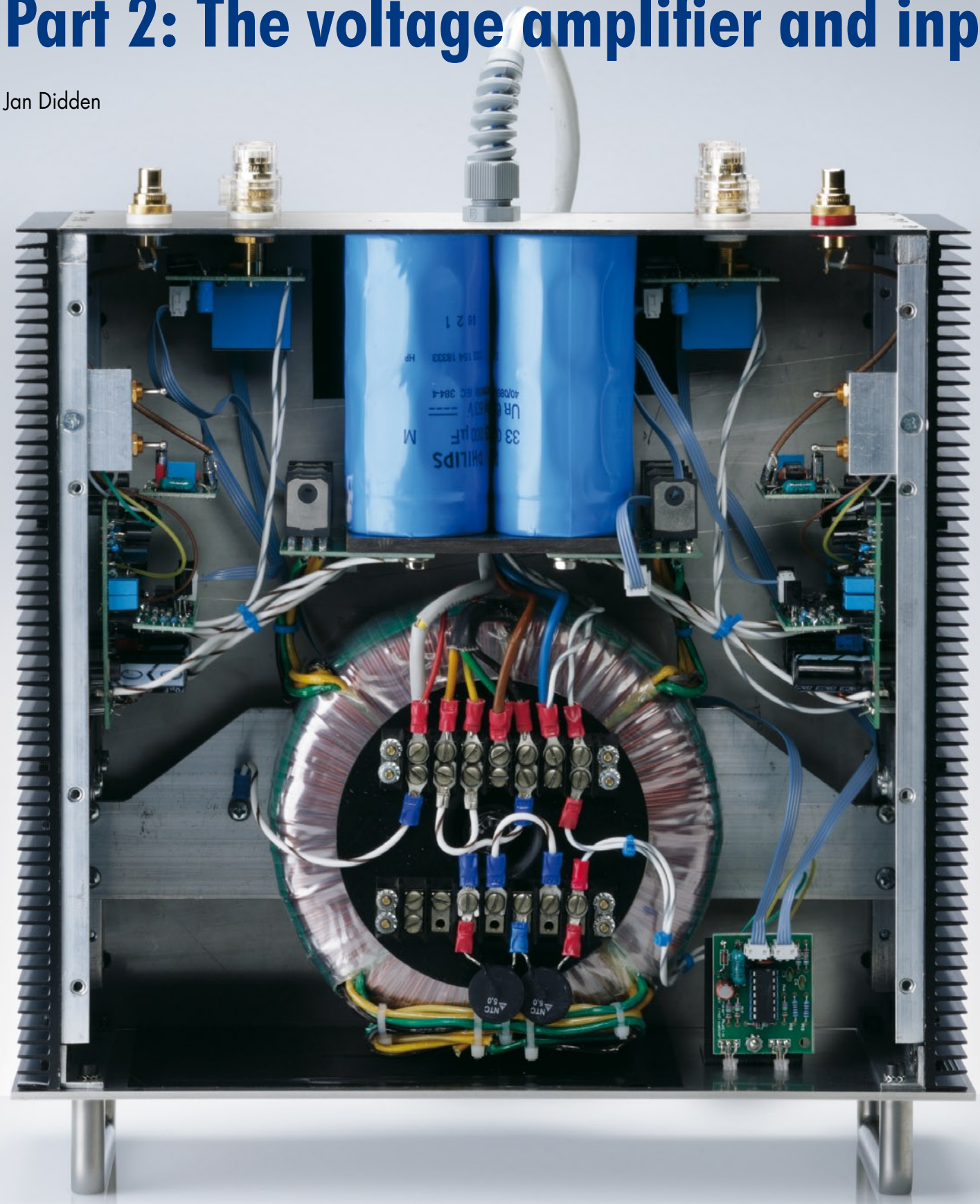




paX: a Power Amplifier w

Part 2: The voltage amplifier and input

Jan Didden



ith Error Correction

buffer stages

Last month we discussed the principle of error correction and developed an error-correction power output stage. In this instalment we will use H.ec in a voltage amplification stage and present the complete amplifier.

Let's revert to the conceptual circuit of error correction as defined by Malcolm Hawksford, shown in **Figure 1a**. We know that if summing circuits S1 and S2 are unity gain summers, we get $V_{out}=V_{in}$, an ideal gain-of-one amplifier stage. But for our voltage amplification stage (V_{as}) that drives the output stage, we need much more than unity gain. Common amplifier gains are around 26 to 30 dB, a gain of some 20 to 30 times. I like the lower value because it is better to have less gain in the power amp than to have a lot of unnecessary gain, only to turn down the volume control to get rid of it. It turns out we can use H.ec in voltage amplifiers quite easily if we insert an attenuator in the V_{out} sense leg, similar as we would do in a regular negative feedback circuit. We do that in **Figure 1b**. The sums are slightly different:

$V_c = (V_{out}/ß) - V_e$,
but still
$V_e = V_{in} - V_c$. .

Substitution and rearranging shows us that $V_{out}/V_{in}= 1/ß$. So, if we make ß, as is customary, from a simple resistive 1:20 voltage divider, we have now an amp with gain, linearised by error correction.
There is one other very important thing to note here. When we found that the open loop gain no longer is part of the amplifier transfer equation, we said that the gain of the amplifier block no longer has any bearing on the final result. That is true in theory, but not in practice. In the case of the power output stage, we said the gain is 'about 1'. A realistic value would be 0.98 at mid frequencies and light load, down to 0.95 at higher frequencies and higher loads. That means that the error correction circuit needs to add 0.02 to 0.05 times the signal level to the input to straighten out the amp. Intuitively we feel that it is advantageous to have only small signals in the error correction circuitry that helps it to work linear and with low distortion. But in the case of the V_{as}, if the forward gain block would have only a gain of 1, the error correction circuit would have to add 19 times the signal level, and it would be much more difficult to design simple circuits that could handle those levels with high linearity. So, what we would want is to make the open loop gain of the V_{as} amplifier block such that the signal levels in the error correction circuit are minimized. This will be the case when the open loop gain is as close as possible to the closed loop gain. Then, there will be quite small differences between the input of the actual amplifier and the scaled down output (by ß), and that small difference then is the error signal. This limits the signal levels in the error correction circuit, greatly relieving the burden on the H.ec loop. In other words, you set the V_{as} open loop gain as close as possible to the required amplifier closed loop gain. This of course is totally at odds with what you would do for a negative feedback amp. There, you would try to get the highest open loop gain you can get away with, stability wise, to have a lot of excess gain for the feedback loop to work with. Not so with H.ec, and a corollary to this is that your V_{as} can now be a very simple gain-of-20 amp.

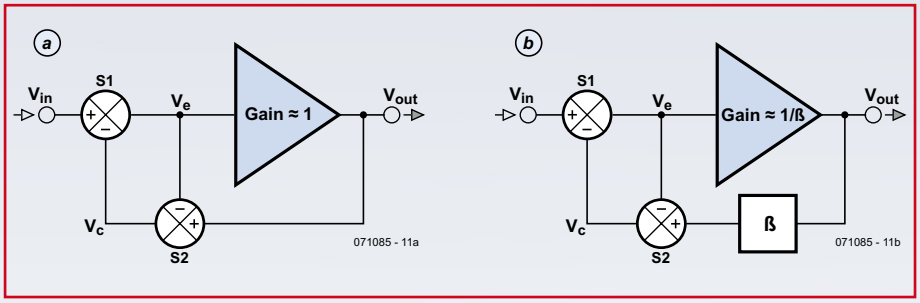


Figure 1. Basic H.ec topology for gain-of-1 stage (a) and arbitrary gain stage (b).

Voltage amplifier

The particular topology I chose is in **Figure 2**. It's very simple. U1 is a unity-gain buffer. V_{in} applied appears at the buffer output across R7. The output current through R7 comes from the supplies, of course, so we find a signal current V_{in}/R7 in the current mirrors formed by Q1 and Q3. The quiescent current for the buffer (I will tell you later which buffer type I used) happens to be about 7 mA. With an R7 value of 220 Ω, and a current of 14 mA peak-to-peak available, this buffer can handle a little over 3 V peak (about 2 V_{RMS}) before running out of class-A, which of course is good for linearity. With an amplifier gain of 20 that is enough to deliver 100 W in 8 Ω.
That same signal current in Q1 and Q3 is mirrored through Q2 and Q4, and flows through R16 to generate the output voltage. As a first approximation, because the same signal current flows through R7 and R16, and the signal across R7 is the same as V_{in}, the gain (open loop) of

this circuit is simply R16/R7 which is then set to 20. So, this is our V_{as} stage. But in the discussion in Part 1 we said that the amplifier output stage needs to be driven by a low (and constant) source impedance (ideally zero) for the output stage H.ec to work; so we add a low output impedance emitter follower stage to the basic V_{as} stage (Q10, Q9). This emitter follower stage is also biased at about 7 mA. Because of D3, the voltage drop across R6 and R8 is about the same, so if we chose R6 = R8, the same current flowing through Q2 and Q4 will flow through Q10 and Q9. D3 and D4 also provide a measure of temperature stabilization to the emitter follower output stage bias current.

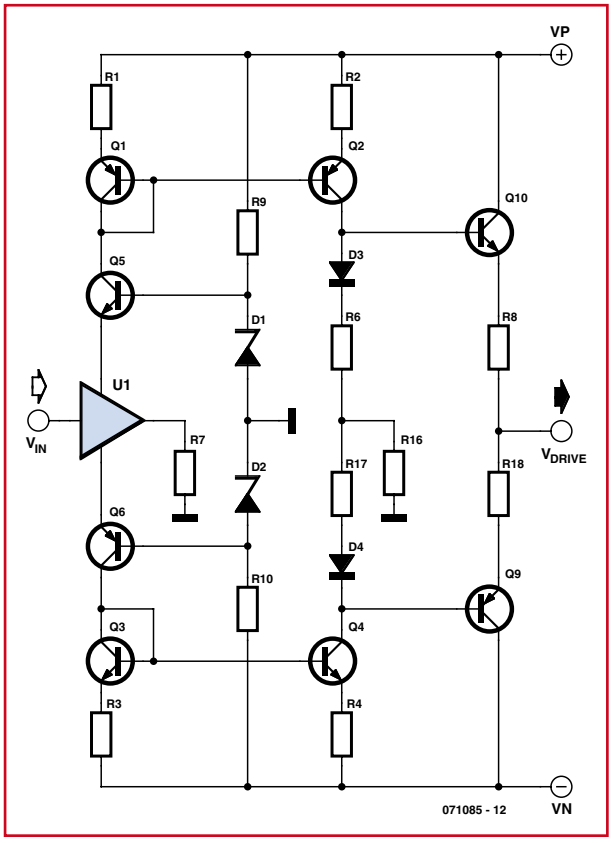


Figure 2. V_{as} basic circuit.

Now that we have the main gain block for the V_{as}, we enclose it in an error correction loop similarly as we did with the output stage: **Figure 3**. There are a few things to note here. Although both the ec sense and the ec generation resistors are given as '*R*', they are not equal. The sense resistance actually is the sum of resistor *R* plus the output resistance of the ß-network (R11//R12). It is the total resistance of R plus R11//R12 that determines the error current into the CCII. That same current generates the ec voltage when flowing through the left side *R*, and these voltages should be equal, so similarly, the left side *R* is actually the series resistance of the nominal *R* and the output resistance of whatever will drive the V_{as}. We'll revert to this issue later.

The second thing to note is that the gain of this amp is not strictly 1/ß. Terminal Y is a virtual earth point. To calculate the exact attenuation from V_{out} to the node R11, R12 and R, we need to account for the fact that for the attenuation, seen from the V_{as} output V_{drive}, *R* appears in parallel with R12. So, the attenuation, and thus the gain, is slightly higher than 1/ß. We need to consider both of these issues when we dimension the error correction sense and generation resistors. Just as with the output stage, we will use an AD844 for the ec circuit, while the buffer is used in the amplifier input stage to drive R7. The complete V_{as} circuit is shown in **Figure 4**.

What we haven't mentioned yet are the diodes D9, D12, D13 and D14. In Part 1 of this article we have discussed what would happen if we overdrive the amplifier. The positive feedback loop is regenerative and will continue to increase the input signal until stopped by some physical limit like the supply voltage or current or voltage limitations in the circuit. (We also saw in part 1 that, because of the lower open loop gain, overdrive can be expected to be less severe; but we still need to deal with it). In the V_{as} stage, this is taken care of by the four diodes across the error correction generation resistor R29 (Figure 4). When the amplifier is overdriven, the error correction current out of pin 5 of the AD844 CCII will increase considerably. This current will start to generate a large correction voltage across R29, to the point that the threshold voltage of the diodes is reached. At that point, the impedance of R29 collapses to just the dynamic diode impedance that is only a few tens of ohms. Further increases in the error correction current will not generate more error correction voltage and the positive feedback loop is broken. This makes the clipping clean, and recovery fast. But we run the risk that the diodes increase the distortion because they may already conduct a small current before the threshold, upsetting the error correction accuracy. It turns out that because of the very small error correction voltages across R29, this can be avoided. In **Figures 6 and 7** you see that if we would use a single pair of soft clipping diodes, the distortion starts to rise before maximum output. With the dual pairs, the difference is very small.

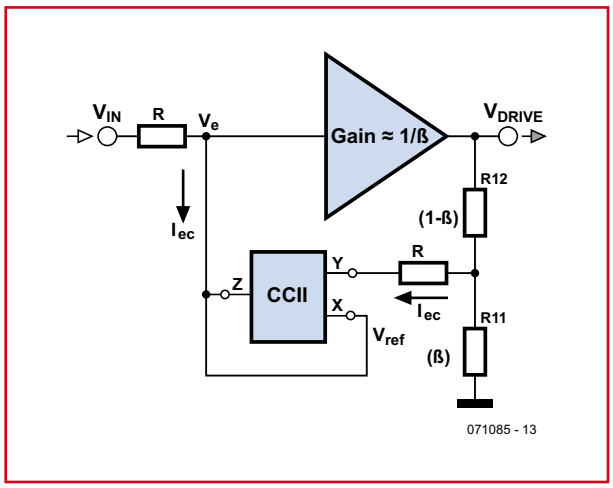


Figure 3. The CCII as the H.ec element for the V_{as} stage.

Figure 8 shows this effect from a different perspective. The soft clipping diodes for the negative signal part have been temporarily removed so only the positive signal is affected. You can see that without the diodes, clipping recovery is delayed (negative part), while with the diodes (positive part) there is only a hint of delay.

Buffer stage and DC offset

All that is needed now for a complete amplifier is the input buffer and the DC offset servo. This is shown in **Figure 5**. Just as with the output stage, we need to drive the V_{as} input resistor, which develops the ec voltage (R29), with a low impedance source. You guessed it: we will again call upon the open loop buffer in an AD844 to drive the V_{as} from V_{in}. The signal enters the buffer in U2 through R51 and R33 at pin 5 and exits at pin 6.

The enemy of your loudspeakers (and the amp as well) is DC offset at the output terminal. Most amplifiers have some sort of means to avoid that. In this amplifier, the output stage doesn't need any additional measures: the error correction ideally duplicates the driving voltage (from the V_{as})

to the output terminal, with zero offset, although there will still be some offset from the error-correcting AD844, which will generate a small DC offset of a few millivolts. The only requirement is that the V_{as} has negligible DC offset. The V_{as} however has higher gain and will amplify its own AD844 offset with that gain. I decided to implement a DC servo to keep the V_{as} offset under control. The servo uses a low offset opamp, a TL051CP. We will use the uncommitted current conveyor in that input AD844 (U2, Figure 5) to couple the servo signal to the amplifier.

The way this works is as follows. Remember that whatever current flows in or out of the low impedance input pin 2, also flows (in opposite direction) out of or into pin 5. We also know that the voltage at pins 2 and 3 will track accurately. When we couple the servo signal to the reference input pin 3, it will cause a current in R50 to keep pin 2 at the same level. That same current will flow through R33 in R49 (and R1 if the source is DC coupled), and in this way the offset correction will be added to V_{in}. R49 assures that this current, which essentially is DC, can flow even if the V_{in} comes from a coupling capacitor. Finally, this input buffer and servo amp have their own ±15 V supply from two zener diodes, D5 and D6. With this circuit, composite offset of the whole amp is just a few millivolts.

Protection circuitry

There is a separate protection system for this amplifier that protects the speakers against DC output as well as the output devices against overload. It also provides delayed switch-on and immediate switch-off. This is described in a separate article in this issue.

Power supply

The power supply for this amplifier should deliver about 2 × 44 V_{DC}. Although the output devices are rated for higher voltages, it is not advisable to increase the supply in trying to get more output power. The allowed dissipation at higher V_{ce} is much less than the rated DC dissipation due to secondary breakdown limitations of the SOA (Safe Operation Area). With loads that dip substantially below 4 Ω, even temporarily, the SOA may be exceeded and an output Darlington destroyed (or the protection activated). The supply

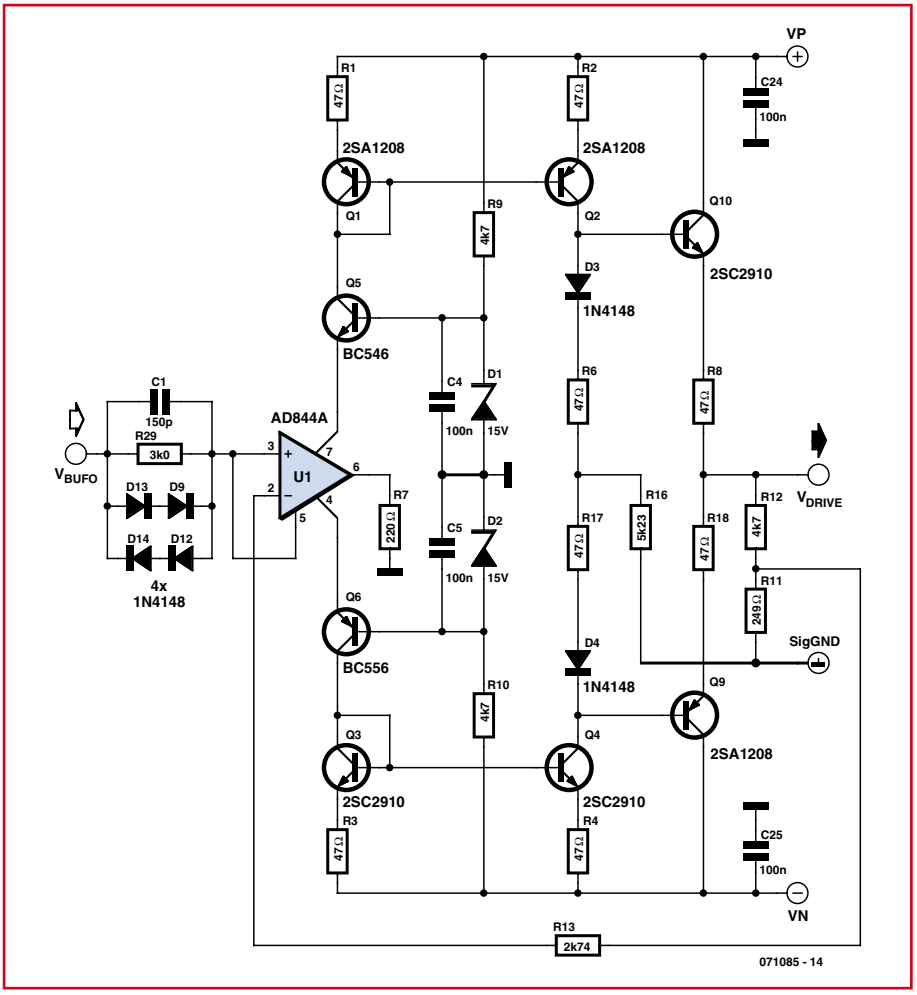


Figure 4. Full circuit of the H.ec V_{as} stage.

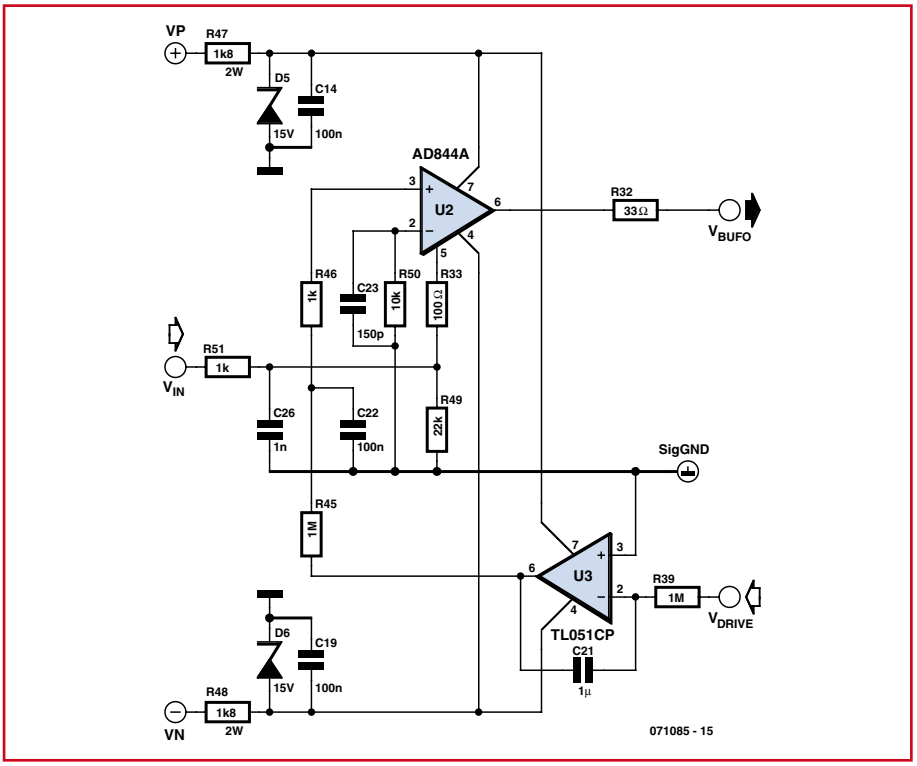


Figure 5. Input buffer and offset servo circuit to drive the V_{as} stage.

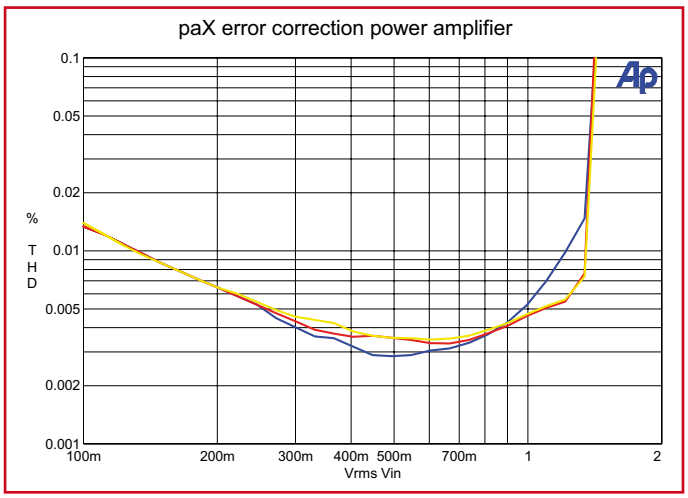


Figure 6. Amplifier distortion as a function of output level, with single diode (blue), dual diode (red) and without soft-clipper diodes (yellow).

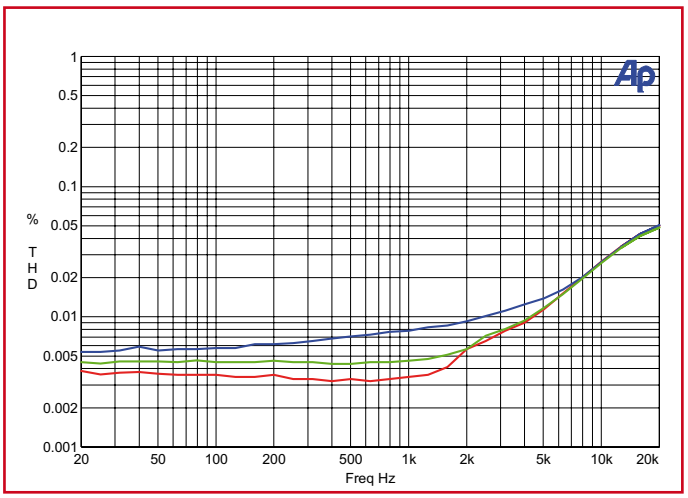


Figure 7. Amplifier distortion vs. frequency at 50 W in 8 Ω, with single diode soft clipper (blue), dual diode soft clipper (green), no soft clipper (red).

for the error correction circuit in the output stage is bootstrapped from the output; that part of the circuit can actually drive the output devices beyond the supply voltage. Consequently, it is the V_{as} that determines how close the output can get to the supply rails. Since the V_{as} will clip first, there is no clipping overdrive and overdrive delay in the output stage. The output can swing within a few volts of the supply, which is better than in most amplifiers (unless separate, higher voltage, V_{as} supplies are used).

The power supply for this amplifier is uncritical. The error correction not only corrects internal amplifier non-linearities, but also any power supply ripple or noise that makes it into the circuits. (The supplies for the error correction AD844's is stabilized separately with zener diodes). Therefore, a classic rectifier-and-reservoir capacitor supply delivering 2 × 44 V_{DC} under load is sufficient for about 100 W in 8 Ω, 200 W in 4 Ω. The power supply circuit details are given in **Figures 9 and 10**. For a stereo version, a 300 or 400 VA transformer should be sufficient; after all, you will not drive both channels at full power for a long period (except maybe on the test bench). You can use the common transformer with a centre-tapped secondary, but other configurations can also be used. One nice option for a stereo amp is to use two completely separated supplies, each with a 250 or 300 VA transformer. That would make it easier to maintain strict star point grounding.

It is important to get the grounding right. Ground currents back to the supply from the speaker, as well as from the reservoir electrolytics, can be quite large and have all kinds of ripple and noise. Such ground currents generate voltages across the ground return wiring. If the ground for the signal is connected to this ground wire at another point, you have effectively created a small ripple signal that appears in series with the input signal. This may seem far fetched, but with very low distortion and very clean amplifiers, even a few mV of these noise signals can be enough to ruin the linearity and distortion figures of an otherwise very good amplifier. Usually one tries to prevent this by using a star ground: All ground returns come together at a single point, and no signal return runs through the same ground wire with another return loop. If you look at the amplifier PCB layout you see that the power connections get to a central star point. On the PCB itself, care has been taken to do the same. There are two or three separate traces that bring the returns for the regulator zener diodes and the decoupling capacitors to the same point. The signal returns from the input network, the gain setting resistors R7, R16 and the error attenuation network R11, R12 are also brought to this point separately. All return wires from the supply, the transformer and the speaker are returned to the star ground. The signal grounds in the amplifier are then returned to this point via a low-value resistor R28, which is then by definition the 'clean' ground point (pad J1 on the PCB is the clean ground and should be used as 'ground' for measurements as well). Any error voltages generated by ripple and pulsating currents in the ground wires cannot end up in the signal, except through radiation. This in turn we can minimize by making all high-current wires short and as far away from sensitive signal areas as possible.

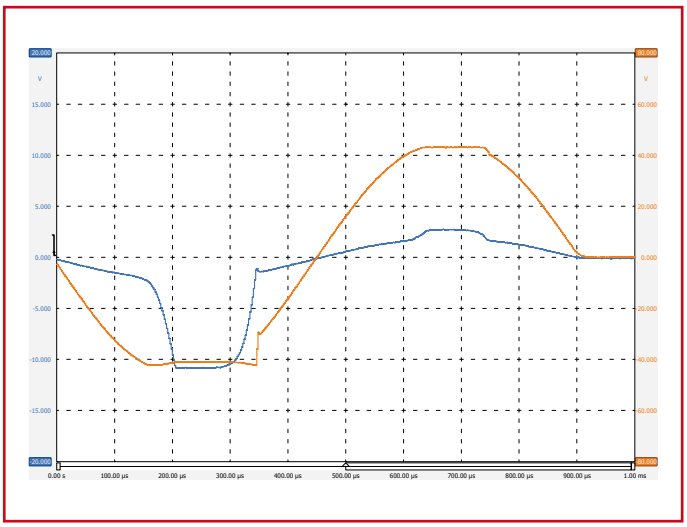


Figure 8. Error correction current (blue) and amplifier output clipping (amber) with soft clipper (positive signal) and without soft clipper (negative signal).

Finally, the rectifier diodes should be types that recover quickly from voltage reversal when switching off, and do so 'softly', that is, without very sharp current steps. Diodes that take a long time to reverse themselves and in the process generate sharp current steps may cause high-

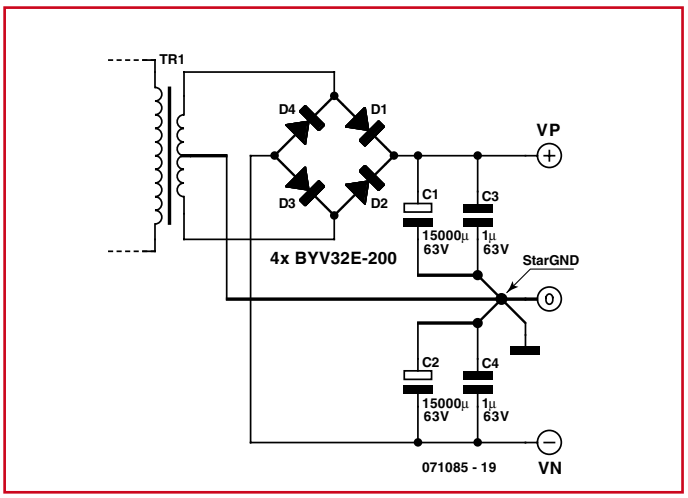


Figure 9. DC power supply. Diodes are paralleled, dual, fast, soft recovery 3-pin TO220 types.

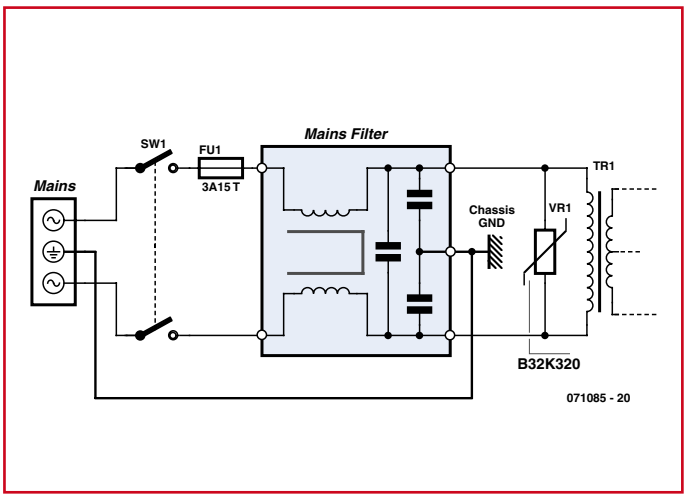


Figure 10. Mains wiring for the power supply, mains filter, overvoltage clamp and fuse.

frequency noise that is difficult to filter out. Fast, soft recovery types don't need capacitors or snubbers; indeed, such capacitors would only increase the transmission of mains-borne noise to the amplifier. My recommendation is to use Philips BYV32E-200 diodes. These are TO220 dual types with a common cathode; the two diodes should be paralleled. They have a relatively low threshold voltage, and are quite inexpensive. They don't need to be heatsinked so they can be put on a PCB in free air. For the reservoir capacitors, a minimum of 15,000 µF should be used per supply polarity. 63 V rating is adequate.

A mains filter as shown in **Figure 10** should be used to keep out high frequency noise and switching pulses riding on the mains. Good mains filters are not cheap but worthwhile; use a type with at least 6 A rating. Ground the filter ground lug as well as the mains safety ground wire to the chassis only. Use a slow-blow fuse of 3.15 A for a stereo version, larger if you use larger reservoir capacitors. A 275 V_{AC} varistor clamps any high-level pulses that make it out of the filter.

Conclusion

So, there you have it, a complete, high quality yet simple error correction power amplifier. The parts list shows all components for one (mono) amplifier. Note that the values of C11, C12, C17 and C18 (output stage) were given as 330 µF in Part I but 470 µF fits on the PCB so these should be used. A separate *Construction Guide* is available as free download from the Elektor website as archive file # **071085-w.zip**.

Although harmonic distortion measurements do not always correlate with sound quality, they do give an indication of linearity and behaviour of an amplifier. Therefore, a few performance curves are given in Figures 6 and 7. If you work in a step-by-step fashion as described in the Construction Guide, checking your work after each major part, it will help to avoid errors and, if errors are made, to quickly isolate and fix them. Also check on my website for any last-minute information, additions or corrections.

This is not a very difficult project but it provides you with an excellent amplifier, which reproduces your source music faithfully, adding nothing, taking nothing away. This amplifier is stable and will happily drive a wide range of different speakers. In short, an amplifier that will let you enjoy your music for many years to come!

(071085-I)

Additional information

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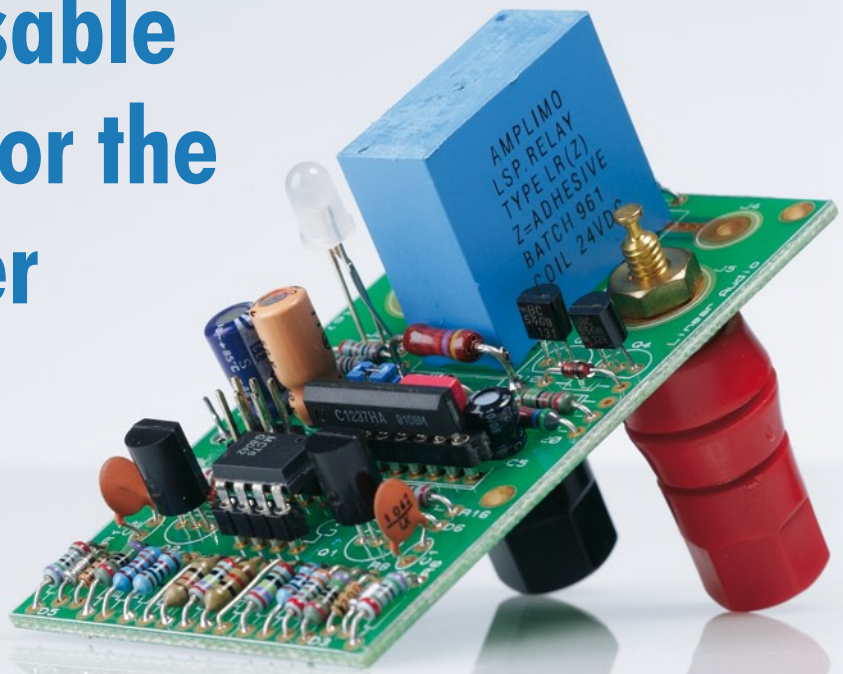


Jan Didden

In Part I and part 2 about the paX amplifier we developed a complete error-correction power amplifier. In this accompanying article a protection system is described that's constructed on a separate small circuit board for mounting directly on the speaker binding posts. We will also discuss the Safe Operation Area for the output devices and how it is modelled in the protection system.

A good protection system for an audio amplifier has two important tasks: speaker protection and amplifier overload protection. Speaker protection concerns a possible excessive DC voltage at the amp output due to either excessive ultra-low frequency signals, or from a circuit failure inside the amp. By the way, you can also get excessive DC output if you have a DC coupled power amp and your preamp gives out DC. If you go on tour with your amp, it would be wise to insert – even temporarily – some input coupling caps.

There are many convoluted circuits to disconnect the speaker from the amp through a high-power relay in case of significant DC offset at the output. These circuits often do double duty in delaying the closing of the relay until after the turn-on transient, as well as immediately opening the relay when power is switched off – again to avoid transient thumps in the loudspeaker.

I used a low-cost, purpose-designed, but not too well known IC: the uPC1237 from, among others, NEC. The NTE7100 from NTE Electronics, is pin- and functionally compatible. It's an 8-pin single-in-line (SIL) chip with all the functions mentioned above. The datasheet gives the formulas for calculating the component values. It can handle two channels for a stereo amp, but I used one chip per channel to make it easier to construct the amp as dual mono.

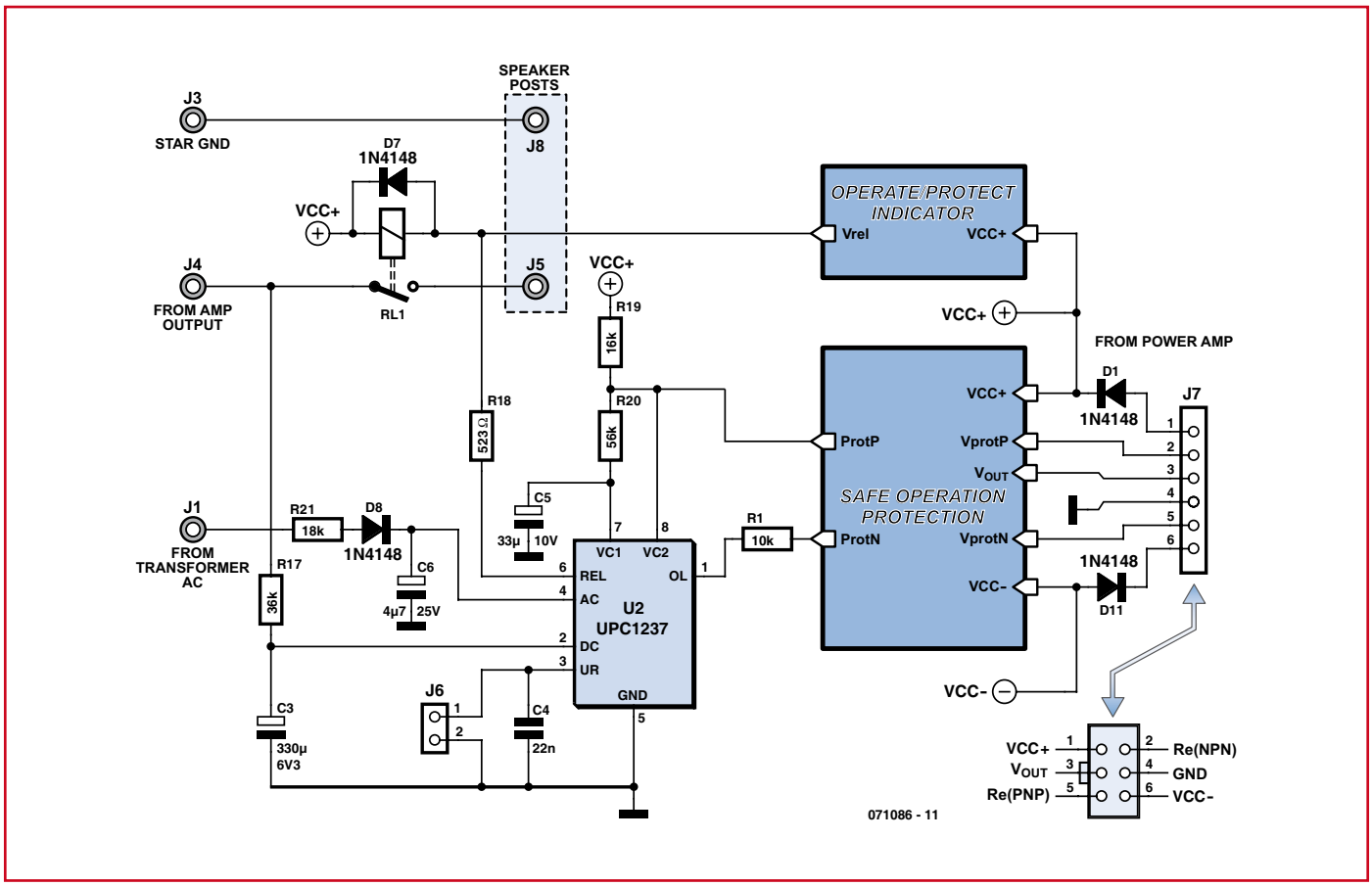


Figure 1. Overall protection system.

For the speaker relay I used a little-known device specially designed for this function and sold by the Dutch company Amplimo. The relay has two parallel internal contacts, one heavy-duty tungsten 100 A contact and a smaller gold contact pair. When the relay closes, the tungsten contact closes first, and is then bridged by the gold contact. The reverse takes place when opening the relay.

Circuit diagrams

The overall protection system is shown in **Figure 1**. The blocks for the Indicator and the Safe Operation Area protection will be described later. The uPC1237 has an internal 3.4 V shunt regulator at pin 8, and the supply current is provided by R19 and R20. The relay switching output (pin 6) drives the relay through R18. Jumper J6 sets the circuit operation. If J6 is closed, the circuit becomes 're-entrant': if there is an error input, the relay falls off, and after a short delay is activated again. If, at that point, the error has disappeared, the relay stays activated, if not, it falls off again and the cycle repeats. If J6 is not closed, the relay is deactuated when an error is present and you have to switch the power off and on again to reset the circuit.

DC offset shut-off

Pin 2 of U2 is the DC offset input. AC on the amplifier output signal is removed by R17-C3 and the DC offset is sensed. Although the uPC1237 only has a unipolar supply (the amplifier's VCC+), pin 2 does accept bipolar signals. The calculations are a bit complex because the internal positive and negative thresholds are not equal. It is all explained in the datasheet. With some care you can set the threshold for positive and negative offset to the same value at 0.6 V_{DC}. These values are set by R17 and C3 as shown in Figure 1.

Switch-on delay

You will also see that a sample of the AC from the supply transformer is connected to the uPC via R21 and D8 to C6. This part of the circuit will delay the loudspeaker switch-on after a power up to make sure the amp has stabilized and there are no switch-on thumps. When the power is turned off, this signal will disappear immediately, before the supply capacitors have a chance to discharge. This way the speaker relay will be opened before the turn-off thumps occur.

Safe Operation Area

The second main part of the protection system is to guard the output devices against excessive low impedance loads and short-circuits. Michael Kiwanuka has written a very informative article on Safe Operation Protection in audio power amplifiers [1]. My own protection circuit is different, but was inspired by Mike's design and has many things in common with it. **Figure 2** shows the circuit. The circuit receives two types of information from the power amp: the I_c in the output devices through V_{protP} and V_{protN} (via connector J7 in Figure 1): this actually is the voltage across the emitter resistors. Secondly, through the components connected to the supply and V_{out} a voltage is developed that represents V_{ce} of the output devices. (There is a separate part to this article that explains the circuit in detail and how

Calculating and setting up the protection system

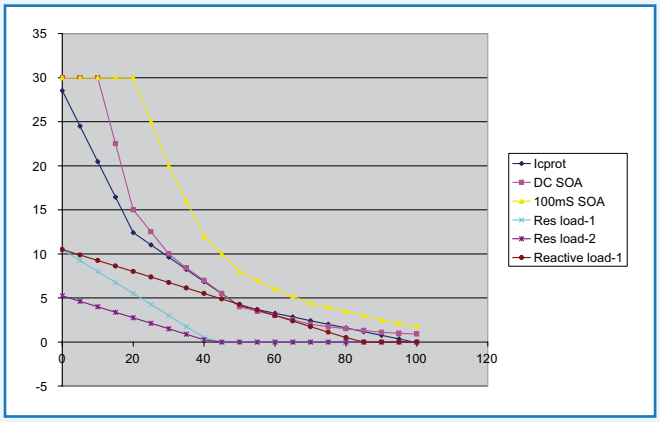


Figure 1. SOA, load lines and protection locus. See text for explanations.

The paX amplifier uses Safe Area Operation (SOA) protection. In this section we will address the specific design equations and how to develop the circuit values for the SOA part.

Figure 1 shows the various curves that we need to develop the SOA protection for two pairs of output devices. I_c (A) is on the vertical scale, V_{ce} (V) is on the horizontal scale. When V_{ce} is zero, it means that V_{out} is equal to V_{supply}. In practice, there will always a few volts V_{ce} remaining at maximum output, but we will disregard that for the moment. The cyan curve shows the safe combinations of DC I_c and V_{ce} for two parallel STD03 Sanken Darlington devices used in this amplifier. The yellow curve shows this for loads lasting no longer than 100 ms. That means that combinations of I_c and V_{ce} that fall below and to the left of the curve, are safe, but as soon as the curve is crossed, the protection system should activate. Since music is impulsive and not DC, one could argue that protection for the yellow curve would be sufficient, but if we use the cyan curve we have an additional safety factor and we also are protected against DC shorts.

Figure 1 also shows some load lines, which are combinations of I_c and V_{ce} required to drive a (resistive) load, assuming ±40 V supplies. The lower one, in pink, is an 8 Ω load, the light blue one is 4 Ω. For example, in the 4 Ω case, we see that when V_{ce} = 0, the output voltage is the supply voltage (40 V in this case) and thus I_{out} in 4 Ω is 10 A. The brown curve is also for 4 Ω load, but now with a maximum reactive component of 90° phase shift. This is a particularly mean load. At V_{ce} = 40 V we are exactly between the supplies (assuming a ±40 V supply) with V_{out} = 0. With V_{ce} = 60 V, V_{out} is actually -20 V negative but I_c is still positive (about 3 A). That means that the upper transistor (N device) sources current even with a negative V_{out}! Under these circumstances (which can happen easily with real speaker/cross-over loads) quite high V_{ce} to I_c combinations can occur although the device dissipation is very much limited as shown in the SOA cure. For instance, in this example, at V_{ce} = 60 V and I_c = 3 A, allowed dissipation (per device!) is 90 W, although the data sheet calls this a 160 W device.

So, we can put in a simple current limiter that follows, say, the 4 Ω complex load line. But then we cannot use the large safe area, especially at low V_{ce} and I_c between 10 A and 30 A, which may come handy with speaker loads that have low impedance dips. It is clear from Figure 1 that a simple current limiter is not enough. What we want is to 'model' the cyan DC curve in our circuit. This can be done with some non-linear circuit elements, and my target SOA protection curve is shown in dark blue. It has three inflexion points at V_{ce} = 20 V and V_{ce} = 50 V.

The way I implemented this is shown in ***Figure 2***, which is the positive half of the full circuit given in Figure 2 of the article about the protection circuit. (The negative part works similarly and will not be discussed). There are 4 distinct points on the blue target curve. The first and last points are defined by V_{ce}=0 and I_c=0 respectively. The other breakpoints are at V_{ce} = 20V and V_{ce} = 50 V. These two breakpoints are caused by diodes D3 (for 20 V/13 A) and D2 (for 50 V/5 A). Remember, all currents are for two parallel devices! At each breakpoint, the diode(s) start to conduct and shunt current away from R14 and R4, so that Q1 conducts later.

To calculate the component values for this rather involved circuit, we start with the simple part: if V_{ce} = 0, the maximum allowed I_c is 30 A for two output pairs. Also at this point, V_{out} = VCC+ so there is no current coming from R6/R5. The voltage to turn on Q1 comes exclusively from the voltage drop across the output devices' emitter resistors, through Rs. We need to ensure that at 30 A, the voltage at Q1 (base) is approximately 0.65 V. Although there are two emitter resistors and two Rs resistors in the circuit, they are in effect parallel, so we will use from now on Re = 0.11 Ω and Rs = 50 Ω. With 30 A through the parallel value of Re, V_{Re} = 3.3 V, which is attenuated through Rs and R4: 12/(50+12) · 3.3 = 0.64 V — close enough.

Now it gets interesting. Lets move to the breakpoint where V_{ce} = 20 V. The allowed I_c is (cyan curve) about 13 A. We assume some values and then calculate the rest: Rs=100 Ω, R4 = 12 Ω; we set R14 to 270 Ω. Let's disregard D2/R8 and D3/R7 for the moment; we just need to be sure later that that was justified (that the diodes don't conduct at up to V_{ce} = 20 V). V_{ce} = 20 V and $I_{c\,max}$ = 13 A gives an effective Vs of Vs = R4/(Rs+R4) · (Re · I_c), which, with the given values, is 0.28 V. We need V_b = 0.65 V, so the current from R5 should gener-

I calculated the various component values).

The purpose of the SOA protection is to limit the combinations of V_{ce} and I_c for the power devices to a safe value. Normally, such a protection circuit would be arranged to take away the drive from the output driver transistors to limit the available output current. The protection transistor (Q1 or Q2, Figure 2) collector would normally be connected to the base of the (pre) driver transistor in the output stage. Q1/Q2 turns on when its V_{be} exceeds about 0.65 V, shunting driver base signal away. But in my experience, even with a V_{be} of only a few 100 mV, the protection transistor starts to influence the driver base signal, resulting in increased error correction and increased distortion.

For this reason I decided to make this an on/off protection circuit: the protection transistors drive the 'overload' pin (1) of the uPC1237 through the dual optocoupler U1, an MCT6. If overload occurs, pin 1 of the uPC is set high via R1 (Figure 1) and the uPC opens the speaker relay. I have the uPC set for auto reentry by jumpering J6: in this mode, the speaker relay will be periodically closed

ate the remaining 0.37 V across R14. So this current needs to be I_{R5} = 0.37/270 or 1.37 mA, which also flows through R6 of course. With a V_{ce} of 20 V (we disregard the small V_{ce} loss across Re), that would make R5+R6 = (20-0.65)/1.37 = 14.1 kΩ. It doesn't really matter how we split up the total value (it does matter for the other values of course, but not for the functioning), so let's make them equal: R5 = 7 kΩ and R6 = 7 kΩ.

At this breakpoint, V_{ce}=20 V, diode D3 should be on the verge of conducting, so D3 should be a zener equal to the value of Vm. Since we have 1.37 mA through R6, Vm = 20 - (1.37 · 7) = 10.4 V, making D3 a 10 V zener.

Now let's move to the next point, 50 V/4 A. Analogous to the 20 V/13 A point, D2 should be on the verge of conducting so we can disregard it, and R8, for now.

As before we calculate the contribution of I_c at Vs: Vs = 12/(12+50) · (0.11 · 4) which is 85 mV, so the V_{ce}-derived current from R5 and R6 should add 0.65-0.085 = 0.565 V at Vb, therefore

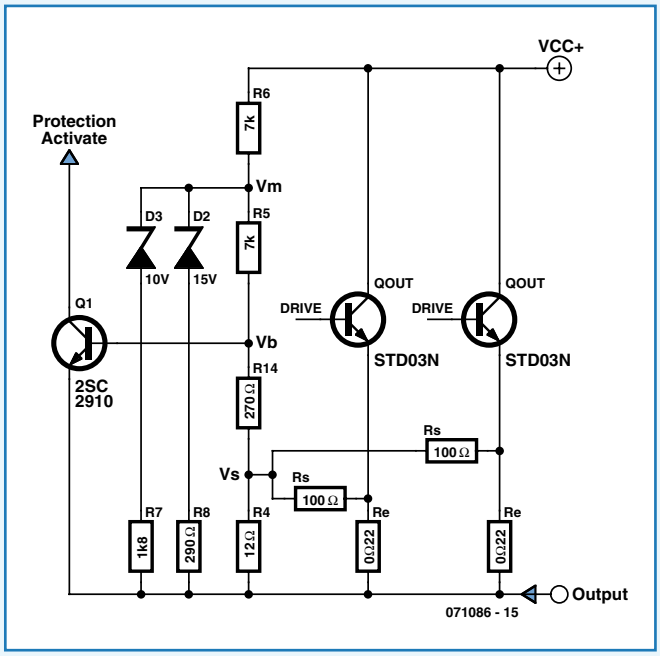


Figure 2. SOA protection circuit.

I_{R14} = 0.565/270 = 2.1 mA. This 2.1 mA also flows through R5 and R6, so Vm = 0.65+(2.1 x 7) = 15.35 V. (This of course means that D2 should be a 15 V zener, and we will use that later).

With Vm = 15.35 V and D3 a 10 V zener as calculated above, we have 5.35 V across R7. The voltage across R6 now is V_{R6} = 50-15.35 = 34.65 V, so IR6 = 34.6/7k = 5 mA. Since 2.1 mA flows through R5, 2.9 mA must flow through R7 with 5.35 V (Vm-10 V from D3) across R7, so R7 = 1.8kΩ.

Moving on now to 100 V/0 A, it gets pretty boring:

I_c=0 so there is no contribution from Re to Vs, and the V_{be} = 0.65 has to be generated by the current through R5 and R14+R4, so I_{R14+R4} = 0.65/282 = 2.3 mA. This current also flows through R5 so Vm = 2.3 · 7)+0.65 = 16.75 V.

The current through R6 is: I_{R6} = (100-16.75)/7 = 12 mA, so the excess of 12 mA-2.3 mA = 9.7 mA needs to be shunted away through D2/R8 and D3/R7.

V_{R7} = (16.75-10) = 6.75 V with R7 at 1.8 kΩ so I_{R7} = 3.75 mA, which sets I_{R8} to 9.7-3.75 = 6 mA.

V_{R8} = 16.75-15 = 1.75 V so R8 = 290 Ω.

So, there you have it, but it would be nice if there was some way to verify this before committing solder (and parts). We have disregarded several things, for instance the loss of V_{Re} for V_{ce} and several roundings in the calculations. I have developed a spreadsheet to try to double check all this (available on *www.linearaudio.nl* and *www.elektor.com*). It works backwards from what we just did: using the component values in the circuit, it calculates at each V_{ce} the Vb contribution from the current through R5, and then finds the I_c that would add just enough voltage across Re to make V_{be} = 0.65 V. Plotting those pairs of V_{ce} and I_c then should give us the actual (blue) SOA curve we wanted in the first place. What we see is that the spreadsheet shows reasonable correspondence to our values, but there are some deviations. The reason is that once I had the spreadsheet, I 'played' with the component values to get the best fit to the SOA curve, or to get 'nice' values for parts. I used a V_{CC} of 44 V and a $V_{ce(min)}$ of 2 V in the spreadsheet. Also, manipulating the R5 and R6 ratio lets you home in on standard zener values. The way to do that is to use Excel's solver to find the ratio of R5 to R6 that results in say D3 = 12 V. Some more playing then gets you to D2 = 18 V. In the end, I used the values from the spreadsheet in the actual circuit as given in the main article. Since we stayed on the safe side with the blue protection curve, small deviations won't cause disaster. Just try it, you can't break anything, but don't mess with the formulas unless you know exactly what you're doing!

I developed this spreadsheet for this particular application and did a fair amount of checking, but I cannot guarantee that it is without errors. If you find any, please let me know and I will update it, giving credit where it is due, of course.

It is not so easy to test the accuracy of such a protection system in real world, and mistakes could be expensive. So this double check of calculating the values and then working backwards to verify them is important to gain confidence in the circuit.

to see if the overload still exists, and if so, it is opened again immediately.
It can be argued that the protection system should work by limiting the output in case of overload and not by disconnecting the speakers. I would agree that for PA duty this would be preferred, but for home use it is a very minor nuisance, if at all. But doing it this way prevents influencing of the music signal by the circuit when there is no need for protection activation. Having used this amp for about a year now, I have never seen the protection system disconnect the speakers, except in one case where I had a problem with a balanced cable which put a signal with 2.5 V_{DC} on the amplifier input. I immediately heard the on-off cycling of the amplifier, so I switched it off and managed to find the problem. After solving the problem all was as it should be. So, for me, this works quite well.

Status indicator

Then, lastly, there is a small bi-stable circuit that takes the relay drive voltage to drive a bi-colour LED which you can place on the front panel. The LED will be one colour when the amplifier is in turn-on delay or in protection and another colour if the amplifier is oper-

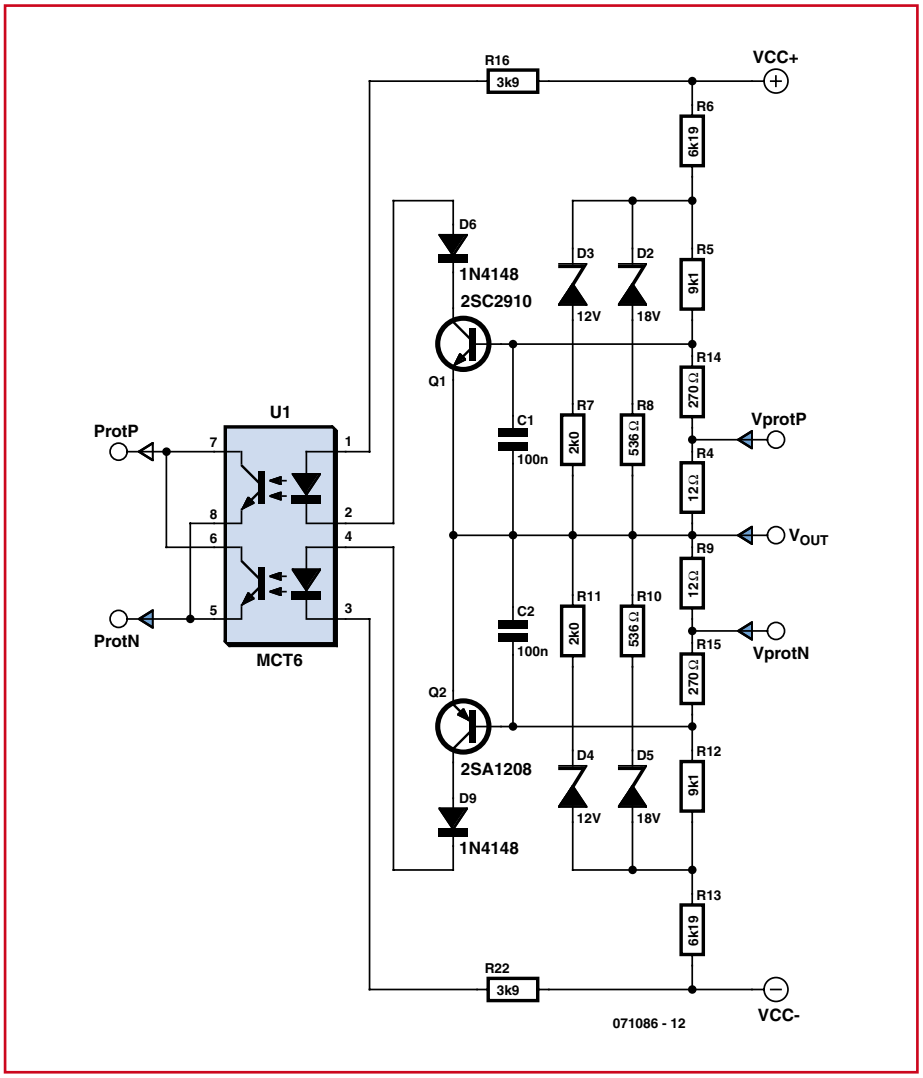


Figure 2. Safe Area Protection system.

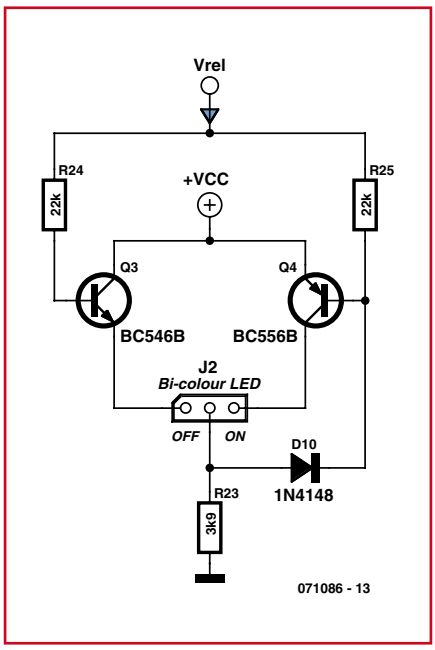


Figure 3. Status indicator.

ating normally. This circuit is shown in **Figure 3**. All components shown in figures 1, 2 and 3 are on the output/protection (o/p) board shown in **Figure 4**.

Construction

Before building the o/p board, first complete the amplifier. We need the amplifier to test the o/p board. The o/p board can be populated first with the DC and delay circuitry around U2. Start with the components shown in Figure 1.

Next, construct the 6-wire flatcable as shown in Figure 1 in the Construction Guide. Be sure to orient the notches in the 6-pin headers exactly as shown! Connect the two boards with the flatcable, again noting the header notch position as indicated on the PCB silk screen. Also connect one side of the power transformer secondary (the AC point) to the protection board at J1 as shown. Don't connect a speaker yet, and don't yet connect the speaker wire from the amp to the protection circuit. Now, when you switch on the amplifier, you should hear the relay pull in after a few seconds. If you find it too fast, you can increase C6 for a longer delay. If you switch off the amp, the relay should immediately open again.

Next we will check the DC offset protection. Temporarily connect a resistor of 100 kΩ from the positive or the negative supply to the speaker input point on the protection board (J4). The relay should deactuate. Check this with both J6 set and removed to verify correct operation.
Then, install all components for the status indicator in Figure 3.

The PCB has labels 'ON' and 'OFF' at J2. That indicates which pin will be active at which status. If you use a red/green LED you would connect the RED pin to J2/OFF and the GREEN pin to J2/ON. You may want to repeat one of the tests described above to verify the correct operation of the status indicator.

The last part will be to complete the Safe Operation Area (SOA) protection components. Put all remaining parts on the protection board. Connect the flat cable, and connect the speaker output from the amplifier (Amplifier J3 to o/p board J4), as well as the star ground wire (o/p J3 to supply star ground).

Switch on the amplifier and verify that it works normally. Then, to simulate an overload situation, connect a resistor of 10 kΩ between the positive supply and the node Q1(base)/R14/R5/ C1 and verify that the relay falls off. Do the same with the negative supply and the node Q2(base)/R12/R15/C2.

Note: If you do not mount the o/p board directly on the speaker output posts, you can connect the speaker return wire directly from the output post to the supply star ground without going through the o/p board. The loudspeaker's 'hot' connection then goes from the o/p board J8 to the output post.

Stand-alone!

This article focused on using this o/p board with my 'paX' amplifier. But you can use it with any amplifier, provided you adjust the SOA circuit values as re-

COMPONENTS LIST

Resistors
(0.25W metal film)
R1 = 10kΩ
R4,R9 = 12Ω
R5,R12 = 8kΩ2
R6,R13 = 6kΩ2
R7,R11 = 2kΩ0
R8,R10 = 560Ω
R14,R15 = 270Ω
R16,R22 = 3kΩ9
R17 = 36kΩ
R18 = 510Ω
R19 = 16kΩ
R20 = 56kΩ
R21 = 18kΩ
R24,R25 = 22kΩ
R23 = 3.9kΩ 1W

Capacitors
C1,C2 = 100nF ceramic
C3 = 330μF 6.3V
C4 = 22nF ceramic
C5 = 33μF 10V
C6 = 4μF7 25V

Semiconductors
D1,D6-D11 = 1N4148
D2,D5 = zener diode 18V 0.5W
D3,D4 = zener diode 12V 0.5W
J2 = dual colour LED
Q1 = 2SC2910
Q2 = 2SA1208
Q3 = BC546B
Q4 = BC556B
U1 = MCT6 (Fairchild)
U2 = UPC1237 (NEC) or NTE7100 (NTE Electronics)

Miscellaneous
J6 = header 2 x 1 pin
J7 = 2 x 3 pin DIL flatcable header
RL1 = Amplimo LS relay
DIL socket 2 x 4
SIL socket 1 x 8 pin
PCB, # 071086-1 from the author or www.thepcbshop.com

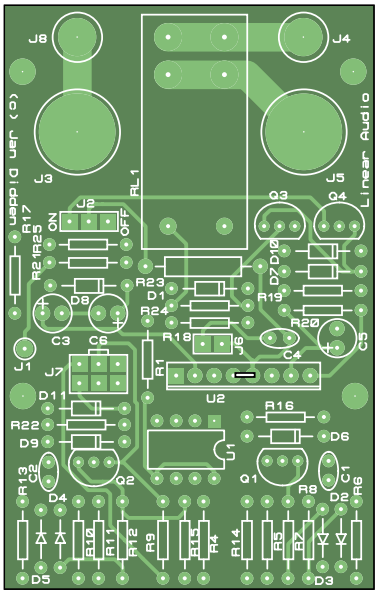


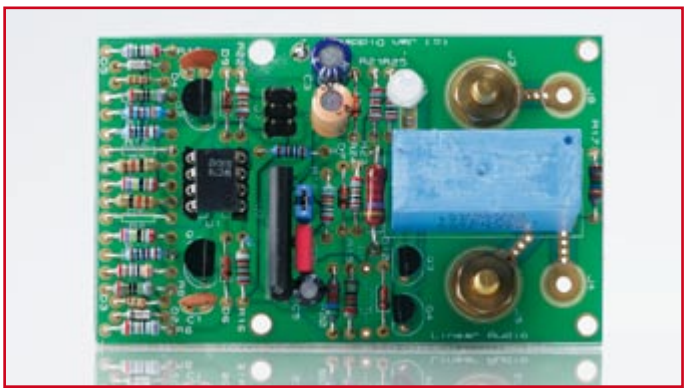
Figure 4. Component placement of the double-sided PCB for the o/p board.

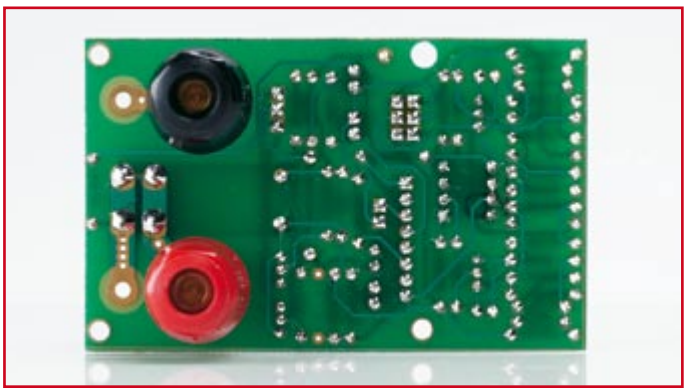
quired, as described separately. The inset in Figure 1 shows the connections you need to make from your amplifier to the o/p board through J7.

(071086-I)

Literature

[1] Transparent V-I Protection in Audio Power Amplifiers, Michael Kiwanuka. Electronics World, October 2002.





Advertisement

MikroElektronika EasyPIC5 Development System

Jan Buiting

Out of Belgrade comes a vast line of microcontroller development tools and related goodies that's sure to make microcontroller geeks drool and students and other beginners start examining their wallets, savings or budgets — the prices sure are attractive! We examined EasyPIC5, one of the flagship dev kits from MikroElektronika.

Many moons ago, development systems for microcontrollers were supplied by none other than … the manufacturers of the relevant devices. Alas, these kits were expensive or hard to come by if you were not a journalist/reviewer or a manager commanding 20 or more staff in the product design department. Also, in the early days, manufacturer-specific dev kits, although comprehensive and with technically fine contents, would give you an uneasy feeling of being chained to, again, the microcontroller manufacturer for support and hardware extensions ("sure, that can be done with our product xyz, I'll connect you to sales…").

Today, that's changed a lot and anyone with a reasonably defined target for hardware product development, or an educational interest, should be able to buy microcontroller development systems that can be relied on to give a head start. Although prices generally have come down, the link to the device manufacturer seems inevitable. Or is it?

Unpacking

The EasyPIC5 box is compact yet sturdy and in general shows good packaging standards applied. The board, measuring 25×21 cms and having rounded corners, struck me a as well laid out and extremely solid (it's 3 mm thick). It has lots of useful markings on the silkscreen overlay and, remarkably in this day and age, no SMD parts except one voltage regulator. The general finish of the board is superb — no hand-soldered wires or knifed PCB tracks revealing design errors a.k.a. 'h/w revisions'. A pity, though, some of the jumper setting instructions are obscured when the graphic LCD (GLCD) is installed on the board.

The review board came with the 2×16 character LCD and DS1820 temperature sensor in a separate package — this is an optional add-on costing $15 extra. MikroElektronika sell a variety of optional add-ons for the board, including a touchpanel and a 128×64 pixel graphic LCD. At $24 and $7 respectively these items are good value for money and it seems wise to order them straight away with the EasyPIC5. Other add-ons include CAN, SmartMP3, RS485, Ethernet and irDA.
A remarkable built-in feature of the board is called MikroICD. This in-circuit debugger allows you to monitor (on your PC), the state of all registers inside the MPU while it executes object code. The associated PC software called PICFlash2 is a free download as well as supplied on CD.

Besides the EasyPIC5 User Manual, the box also contains 'hard copy' i.e. printed documentation of the PICFlash2 and mikroICD utilities — a rare find in this day and age of CD-ROMs and Internet. All printed matter is bright, copiously illustrated and has a consistent layout and use of colours, from the Quick Start leaflet right up to the print on the CD-ROM.

EasyPIC5 overview

Despite claims in favour of competing devices, Microchip PIC microcontrollers have a leading position in terms of acceptance among not only enthusiasts and students, but also seasoned workers in the embedded industry. At the heart of the EasyPIC5 board sits a PIC16F877 in its 40-way DIP case. However you can remove it — besides the DIP40 socket, DIP20, DIP18, DIP14 and DIP8 sockets are available on the board to take PICs with fewer pins. The EasyPIC5 documentation tells you which are suitable.

I/O-wise the PIC is totally accessible with all its ports bonded not only to connectors and DIP switch arrays but also LEDs for easy visualisation of logic states as you program along (and make errors!). Input to the digital ports is easy to simulate by means of 36 pushbuttons labelled with port line names. The analogue world is not forgotten either with PIC pins RA0-R5 on pinheaders and two potentiometers on the board to simulate discrete analogue levels between 0 and 5 V.
For higher level connectivity, the board has RS232, PS/2, USB and a 4-digit 7-segment display, not forgetting the USB comprised in the MikroICD of course.

Hardware fans will like to know that the complete schematic and board layout of EasyPIC5 may be found on the CD in the kit.

At $129 (plus P&P and options) and the dollar in the toilet at the time of writing, EasyPIC5 is good value for money.

POS and NEG

My only criticism of the EasyPIC5 kit proper is that the 2x16 LCD and the DS1820 should have been included in the package instead of supplied as an option at $15 extra. These add-ons make for a lively start for first time users like myself. I took the DS1820 temperature sensor project as my first attempt to use the board and it was up and running in less than half an hour, including a short experiment with the MikroICD feature.

The kit and the software tools supplied succeed in freeing your mind from hardware intricacies and instead concentrating on software and understanding and optimising the PIC code (in that order). For example, using MikroBasic it wasn't too much trouble to program three temperature levels at which PIC output lines are activated. When I got the hang of it, cheerfully debugging an associated indication using the 7-segment LED display, I was told to stop and finish this review.

At $129 (plus P&P and options) and the dollar in the toilet at the time of writing, EasyPIC5 is good value for money. A wide distributor network is available as well as support, both directly from MikroElektronika themselves and from knowledgeable users in their online Forum, where critical users are not shunned either and all the latest on updates etc. can be found. Further encouraging points to mention are the neatly produced manuals, the non-SMD approach, the wide range of low-cost add-on boards, and a fine selection of get-you-going examples. Users will also appreciate the trial versions of MikroC, MikroPascal and MikroBasic on the CD with the kit. Registration keys for these compliers can be obtained online from MikroElektronika.

(071070-I)

Web Links

MikroElektronika: www.mikroe.com
UK distributor: www.paltronix.com
US distributor: www.circuit-ed.com

Tiny Counter

Jochen Brüning

Frequency counter module using ATtiny2313

Most small function and signal generators do not have a very accurate frequency control and do not offer a built-in frequency counter. Help is at hand with the tiny frequency counter module described here, which consists essentially of just an ATtiny2313 microcontroller and an LCD panel. The microcontroller is clocked at 20 MHz, and so the counter module can be used at frequencies of up to 5 MHz without the need for a prescaler.

This counter module is therefore ideal for retrofitting to an existing signal generator or as the main component of a tiny self-contained frequency meter. In the former case it will probably be possible to derive power for the module from the unit's own power supply, and the signal input of the module is best connected to an existing square-wave (5 V level) output. The display ranges from 0 Hz to 5 MHz with automatic selection between units of Hz, kHz and MHz according to the input frequency.

Mini counter

The starting point for the module described here was the minimalist 1 MHz frequency counter design by Hergen Breitzke described in the July/August 2005 issue of *Elektor Electronics* [1]. That design employed an AT90S2313 programmed using the BASCOM AVR Basic compiler. This version is based on the same principles but uses an ATtiny2313 rather than the AT90S2313. The newer device can be clocked at up to 20 MHz, which allows us to extend the maximum frequency from 1 MHz to 5 MHz. Fortunately 20 MHz crystals are readily available off-the-shelf. The processor clock speed directly determines the maximum frequency that can be counted: according to the datasheet, the maximum allowable frequency at the counter input pin is one quarter of the processor clock frequency, and this is how the 5 MHz limit arises.

To make the display as easy to read as possible the frequency value is shown in MHz, kHz or Hz as appro-

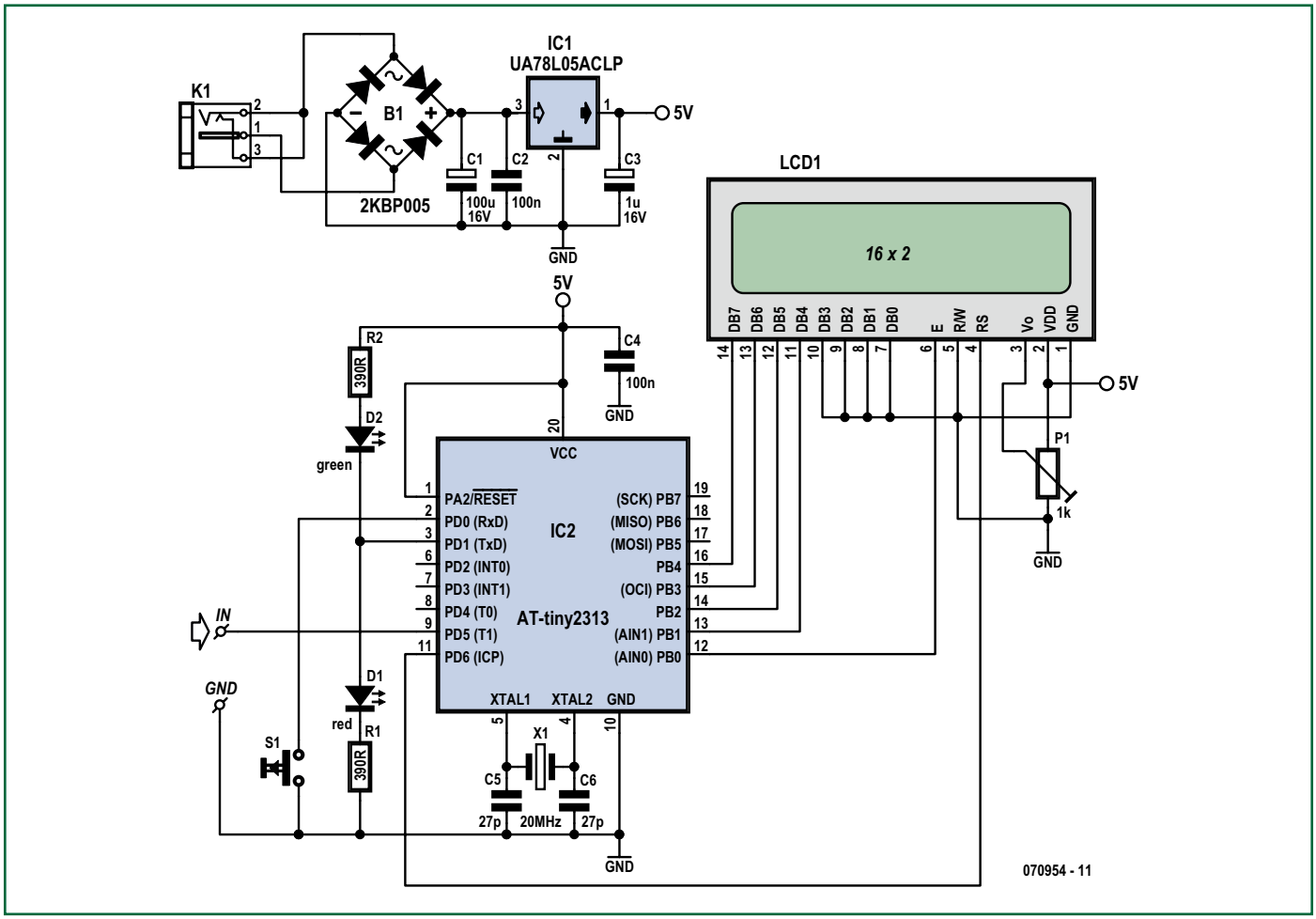


Figure 1. As can be seen from the circuit diagram, the frequency counter consists of just a microcontroller with accompanying voltage regulator and LCD panel.

priate, with the decimal point being shifted as needed. The display does not change to and fro rapidly when the unit switches between ranges.

The frequency value is deliberately shown as only five digits. In the highest range (MHz) the 10 Hz and 1 Hz digits are suppressed so that the display is steady and easy to read. If required, the software can easily be modified to show these digits. The hex file and source code for the software are naturally available as a free download from the *Elektor* website.

It is also possible to cause the suppressed digits to appear without modifying the software. The circuit diagram in **Figure 1** shows a button (S1) connected to pin 2 of the microcontroller. When the button is pressed and pin 2 is taken to ground, the counter will show the 10 Hz and 1 Hz digits when in the MHz range. A switch could be used instead of the button or, if this facility is not required, the button could simply be omitted altogether.

Construction

As can be seen from the circuit diagram in Figure 1, there are no special components in the design and the unit is very simple, consisting essentially of just the microcontroller, a voltage regulator IC and the LCD panel.
Just a few components are required to support the operation of the microcon-

Features

- Frequency range 0 Hz to 5 MHz
- Accuracy dependent on crystal, typically 50 ppm to 100 ppm
- Display in units of Hz, kHz or MHz with automatic selection
- Stable display even when range changes
- Selectable 5-digit or 7-digit display using pushbutton
- Indication of gate open and display update via red and green LEDs
- Power supply: 5 V DC regulated or 6 V to 9 V AC or 9 V to 12 V DC unregulated
- Current consumption approximately 40 mA (when display specified in parts list is used)
- Simple construction
- No SMDs, no special components
- Printed circuit board and ready-programmed microcontroller available
- Hex file, source code for software and printed circuit board layout available for free download from *www.elektor.com*.

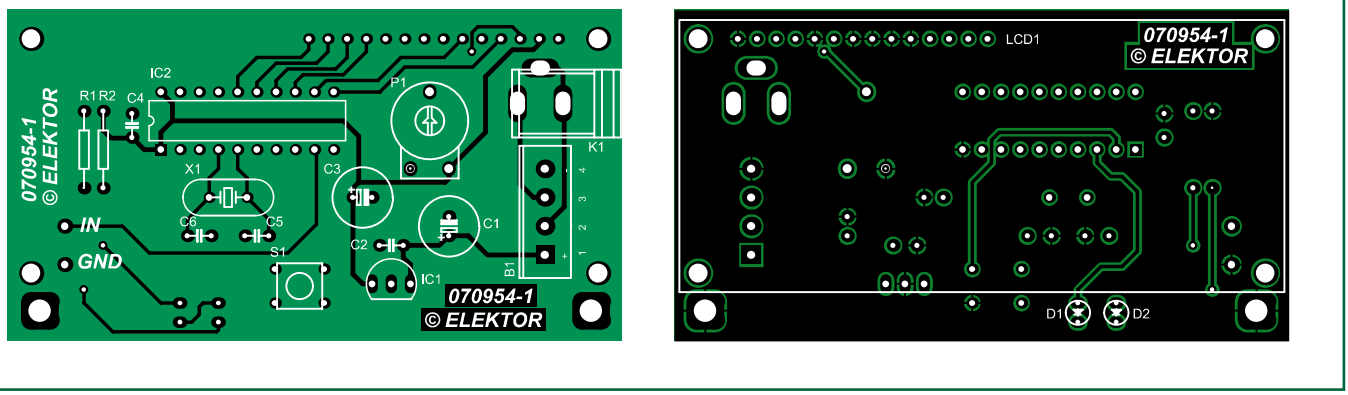


Figure 2. The double-sided printed circuit board for the frequency counter module. There are no SMDs in the design.

Components list

Resistors
R1,R2 = 390Ω
P1 = 1kΩ preset

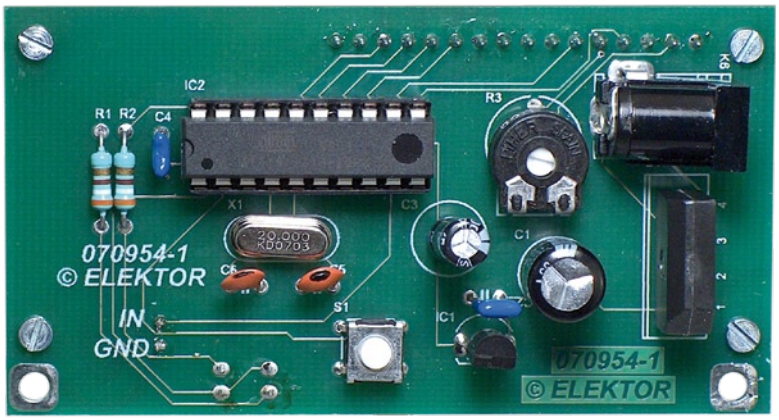
Capacitors
C1 = 100µF 25V radial
C2,C4 = 100nF
C3 = 1µF 25V radial
C5,C6 = 27pF

Semiconductors
IC1 = 78L05
IC2 = ATtiny2313, programmed, Elektor Shop # **070954-41**
B1 = 2KBP005
D1 = LED, 3mm, red
D2 = LED, 3mm, green

Miscellaneous
LCD1 = LCD module, 2 x 16 characters, e.g. Displaytech 162
X1 = 20MHz quartz crystal
S1 = miniature PCB mount switch
K1 = mains adapter socket, PCB mount
14-way pinheader, 1 row, lead pitch 2.54 mm
2 solder pins
PCB, ref. **070954-1**
Software and PCB layout, free download from www.elektor.com

troller: decoupling capacitor C4, and crystal X1 along with load capacitors C5 and C6. We allow ourselves the luxury of two LEDs connected to a spare processor pin. These light alternately in synchrony with the gate time of the counter (which is fixed at 1 s). The red LED lights when a measurement is taking place, and the green LED lights when the reading is transferred to the display. If the signal source has a very stable frequency, the display will not change from reading to reading, and the LEDs then give comfort that measurements are indeed taking place.

A socket (K1) is provided on the printed circuit board (**Figure 2**) to connect a mains adaptor. The power supply circuit consists of a bridge rectifier (B1), a smoothing capacitor (C1) and a 5 V regulator (IC1) with a further smoothing capacitor (C3) at its output. The bridge rectifier suggested in the parts list can be replaced by four individual type 1N4001 diodes arranged as shown in the circuit diagram. Because a full-wave rectifier is used, the circuit can be powered from an AC source (6 V to 9 V) or a DC source (9 V to 12 V) of either polarity. Current consumption is only around 40 mA if the display specified in the parts list is used, and so even the smallest of mains adaptors will be adequate. If the counter module is installed in a device that already has a regulated 5 V supply, components IC1, C1, C2, B1 and K1 can be omitted and power wired directly to the pin of IC1 connected to the positive side of capacitor C3 and to ground.



The double-sided printed circuit board uses no SMDs and all but three components are mounted on the top side of the board. The LCD panel is mounted on the back of the board, connected using a 14-way header and secured using four screws (see photographs). The two LEDs (D1 and D2) are also mounted on the back of the board so that they face the same way as the LCD.

In operation

Before applying power, check that all the components have been fitted correctly and inspect all the solder joints. When power is applied the two LEDs should flash once

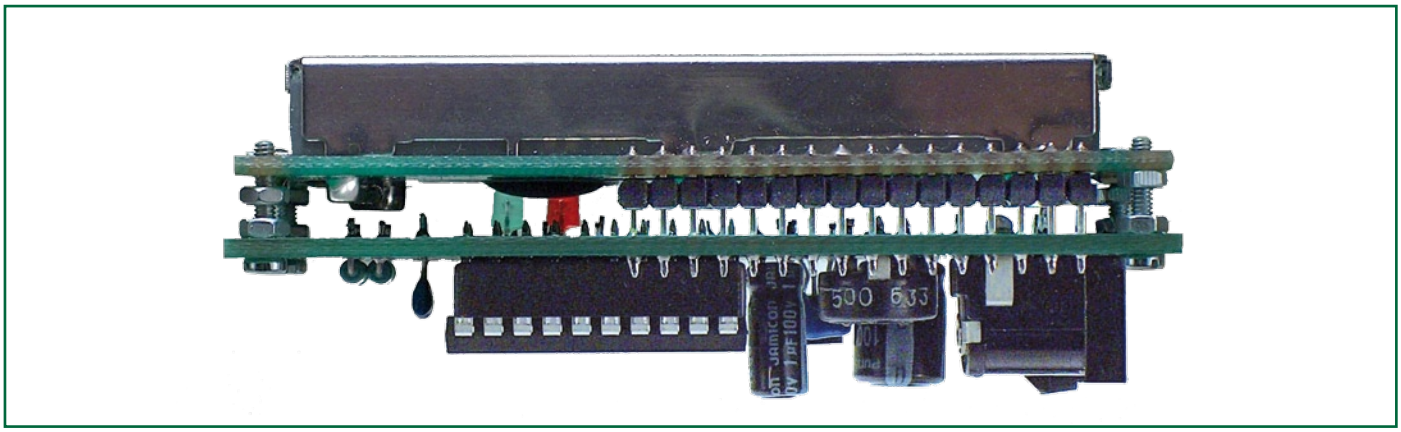


Figure 3. Prototype of the frequency counter module. The two-line LCD panel is mounted on the back of the board using a 14-way pinheader, and is secured using four screws.

per second as described above, and, if the input is shorted to ground, the display should show 0 Hz. If the input is allowed to float it will probably pick up mains hum (a piece of wire can be used as an antenna to help) and the counter will read 50 Hz.

If the display is blank, the problem can most likely be rectified using the only adjustment point on the module: display contrast potentiometer P1.

If a TTL-level square-wave signal with a frequency of at most 5 MHz is now connected to the input its frequency should be displayed. The accuracy of the reading depends on that of the processor clock frequency, which in turn depends on the crystal. An error of 100 ppm in the crystal frequency corresponds to a measurement error of 100 Hz at 1 MHz, and a crystal error of 50 ppm corresponds to 50 Hz at 1 MHz. In the audio frequency range an accuracy of better than 1 Hz can be expected.

For applications where a TTL-level signal is not available a small preamplifier is required to produce the necessary square wave. We will be addressing the subject of preamplifiers and prescalers for frequency counters in *Elektor* in the near future.

(070954-I)

Figure 4. The units used for displayed switch automatically between (a) Hz, (b) kHz, and (c) MHz, according to the input frequency.

Reference

[1] 1 MHz Frequency Counter, *Elektor Electronics*, July/August 2005, p. 100.

Where is the counter?

In order to measure frequency the circuit needs a timer to define the gate time and a counter to count the number of pulses that arrive during the gate time. However, there is no counter in the circuit diagram, just a microcontroller IC.

The solution to this puzzle is that the counters are inside the microcontroller. There are two internal hardware counters, one of eight bits and one of 16 bits, which can be configured as timers or as counters at will. In our application the 16-bit counter is configured to count the 5 V (TTL- or CMOS-level) pulses that appear on input pin 9. The maximum value that the counter can store is 65535, and this limit is overcome by arranging for an interrupt to occur each time the counter overflows. The number of interrupts that occurs is counted in the interrupt service routine (ISR). At the end of the gate time the interrupt count is multiplied by 65536 and added to the current counter value. If the gate time is one second, the result will then be the input frequency in Hz:

f = interrupt count x 65536 + Timer1 value

The gate time is derived using the 8-bit counter, which is configured as a timer with a divide-by-1024 prescaler. In this way the 20 MHz processor clock is divided down to create a constant gate time of one second.

Measuring on the PC Display

Software for measuring purposes

Cris Badea & Thijs Beckers

Virtually every computer these days is equipped with a reasonably decent sound card. In addition to its audio uses it can also be used for measuring purposes. Install the appropriate software and you have a versatile measuring instrument that can accomplish the most complicated measurements in no time. But which software is the most appropriate? In this article we help you get oriented by giving you an overview of what can be found out there.

Computers nowadays are fast enough to be useful for making measurements. That is a far cry from 20 years ago when a computer had a 286 processor, 1 MB of memory and a 10 MB hard disc. But now, when we have all those gigabytes and gigahertz at our disposal we can very easily do FFT and other complicated calculations in near 'real-time'. What follows is a selection of software packages that have been purposely developed for transforming a PC into a test instrument.

Different purposes

Within this limited group of software applications a further division can be made into three subgroups: software that is

intended for the design of loudspeakers and to make spatial measurements of loudspeakers, software which is designed for general purpose electronic measurements and software intended specifically for audio measurements. There is actually a further subgroup of software that specialises in the acoustic measurement of rooms, but we have included these with the loudspeaker design software.
For this evaluation we used an RME Multiface [1] card. This card is supplied with various drivers such as MME, WDM and ASIO2. The Multiface is capable of sampling 24-bit signals at 96 kHz with a latency of 0.37 ms. This makes this card very interesting for 'fast' measurements such as MLS-measurements (Maximum Length Sequence). The card has 8 analogue inputs and outputs. This makes the card also of interest when more than two channels need to be measured, for example when testing 5.1-configurations, where the perfect position of the loudspeakers needs to be determined for a particular room.

Loudspeaker design and room simulation

When designing a loudspeaker it is important that the frequency characteristic and the impulse response of the loudspeaker are either known already or can be measured. The impulse response of the room used for the test is also very important, since this affects the acoustics. In recording studios, for example, special attention is paid to the design of the room and what effect this has on the sound.
Measuring the frequency characteristic is very simple in principle. Connect a noise source to the loudspeaker and measure the frequency response with a measuring microphone and a spectrum analyser. It is best to do this in a 'dead room', a room that is virtually free of reflections and rejects practically all sound from the outside. Except that this situation is not very realistic in practice. You don't listen to music at home in a dead room now, do you?
So it is preferable to do the tests in the listening room itself. And if that happens to be your living room than it would be nice if the barking dog next door or the car that happens to drive past are not included in the measurement. The MLS measurement has been invented to allow all disturbing influences from outside the measurement to be excluded. With this measurement technique all parameters are derived from the impulse response.
The Maximum Length Sequence is a periodic pseudo-random binary sequence that functions as the test signal. This signal can be generated using a shift register with feedback. It is possible to mathematically calculate the ratio between the sent and received (measured) signals. The result is a curve with information about the source or the room, depending on what the goal of the measurement was.

Software for electronic applications

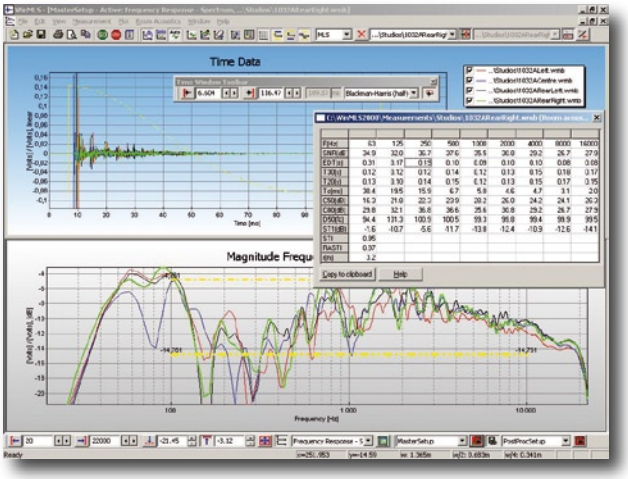
In this category fall the various applications that make it possible to use the PC as, for example, an oscilloscope, spectrum analyser or function generator. Since the signal to be measured has to enter the PC in one way or another, some kind of interface is required. The sound card is the most obvious candidate, because nearly all computers these days are fitted with one.
The quality of the measurement is strongly dependent, of course, on the quality of the sound card. The frequency range also is usually considerably smaller compared with 'dedicated' equipment. A sound card is therefore unsuitable for high frequency applications, but is quite usable at lower frequencies, especially with some of the currently available sound cards that can handle a sampling frequency of 192 kHz at a resolution of 24 bits. Accurate measurements up to 96 kHz belong to the possibilities.
The limitations of a sound card can be overcome with special interface cards, for example from National Instruments or Agilent. These are generally intended for industrial applications and are typically priced accordingly.

Software for audio measurements

A wide variety of different software packages are available for professional audio applications. The amount on offer is so large that it is impossible to cover all of them here, so we made a selection.
What is typical of this software is that it can be divided into two groups: stand-alone and VST-plugin. VST stands for 'Virtual Studio Technology'. It is a standard that has been developed by Steinberg [2] for virtual musical instruments (VSTi) or effects (VSTfx).
As already mentioned, the amount on offer is huge, but when it comes to features there is remarkable similarity: volume level meters, oscilloscopes, spectrum analysers and correlation measurements. These are, of course, the most frequently used tools when working with audio.
Extensive information about potential measuring techniques can be found on the internet, among those is a document written by Swen Müller and Paulo Massarani [3]. This not only contains information on the 'stepped sine' technique but also MLS and the differences between these two techniques.

Loudspeaker design and room simulation software

WinMLS 2004

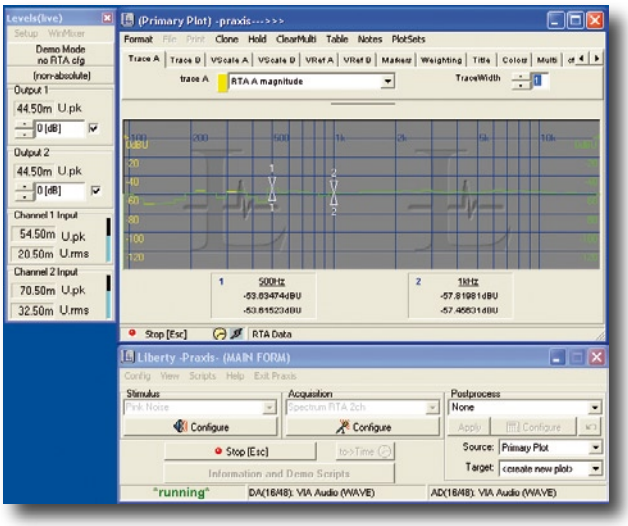


As the name of the program indicates, WinMLS 2004 can be used to make MLS measurements. The program generates a very detailed frequency characteristic. There is a selection of signal sources available. The setting options are nearly endless, which makes this software very comprehensive. Except that how to use it is not always very clear.
The software is very reliable and accurate and optimal for system calibration and spacial measurements, help when designing loudspeakers and is even suitable for resonance measurements of buildings.
The screen shot shows several features such as time- and frequency-windows and room acoustics.

WinMLS is available in various configurations which vary in price from $ 100 to $ 1000. The software is only suitable for Windows and can use any sound card that is compatible with Windows. For more information: www.winmls.com

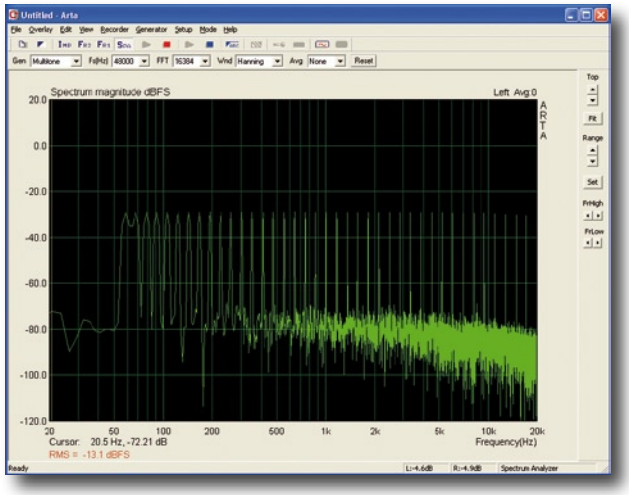
Praxis

The Praxis software from Liberty Instruments Incorporated is essentially the same as WinMLS. But Praxis has a few extras. For example, an RTA-function (Real Time Analyser). This can be used to make direct ('real-time') measurements. The settings can be stored as presets.
The documentation is quite extensive and there are a large number of wav-files that can be downloaded from Liberty Instruments that can be used to carry out measurements and tests.
On this website you can find many examples and explanations how certain measurements should be made including the required files and descriptions.
For programmers, the manufacturer also has made a Script Designer available online. Script Designer can be used to write applications for Praxis. The script is based on Microsoft Visual Basic and Borland Delphi. It was during our evaluation not at all obvious how the AudPOD interface is circumvented to enable you to use your own microphones, but the website clearly indicates that this should be possible.
The accompanying screen shot shows the important windows of Praxis, which allow most of the settings to be changed and measurements performed. Praxis is clearly a Windows based application. The price amounts to $ 998. The 'free' version lets you do quite a lot but not all the program's features are available. For more information: www.libinst.com.



ARTA, STEPS and LIMP

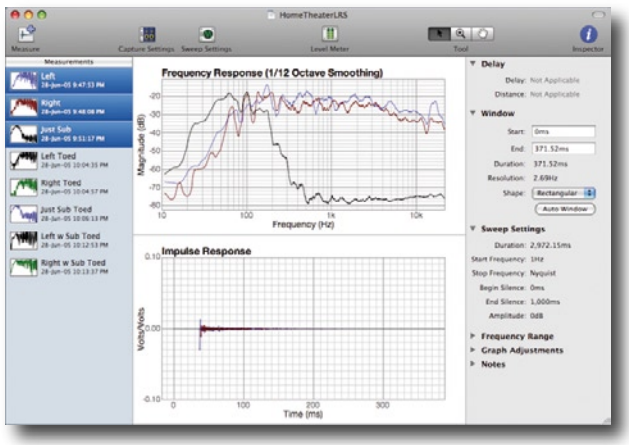
A fantastic set of programs has been developed at the electronics university in Split in Croatia. The set comprises three applications: ARTA for impulse response measurements, real-time spectrum analysis and frequency analysis, STEPS, which uses 'stepped-sine' excitation for frequency response measurements and LIMP for the measurement of loudspeaker impedance.
ARTA can be used for loudspeaker measurements, room parameters and speech intelligibility analysis. It is very user friendly and well-organised. The software offers various measurement sources which are completely configurable. Among others, you can use white noise, pink noise, MLS, linear/log 'stepped sine' and periodic white and pink noise. The test results are very clearly displayed and further calculations using these results are very easily made.



The manuals are very extensive and easy to follow. There are examples of different configurations, measurements and settings.
A comprehensive procedure for the calibration of the sound card is also available. This calibration is obviously very important when doing these types of tests.
The software is only suitable for Windows and costs from £ 36 (€ 49) to £ 110 (€ 149). The demo version does not allow anything to be saved, but is otherwise fully functional. More information at: www.fesb.hr/~mateljan/arta

FuzzMeasure Pro 3

Attention Mac users! This is one of the few applications of this genre for OS X.
FuzzMeasure was originally intended for room measurements, but its application is much broader however. The main purpose of this software is to calibrate rooms such is live podiums, auditoriums, studios, etc. FuzzMeasure is not only suitable for measuring delays and reflections in rooms but can also be used to generate loudspeaker characteristics, for example.
The program uses the swept-sine method, which avoids ambient noise and distortion.
The software is only suitable for OS X Leopard and costs $ 150. At the time of writing the software is up to version 3.0.2, which contains a few bug fixes compared to version 3.0. You can find more information at www.supermegaultragroovy.com.

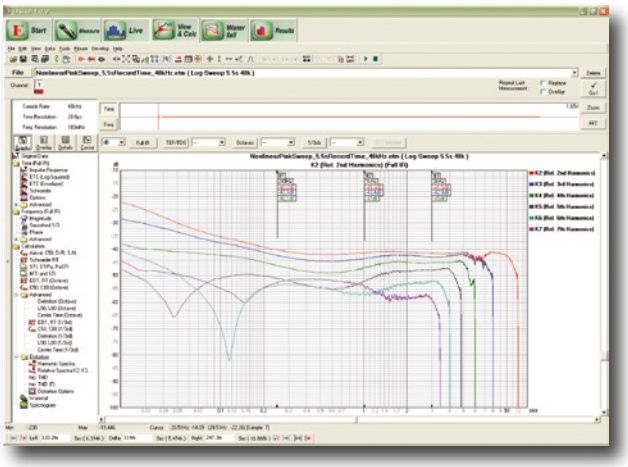


Software for electronic applications

EASERA

EASERA is the most complete software package that we came across. With a price tag varying from $ 750 to $ 2250, EASERA has a very big arsenal of measuring features.
What makes the package very interesting is that it still uses a sound card and not an expensive expansion module. EASERA gives the option of choosing between several different drivers, such as the ASIO drivers, which are famous as the fastest drivers for audio processing.
The software consists of four modules: a measurement module, a signal generator, real-time analyser and post-processing module. If this is not enough you can expand the software package with the Time Delay Spectrometry module from Gold Line (www.gold-line.com).

EASERA can perform measurements using, among others, swept sine and MLS and with these can take into account the room and different types of background noise. The program can also analyse wav-files and it can use the inputs



of the sound card to record signals.
Calibrating the sound card is simple, provided the card has a synchronisation clock. If the card has multiple inputs or outputs, a second input or output can be used for synchronisation and to determine the delay. All the settings are quite easy to use, despite the large number of options available.

EASERA also has automated functions, such as microphone calibration, adjusting the input sensitivity and compensating for the frequency characteristics of the hardware used.
Comprehensive FFT measurements can be made in real-time, volume meters can be consulted and spectrograms can be displayed. Presets can be stored, so that they can be used again or later on during post-processing.
The real fun starts at post-processing. Available to you are calculations for Room Acoustics, Electro Acoustics, RMS, noise levels, echo grams, etc. Here it is also possible to manipulate the various signals in both the time and frequency domains.

EASERA can monitor up to 32 inputs with a sampling frequency of 192 kHz, which is also of interest for PA-applications at concerts.
EASERA is the perfect tool for the professional sound engineer. The functionality is practically endless and the reliability is high. More information can be found at www.sda-softwaredesign.de and www.easera.com.

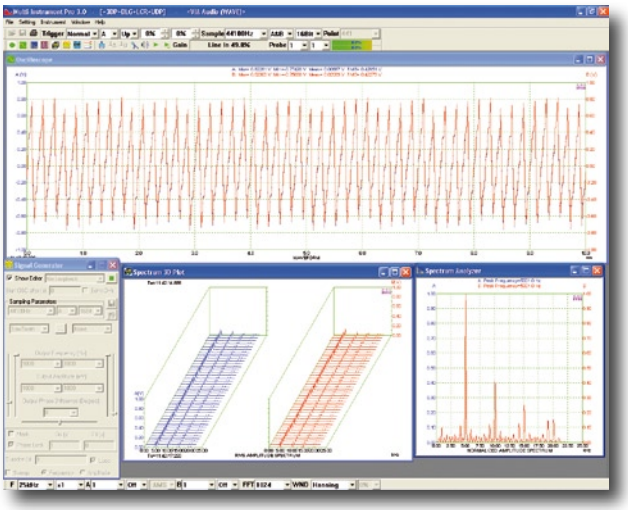
Multi-instrument 3

Multi-Instrument 3 is a very intelligent and functional program. It provides the following measuring instruments:

- a digital oscilloscope with transient recorder, data recorder, voltmeter, Lissajous plotter and digital filter.
- a spectrum analyser with amplitude spectrum analysis, power spectrum analysis, octave analysis, phase spectrum analysis, correlation analysis, frequency response measurements, distortion analysis, noise analysis, dynamic signal analysis, etc.
- a signal generator with a function generator, an arbitrary waveform generator, a burst generator, a white and pink noise generator, a multi-tone generator, an MLS generator, a musical scale generator, DTMF generator, and frequency and amplitude sweep.
- a multimeter with voltage measurement, SPL measurement , frequency measurement, RPM measurement, duty cycle measurement, etc.
- an LCR meter with inductance meter, capacitance meter, resistance meter and impedance meter.

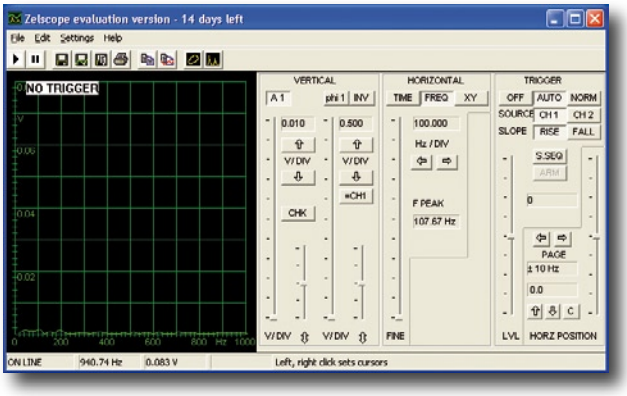
A matching probe makes this software quite unique. The probe has an audio plug which can be connected directly to the input of the sound card. An attenuator is built into the probe which protects the audio inputs of the computer against over-voltages. The probe can be used to safely measure voltages up to ±24 V.

The price of Multi-Instrument is between $ 50 and $ 200, depending on which version and options you choose. The probe costs $ 30. There is also a version intended for Pocket PCs, Pocket Multi Instrument 1.0. This version does however have fewer features compared to its 'big brother'. For more information surf over to: www.virtins.com



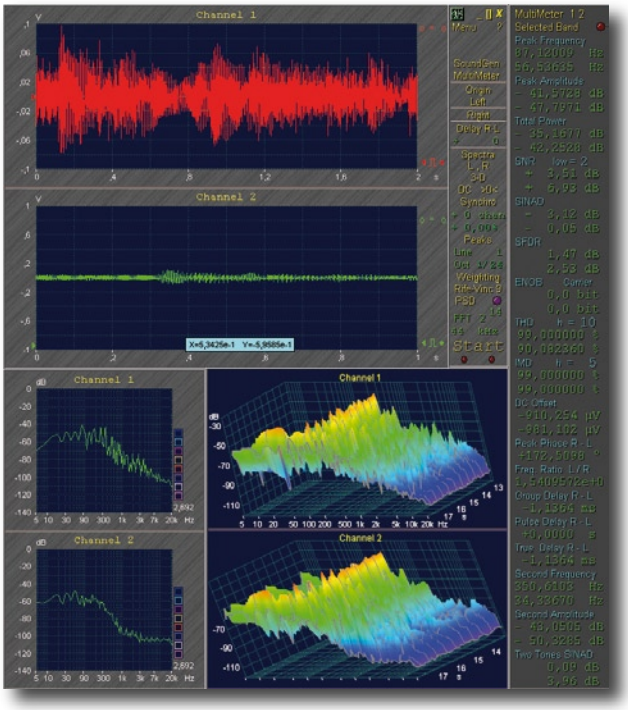
Zelscope

Zelscope turns a PC into a dual-channel storage scope and spectrum analyser. It uses the sound card as A/D-converter and shows in real-time the wave shape and spectrum of the signal.
The program is quite easy to use and reliable. Zelscope costs $20. For more information surf to www.zelscope.com



OscilloMeter 6.0

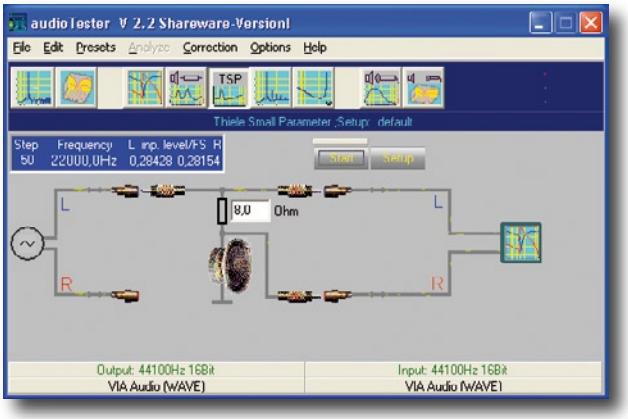
This Russian software is not likely to win a beauty contest, but there are no complaints about its functionality. It is quite comprehensive, but the cluttered design makes is quite hard to use. What is convenient however, is that as soon as you start the software you have four information windows, a dual-channel oscilloscope and spectrum analysis (optionally in 3D) of the left and right channels. Additionally there are extensive generator functions and multimeter options.



The demo version is restricted to only 15 seconds of unlimited functionality. After this the measurement stops. It does work again when you restart it. To remove this limitation you need to send $500 to the designer, who will then send you a registration code. More information can be found at http://shmelyoff.narod.ru

AudioTester

AudioTester is quite a simple Windows application which consists of an oscilloscope, a spectrum analyser and a signal generator. The signal generator WaveGen is a very comprehensive module that is intuitive to use. It offers various waveforms and step and pulse signals. The design gives the appearance that you're using a physical instrument and not software. You can find more information at www.sumuller.de/audiotester



Software for audio measurements

Digicheck - RME

This free software works only with sound cards from RME. It is a very intuitive to use, stand-alone program (only for Windows) with various functions: stereo and multi-channel level

measurements, spectrum analysis, vector audioscope, correlation measurements and bit statistics. The program can record multiple channels simultaneously (Global Record). The picture shows the Totalyser, which shows the spectrum analyser, the level meter and vector audioscope.
More info at www.rme-audio.com

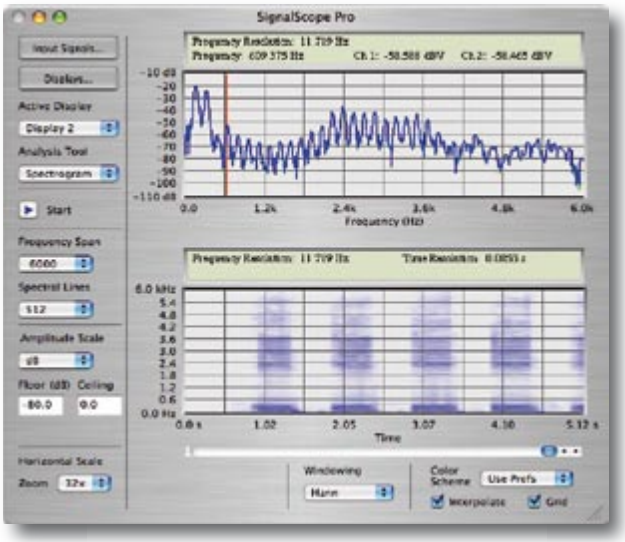
Spectre

The layout of Spectre is very nice and well-organised. It is set up in modular fashion so that you can arrange your own desktop. The software is very extensive. A few of the test instruments are: level meter, VU-meter, BBC meter (peak meter with BBC scale), oscilloscope, spectrograph, low end

meter, high end meter (separate parts of the audio range), level history meter, waveform meter, spectrogram, Lissajous meter, power balance meter, correlation meter, etc. In addition, spectrum comparison, phase comparison, coherence measurement and playing of sound files also belong to the feature list.
On the website www.audiofile-engineering.com you can find more information about Spectre. The software package costs $ 120 and is only suitable for Mac OS X.

Electroacoustics Toolbox and SignalScope pro 2.0

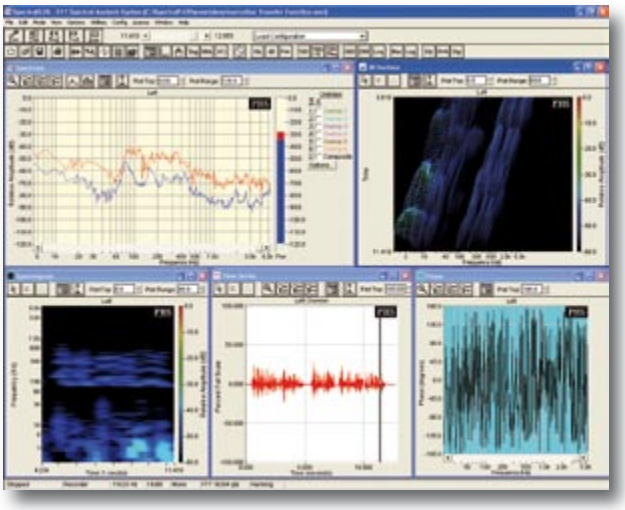
These two applications by Faber Acoustical are only suitable for Mac OS X. Electroacoustics Toolbox is a comprehensive package that consists of several modules. There is a Dual FFT analyser which can, among other things, make the following measurements in the frequency domain: amplitude transfer function, phase transfer function, coherence, group delay, signal to noise ratio, etc. In the time domain the following measurements are possible: impulse response, quadratic impulse response and cross-correlation.
There are several other modules available, including an FFT analyser, an octave band analyser, an oscilloscope, a sound level meter, a 3D spectrogram plotter and an X/Y plotter.
Signalscope is a comprehensive oscilloscope with FFT features. Signal scope is really a 'lite' version of Toolbox. It uses a single window where everything is set up and



measured.
Electroacoustics Toolbox costs about £ 370 (€ 500) and can be ordered from the Faber Acoustical website: www.faberacoustical.com. SignalScope, which costs about £ 55 (€ 70), is considerably cheaper than Toolbox and can be purchased from the same website.

SpectraPLUS

SpectraPLUS is an audio spectrum analyser which is mainly targeted at real-time measurements. It is only available for Windows and comprises various 'options' (modules), which have to be bought separately. The most important functions are: real-time FFT analysis of the signal at the sound card input, recording and playing of wav-files, displaying the measured signal in the time domain, in the frequency domain and in 2D and 3D spectrograms.
The FFT measurements are very extensive and the resolution is high, 1,048,576 points. The octave analysis can be set



from 1/1 to 1/96. The measurements can be made at up to 24 bit and 200 kHz sampling frequency, depending on the capabilities of the sound card.
Ten different options are available which are suited for different applications. For example, the base package offers you only a mono channel that can be used for measurements, an FFT analysis which is limited to 1/1 and 1/3 octave analysis, phase measurement and microphone compensation.
The base package of SpectraPLUS costs $ 295. Each additional option or module costs a further $ 200. There are

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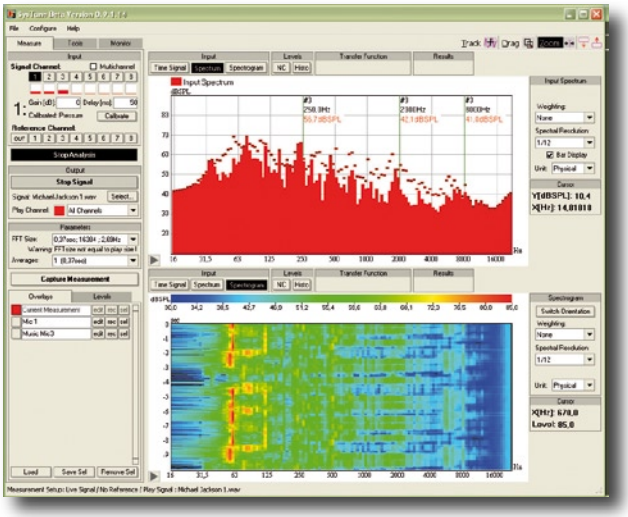
also bundles for $ 595 and $ 795 and the complete package costs $ 995. You can find more information about SpectraPLUS here: www.telebyte.com/pioneer/index.html

EASERA SysTune

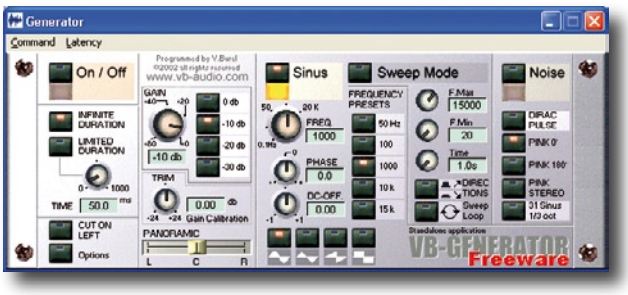
Most of the description of EASERA also applies to SysTune. It is very comprehensive and reliable, but quite expensive. In addition to the fact that you can use SysTune to measure 8 channels at a sampling frequency of 192 kHz, simultaneously and in real-time, SysTune also offers the following capabilities: the program gives a choice between live input signals or internally generated signals, impulse response measurements, spectrogram measurements, multiple-channel FFT, phase measurements in real-time and much more.



For the price of $600, SysTune comes as a complete test system, which not only lets you make all kinds of measurements on the incoming signal, but can also do spatial measurements and measurements for the positioning of loudspeakers in studios and auditoriums. More information: www.easerasystune.com

VB Audio

VB Audio is a company who mainly develop VST plugins. They have developed a range of plugins which are intended for audio measurements, for example, Frequencies Analyser, LF Generator and VU Meter. The names already indicate what they do.



What is very interesting, is the stand-alone application FFX16. This application can 'load' several plugins. This transforms the PC into a real-time audio processing and measuring instrument. The 'stacking' of plugins makes it possible to measure several frequency ranges at the same time, by first separating the desired frequencies with band-pass filters.

The Frequencies Analyser has this function built in. In addition to level measurements in the frequency domain the plugins can measure the difference in frequency between left and right channels and display spectrograms.
You can generate various waveforms with the LF Generator. Impulse and sweep modes are also included. The VU Meters is a very stable and accurate meter that is very flexible to use.
On the VB Audio website you can find much more information about these plugins: www.vb-audio.com.

Conclusion

With a simple sound card you can quickly measure all kinds of things using a computer. The results of these measurements depend of course on the application for this 'test set-up' and the quality of both the hardware and the software. Cheaper cards often have high latency and a low maximum sampling frequency. This can cause problems when calibrating, which leads to inaccurate measurements.

Software that is much too cheap often means that there is no money and therefore no time for development and testing, so that it is less reliable and the test results may be questionable.

A small step up and still reasonably affordable are for example TiePie [4] and Picotech [5]. The best solution depends on the measurements required and the financial room available.

In conclusion we can state that there are plenty of programs available that are very good at making measurements using the sound card. Obviously, this type of solution cannot compete with professional test instruments from, for example, National Instruments. But then, these cost considerably more.

(071084-I)

Web Links

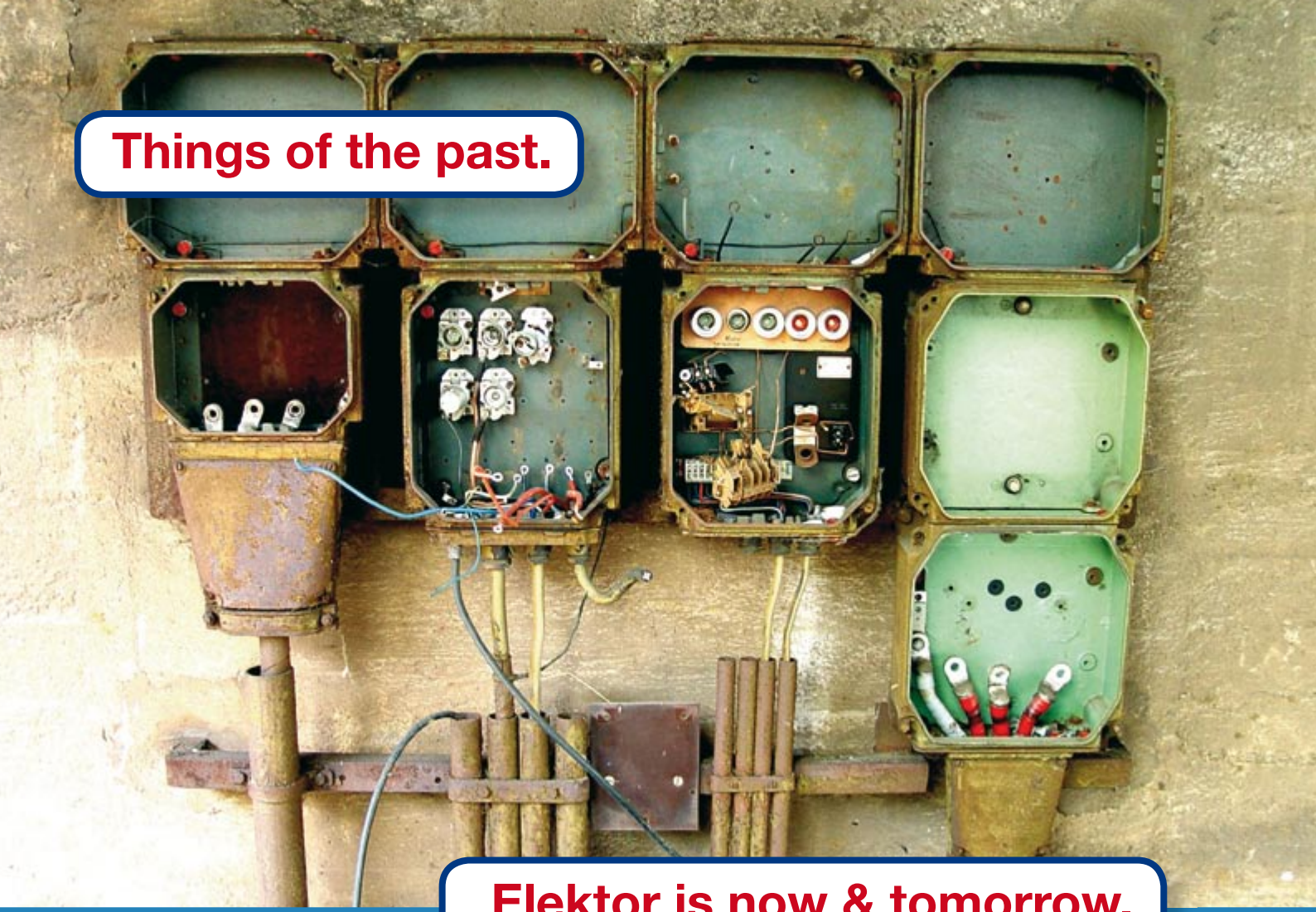
[1] www.rme-audio.de/en_products_multiface_2.php

[2] www.steinberg.net

[3] http://saturn5.com/~jwb/mueller.pdf

[4] www.tiepie.com

[5] www.picotech.com



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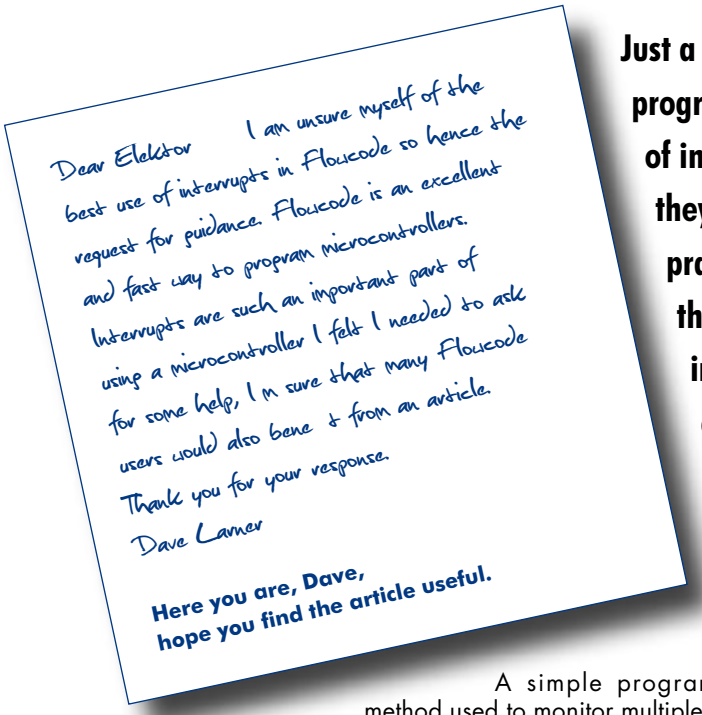
E-blocks: Flowcode Interrupts

Who's afraid of INT?

Sean King (Matrix Multimedia)



Just a mention of the word 'interrupt' makes many novice programmers shiver nervously and state that the use of interrupts is 'far too complicated for them' and that they can 'make do without'. Actually the principles and practical use of interrupts is not that complicated, and in this article we hope to take some of the mystique out of interrupt programming to encourage you to make use of this really useful programming technique.

A simple programming method used to monitor multiple events within a program, and react accordingly, is to continuously test and react as each event occurs. This methodology is termed 'Polling' and it can be achieved relatively easily and successfully in simple loop program with a series of 'IF' statements and associated subroutines. But as programs become complex the use of subroutines, which may include delays and tests for further external events, means that it is increasingly difficult to guarantee the response of a program to an external event within the required response time. On top of this the use of polling is inefficient as every failed test for an event is a waste of system resources.

To overcome this problem the internal circuitry of microcontrollers is designed to allow programmers to run predetermined subroutines on the occurrence of an external, or internal, event — separate from the main program. This provides interrupts with two big advantages:

1. the main program does not need to test for the interrupt events, simplifying the program structure;

2. Response to an interrupt event will be quick!

Examples, please

An external digital input interrupt

As an example, consider a domestic burglar alarm: if polling alone was used then it would not be possible for the alarm to be triggered whilst a user was entering a key code to unlock the system: the program would be waiting for the

user to enter a key and could not service the alarm trigger routine. However if the sensor input is connected to an interrupt pin then the programmer can develop a system where the alarm trigger routines are run whatever the rest of the program is doing.

Internal timer interrupt

An example of an internally generated interrupt is the timer interrupt. Within a microcontroller, a digital counter block, made up from a chain of flip-flops, is connected to the main system clock. The counter block generates an internal interrupt signal each time the counter overflows. The design of the counter block is enhanced so that the effective length of the counter block is determined by the contents of a writable memory register within the chip, allowing the programmer to determine the effective length of the counter. Together this digital block of circuitry and the memory register is called the 'prescaler' and it allows programmers to generate an interrupt every, 2, 4, 8, 16, 32, etc. counts, depending on the length of the counter.

The timer interrupt is incredibly useful: if you have a microcontroller clocked with a crystal at 19660800Hz with a 16-bit prescaler counter then it produces an internal interrupt at 19660800/65536: an interrupt 300 times per second. So all you have to do is have a small timer interrupt routine that counts 300 of these and you can accurately produce a clock that shows time passed in seconds.
In practice there are many variations of the external digital interrupt and the timer interrupt: external interrupts can be active low or high, some microcontrollers have timer interrupts that can be triggered on an exact count match, etc.

Other internal interrupts

Most microcontrollers are integrated with a collection of peripheral devices. Each peripheral device contains hardware that is optimised to perform task that would be difficult, time consuming, or even impossible for an unaided microcontroller to undertake. Most of these devices have the ability to generate interrupts when special events occur. Here are just a few more examples:

- UART, SPI, I²C: interrupts can be triggered when data is received or a transmission complete.

- A/D converter: interrupt triggered when the A/D conversion is complete and sample available.

- Data EEPROM: interrupt triggered when write operation is completed.

- Comparator: interrupt triggered when the input has changed from previous status.

Putting it into practice

The example program you can download from the Elektor website (archive # 071069-11.zip) shows how a Flowcode program written for the ATMEGA32 can use two interrupts to create a high speed analogue data logger. Download it, unpack and open it with Flowcode for AVR.

When a microcontroller is powered up, all interrupts are off by default – so the first task a programmer has is to turn them on. The 'main' flowchart contains a sequence of three icons which configure the chip to be suitable for our purposes.

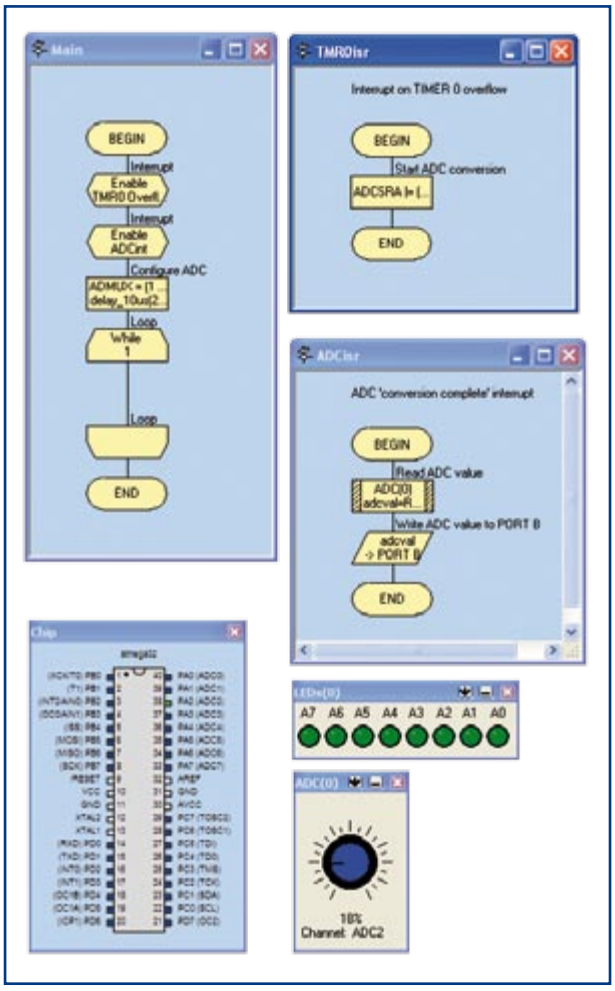


Figure 1.
A practical example of an interrupt driven program.

Flowcode is supplied with an interrupt function block. You select it from the vertical toolbar at the left of the screen by clicking on the small yellow lozenge with 'INT' in it. It provides direct support for several of the more common interrupts. There is also a custom interrupt option that can be used to configure each of the unsupported interrupts offered by the target device.

The first icon configures the timer interrupt. Clicking on it results in the dialogue box shown in **Figure 2**.
Here you can see that we have selected the TMR0 (TiMeR 0) overflow interrupt to be enabled and that when the timer 0 overflows the macro, or subroutine, in the flowchart TMR0isr is called. Clicking on the Properties button reveals the screen in **Figure 3** where you can see that the parameters of the timer 0 overflow interrupt can be selected. The interrupt frequency here is 1200 Hz which means that the macro TMR0isr is called 1200 times a second.

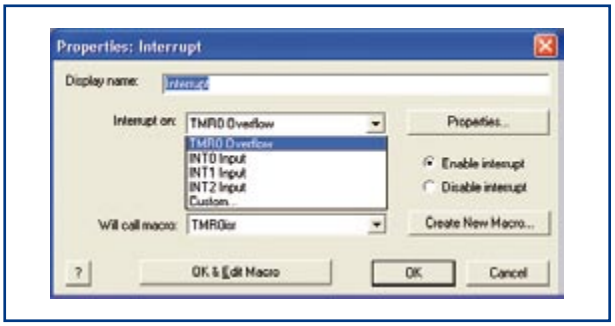


Figure 2.
First interrupt icon properties.

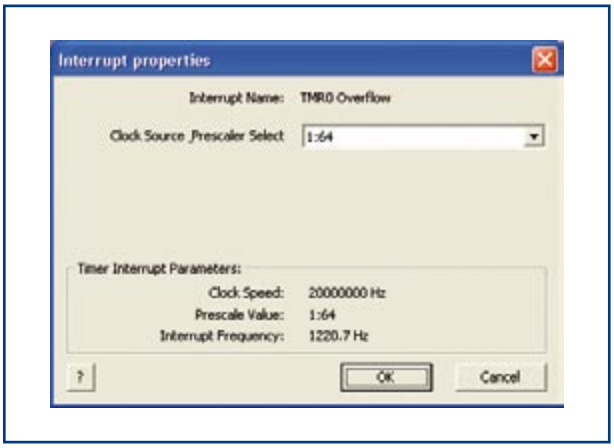


Figure 3.
The properties of the Timer 0 interrupt.

For those who are curious, here is the maths on Figure 3:

The clock is 20 MHz. The prescaler is 1:64 – effectively a 6 flip flop counter. $2^6 = 64$. However the clock feeds into an 8 bit counter before it reaches the prescaler – effectively a 14 bit counter. $2^{14} = 16384$. So the actual interrupt frequency is 20000000/16384 = 1220.703Hz.

In this case the TMR0 interrupt has been configured to generate an interrupt at a frequency of 1220.7Hz (819.2µs), see Figure 3.
From the 'Interrupt on' drop box shown in Figure 2 you can see that other interrupts are available which are as follows:

- INT0: interrupt when a selected transition is detected on the INT0 pin;
- INT1: interrupt when a selected transition is detected on the INT1 pin;
- INT2: interrupt when a selected transition is detected on the INT2 pin.

If you are just starting out with interrupts then use of the timer and INT interrupts will be as far as you want to go for now. Once you have mastered these then you may want to learn a little C code, dig into the datasheets of the microcontroller and you can then take advantage of more advanced interrupts as follows.

The second icon in the flowchart configures a second interrupt in the Atmega chip: the A/D Converter Conversion Complete interrupt. Once this is on the flowchart if you click on the icon and select the 'Custom…' option from Figure 2 you will get a new dialogue box as shown in **Figure 4**. Here you need to enter appropriate C code which enables the interrupt by setting the status of the ADCSRA register (ADC Control and Status Register A), and then additional C code which ensures that the selected Flowcode macro is called. Using interrupts like this requires some knowledge of the inner workings of the microcontroller device itself, and a little C code.

The third icon in the program sets up several variables for the program. After this we get to the main program loop. As you can see this is a 'loop while 1' pair which simply loops the program round the loop forever. The odd thing about this program is that there are no instructions in the main loop at all!

The TMR0isr macro is called each time a timer-0 interrupt is issued. This macro contains a single C command that initialises the ADC conversion in the Atmega chip. Note that a Flowcode ADC conversion hardware macro is not used here as these require a response from the ADC hardware inside the chip (curiously enough using the Polling technique) suspending operation of the main program until conversion is complete, or a timeout period has elapsed.

Techtalk 'onINT'

After a Power-On-Reset, interrupts are usually disabled. The microcontroller has several levels of control over its interrupts. A Global Interrupt Enable (GIE) flag is available in one of the system registers to allow the entire interrupt system to be enabled or disabled in a single instruction. Individual interrupt enable flags (e.g. TMR0IE) are contained in various system registers allowing each interrupt to be enabled and disabled independently.

An interrupts will only be generated when they are enabled both individually and globally. When an interrupt is generated it will set a flag in one of the system registers (e.g. TMR0IF). This can be used to confirm the presence of the interrupt request, and should be cleared before returning to the main program.

There are several different requirements for clearing interrupt flags, depending on the interrupt type, device family etc. Reference should be made to the device data sheet.

Interrupt operation

When an active interrupt condition is detected, the microcontroller completes the machine instruction it is currently executing, saves the address of the next instruction to be executed in the main program onto the stack, and loads the program counter with an alternative address — similar to a programmed subroutine call. The address loaded into the program counter is that of an interrupt vector. What the microcontroller expects to find at the interrupt vector address depends on the device type.

Two popular devices are the PIC16F877a and the ATMEGA32.

The PIC device has a single interrupt vector and expects to find a sequence of instructions starting at the vector address. One of the first tasks to be carried out is to identify which of the potential sources generated the interrupt, before branching to the appropriate service subroutine.

The ATMEGA32 has a separate interrupt vector for each interrupt source. There is no need to identify the source of the interrupt in this case so the device expects to find the address of the service routine at the vector address.

The outcome of the response to an active Interrupt ReQuest (IRQ) is that the program flow is diverted from the main program and directed to the appropriate Interrupt Service Routine (ISR) that performs the tasks required by the interrupt event, clears the interrupt, re-enables the interrupt system (if necessary), and returns the program counter to the next instruction in the main program.

The ADCisr macro is called each time an ADC Conversion Complete interrupt is issued. This macro then reads the sample ADC value and outputs this value onto a bank of LEDs on Port B.

Back to the program

The entire program is handled by interrupts. The TMR0 interrupt generates interrupts at a frequency of 1200.7 Hz. The TMR0 interrupt service routine macro (TMR0isr) starts the ADC conversion and returns to the main program loop. The ADC Conversion Complete interrupt service routine macro (ADCisr) reads the converted ADC value and writes it to PORT B before returning to the main program loop. Almost any program could be written in place of the main While loop, without affecting the operation or timing of the data logging function. Of course this is not necessarily a practical program, but hopefully it illustrates the use of a simple timer interrupt as well as giving an example of a more complex interrupt and an idea how these are set up.

Interrupt pitfalls

It is important that interrupt service routines are completed as quickly as possible. Most will transfer small amounts of data, update a variable, or trigger another event. Program loops, macro calls, and complex calculations should be avoided. The delays involved in writing data to the LCD could cause problems in a multi-interrupt application. In this case the interrupt service routine should transfer any necessary data to a suitable location and create an indicator that the main program can use to detect that an interrupt has been serviced and further action is required.

The fact that interrupt response times are down to individual machine instructions can cause problems if an interrupt occurs during a multi-instruction operation, especially if the interrupt service routine modifies a variable that is in the process of being used by the main program. There are many techniques for avoiding this problem, enough to justify another complete article.

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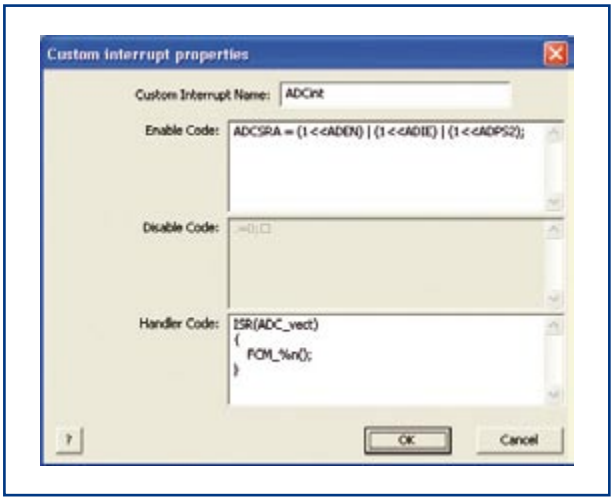

Figure 4.
The advanced ADC complete code in C.

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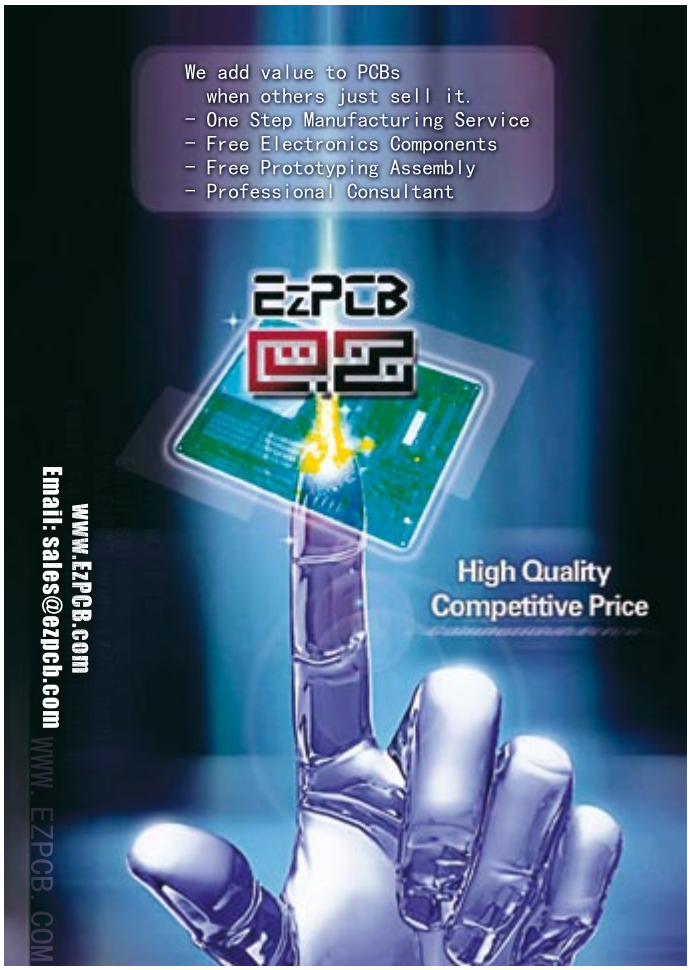


An SPI-networked Microcontroller

Dirk Böhm

A little over a year ago Microchip [1] launched the first Ethernet controller with SPI connectivity — and just 28 pins. With the ENC28J60 available also in a solder-friendly DIP version, this makes embedding a microcontroller in a local network particularly simple and attractive. The basic circuit (see diagram) requires only a handful of extra components, enabling the whole affair to be built conveniently on a piece of Veroboard (stripboard) or on a solderless prototyping breadboard.

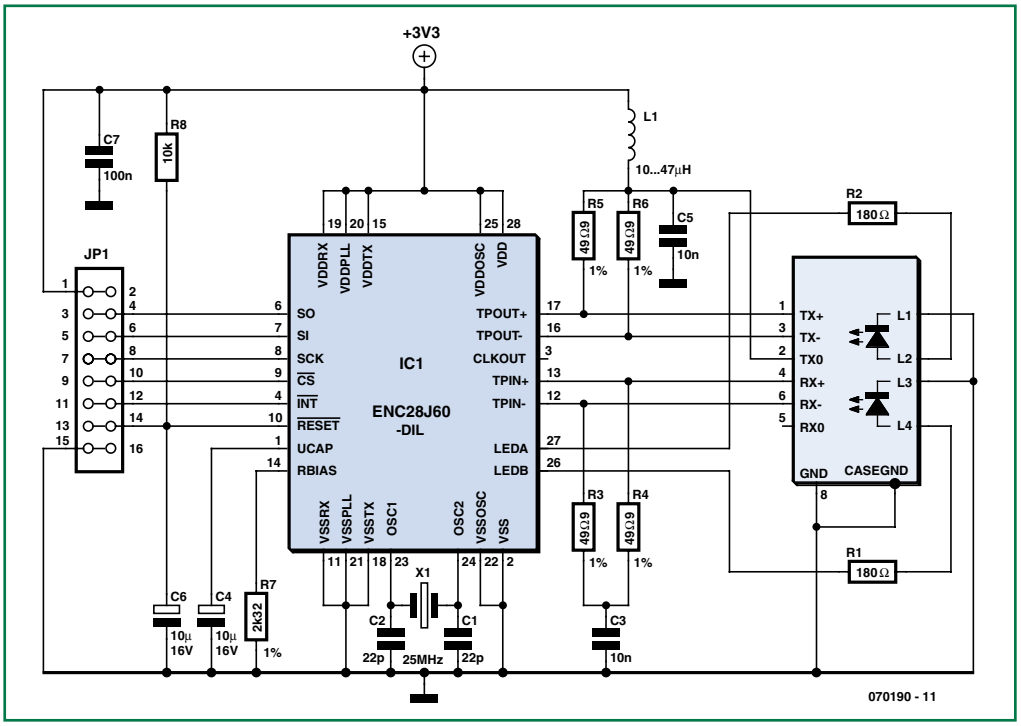
A MagJack integrated module from Belfuse [2] is our choice for the network connector. Apart from this you will need a 25-MHz crystal oscillating at its fundamental or natural frequency. Online suppliers of the microcontroller, connector and crystal include [3] and [4] but you may well know of other firms that are closer to hand. The 1% tolerance resistors, capacitors and coils are available from the usual mail order firms, such as Maplin, Rapid Online and Conrad Direct.

Once you have powered up the module you need to apply a frequency of 6.25 MHz on PIN 3 (CLKOUT), otherwise a link will not be established to the network. This 6.25 MHz signal must come from a crystal oscillator operating on its fundamental frequency. If you cannot detect any trace of the 6.25 MHz signal try removing the capacitors experimentally.

For your very first trial you should try activating the LEDs connected to the microcontroller. If this works read out the Revision ID. Should something prevent reading to and from the Register, sending some packets should unblock this. If you don't feel like developing the TCP/IP Stack from scratch you can download an oven-ready TCP/IP Stack absolutely gratis from Microchip!

For developing network application software we recommend installing the Ethereal network sniffer, downloadable at [5]. This lets you log all the packets passing in broadcast mode or direct to and from the controlling PC.

One final tip: it's crucial that you download the errata and update information relevant to the particular Revision ID of the module you are using [1]!



SPI in a nutshell

The Serial Peripheral Interface Bus or SPI (often pronounced 'es-pēē' or 'spy') bus is a synchronous serial data link standard named by Motorola that operates in full duplex mode. Devices communicate in master/slave mode where the master device initiates the data frame. Multiple slave devices are allowed with individual slave select (chip select) lines. Definition from Wikipedia [6].

(070190-I)

Web Links

[1] www.microchip.com
[2] www.belfuse.com
[3] www.csd-electronics.de
[4] www.microcontroller-starterkits.de
[5] www.ethereal.com
[6] http://en.wikipedia.org/wiki/Serial_Peripheral_Interface_Bus

Symmetrical square wave

Patrick Knöbel

Just about anyone must be familiar with the NE555 by now. It is one of the most common components in do-it-yourself circuits. This IC, however, was not designed specifically to generate a clock signal, and certainly not one with a duty-cycle of 50%, although it is frequently used for that.

There are of course a number of circuit possibilities that could realise a duty ratio of 50%. **Figure 1** shows a solution that uses two diodes. Capacitor C is, via the diodes, always charged and discharged with the same resistor value, so there is no asymmetry and the duty-cycle stays at 50%. We can calculate the (clock) frequency as follows:

$$f = 1.44 / (2RC)$$

where $R_1 = R_2 = R$.

It is however not possible to calculate the frequency exactly because the forward voltage drops of the diodes are not known.

This and the fact that six parts are required make it worthwhile to think about another solution. The engineers that STMicroelectronics [1] thought the same.

Their data sheet for the NE555 contains a circuit that, for a clock generator with 50% duty-cycle, requires only three external components (see **Figure 2**).

The amount of time that the output is high (t_1), is calculated as follows:

$$t_1 = 0.693 R_1 C$$

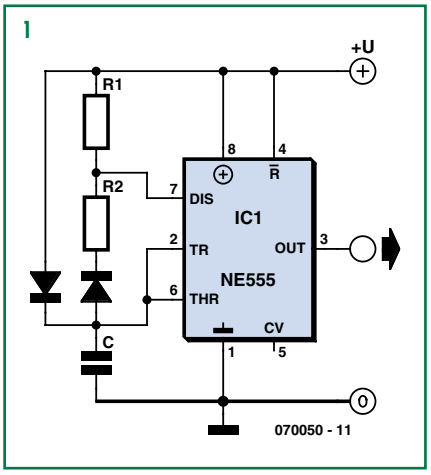
The time that the output is low (t_2), is a little more complicated:

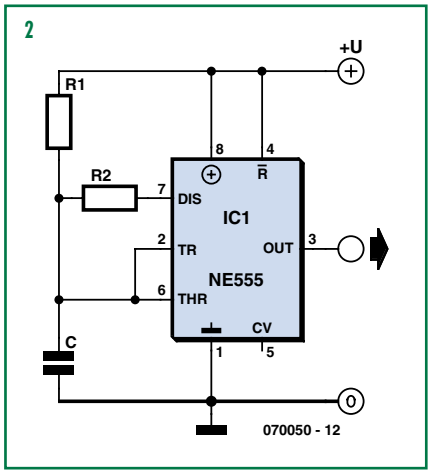
$$t_2 = (R_1 \times R_2) / (R_1 + R_2) \times C \times \ln((R_2 - 2R_1) / (2R_2 - R_1))$$

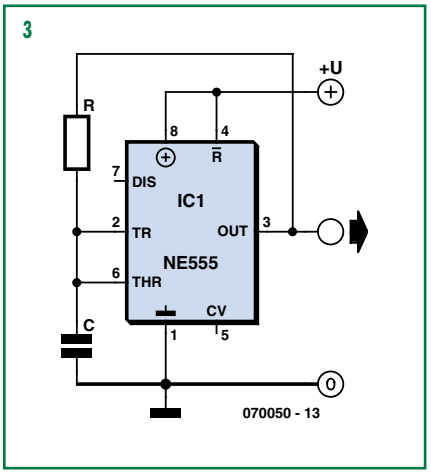
For a duty cycle of 50% it is true that $t_1 = t_2 = t$. The clock frequency is then:

$$f = 1/2t.$$

The disadvantage of this circuit is that it is not easy to select the values for the components. For example, R_2 may not be greater than $\frac{1}{2}R_1$.







So there is an opportunity to do better still. And this is shown in **Figure 3**. This extremely simple schematic shows a clock generator using an NE555 with a 50% duty ratio in its minimal form. It requires only three components in total, including the timer IC itself.

The frequency can be calculated with this formula:

$f = 0.72 / RC$

Where most people would normally use a D-flipflop, we solve that with this circuit using only a capacitor and a resistor. It is not likely to get much simpler than this.

(070050-I)

Links:

[1] www.st.com

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Looking back on the poor weather conditions of the last few months it seems prudent to have a Hexadoku puzzle in stock for yet another a rainy day. If you've not participated before, by all means do so and you may win one of the prizes: an E-blocks Starter Kit Professional and three Elektor Shop vouchers.

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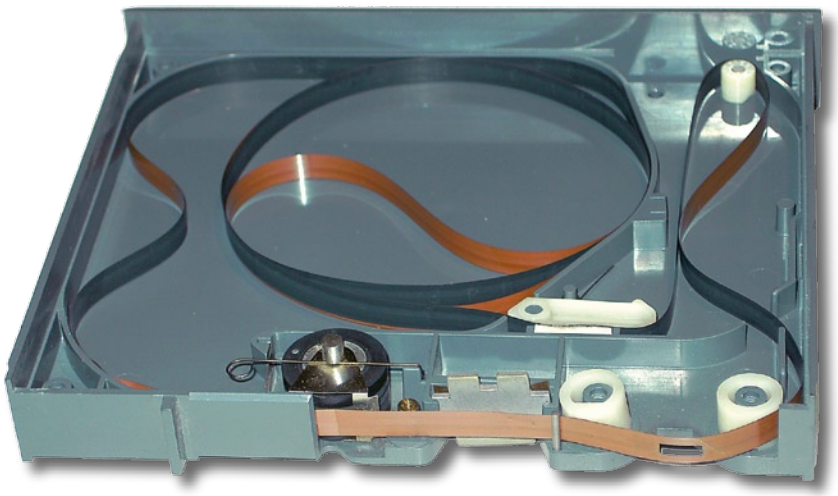
7	D	1	9	0	8	4	6	3	C	5	B	E	2	F	A
C	2	6	3	D	5	E	A	F	0	4	8	7	9	B	1
F	4	E	8	B	9	7	3	1	6	2	A	5	C	D	0
0	A	B	5	F	1	C	2	D	9	E	7	8	4	6	3
D	8	F	B	A	4	1	0	9	E	3	5	2	6	7	C
6	3	C	E	5	B	9	7	A	2	8	0	D	F	1	4
5	9	2	4	E	3	6	F	7	1	C	D	B	A	0	8
A	7	0	1	C	2	D	8	B	4	6	F	3	E	9	5
8	C	3	A	6	F	0	B	E	D	7	2	1	5	4	9
2	1	5	D	9	A	3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

'Alibi-Nota' telephone answering machine (1972)

Peter Beil

As early as 1972, a telephone answering machine appeared on the market that was second to none: The 'Alibi-Nota FL' with remote listening / erasing functionality. Zettler, a company famous for its pioneering telecomms technology, had succeeded in going round the extremely strict regulations laid down by the German telephone authorities, forbidding private users to send control signals of any kind (be it carriers or dial pulses) over the public telephone system (PTS).

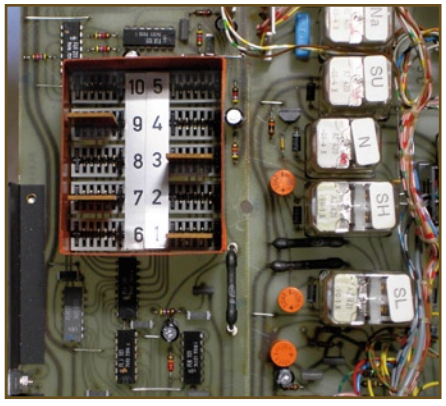


Pulse dialling was the *de facto* standard at the time and DTMF (tone dialling), in its infancy.

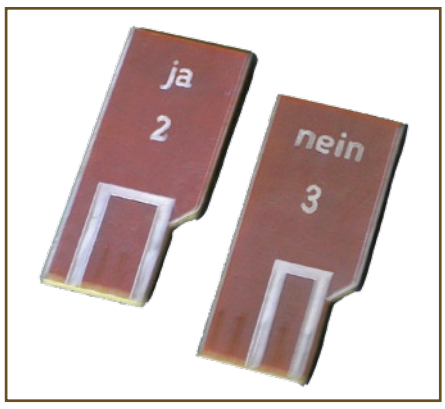
The idea of remotely controlling an answerphone machine was ingenious and relied on a 'binary' method: ten short 1-kHz tones played after the welcome message had to be answered or not. In practice, callers had to blow into the mouthpiece or say a word out loud in response to two text-announced tones, or muffle the mouthpiece in response to two other tones.

The resultant '0' and '1' code allowed the Alibi-Nota (what's in a name!) to validate the caller/user.
The code was programmed using small plug-in boards marked 'yes' and 'no' and inserted into slots marked 1-10 located at the underside of the equipment.

Pitfalls — sure! 'Static on the line' — quite normal at the time — would have upset the operation of the Alibi-Nota machine as it was unable to discern between 'yes' and 'no'. As part of the dialogue, further check tones had to be 'answered' correctly, if not, the machine would stop the playback and disconnect. To use the remote erase function, you had to respond to the last tone prompt as well (the last tone naturally was within the call you were making).



Alibi-Nota was a full-fledged tape recorder recording at 2.4 cm/s — fully adequate for the limited frequency response of analogue phone lines. It was fitted with a call counter, a ring pulse counter and adjustable recording length. For each key, the control buttons could be locked in any position. The front side had a replaceable cassette for the fixed message. Inside we find an endless tape with a clearance in it for on/off switching and switching over.



Sporting a microphone, footswitch and fast tape rewind the machine was also suitable for use as a Dictaphone. The complete Alibi-Nota weighs 15 kgs. The tape recorder proper is quite conventional, but the remote control unit is a masterpiece of engineering. Removing the one kilogramme steel cover of the encoder bay reveals a large vertically mounted board that can be hinged out. The relays allow the equipment to be controlled 'in parallel' and the logic circuits used are now long forgotten types from Siemens & Halske like the FLH131, FLJ121 and FLK101.

To date this answerphone is fully functional on the analogue phone system. In 1972 it would have set you back the equivalent of about a month's wages.

(071073-I)

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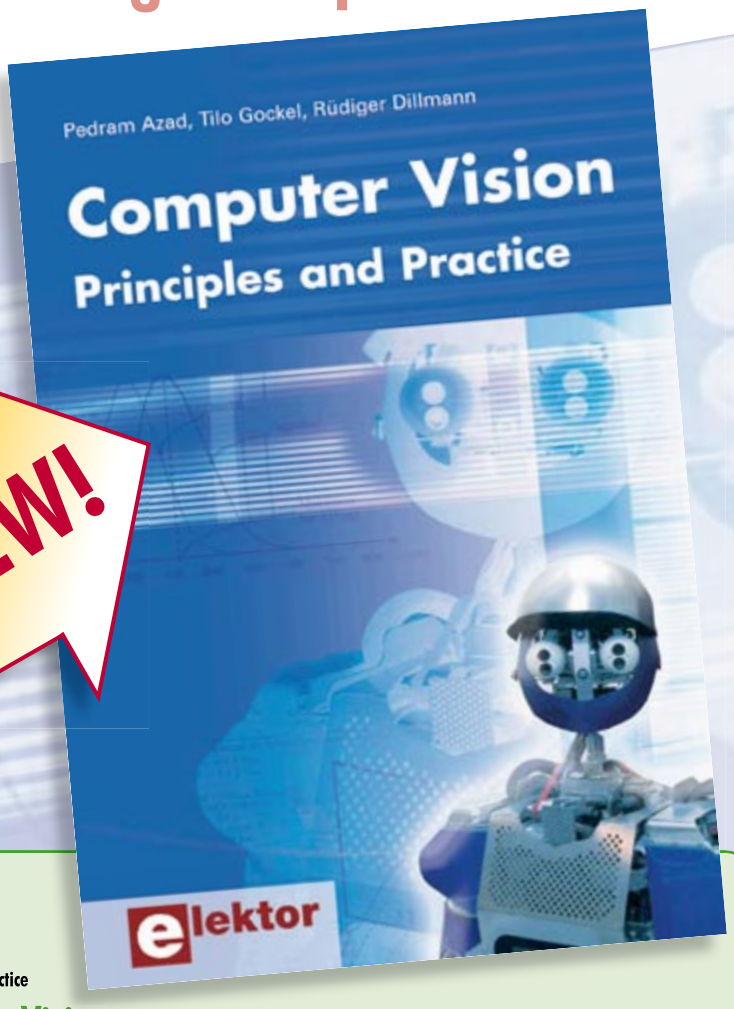

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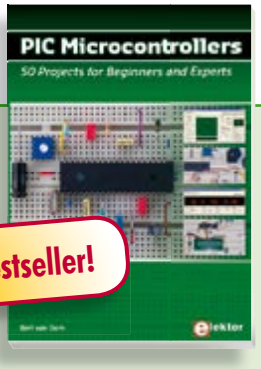

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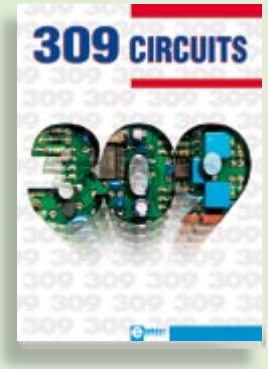

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DigiButler

(May & April 2008)

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

Kit of parts including SMD-stuffed PCB, programmed microcontroller, all leaded parts and CD-ROM containing CodeWarrior, TBLCF documentation, datasheets, application notes and source code files.

Art.# 071102-71 • £29.00 • US$ 58.00

More information on the Elektor Website:

www.elektor.com

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Elektor Internet Radio

(April 2008)

In the good old days, you had to modulate audio signals onto an RF carrier so they could be received and demodulated to produce something more or less audible. 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 Elektor Internet Radio. All open-source!

PCB, SMD-populated

Art.# 071081-71 • £115.00 • US$ 230.00

Datalogger "deLuxe"

(March 2008)

We have had the pleasure of proposing various data acquisition units over the last few years. This Datalogger "deLuxe" is a nice exercise in product development. It actually utilises an SD card as the media for data storage. The hardware design is compact and that makes the firmware and software features even more interesting.

Kit of parts incl. PCB, programmed controller and display

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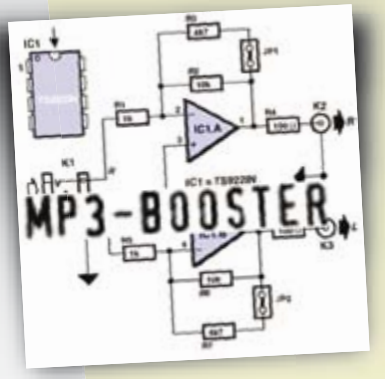

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on the testbench: PC soundcards

All PCs are now sold with a plug-in soundcard or equivalent on-board circuitry for processing audio signals. To electronics designers, the soundcard doubles as a fine instrument to do (low-frequency) measurements, effectively turning the PC into an analyser or an oscilloscope.

Sufficient resolution of the soundcard is perhaps the single most important condition for accurate measurement results. Hence we ran laboratory tests on a number of soundcards on the market with different price tags. The results are presented in the June 2008 issue.

Colourful Computer Light

We live in a colourful environment these days. Everything is in colour: TV, advertising billboards, mobile phone displays and LEDs. Philips added a further dimension to all this with their Ambilight, Wake-up Light and Living Colors lamp. We will work with the latter in this Modding & Tweaking article. The wireless remote control offers interesting possibilities once the protocol has been cracked...

Switch-mode audio power supply

Lots of electronic equipment is powered by a switch-mode power supply (SMPSU) because it's light, efficient and compact. Alas, SMPSUs suitable for use with audio power amplifiers are rare finds. That's going to change with SAPS-400, a module with an adjustable output voltage to ±60 V and good for a whopping 400 watts of output power. SAPS weighs just 500 g and is a little larger than two cigarette packs.

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