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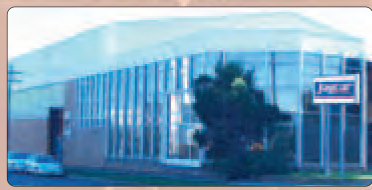

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NEW FOR '06

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NEW FOR '06

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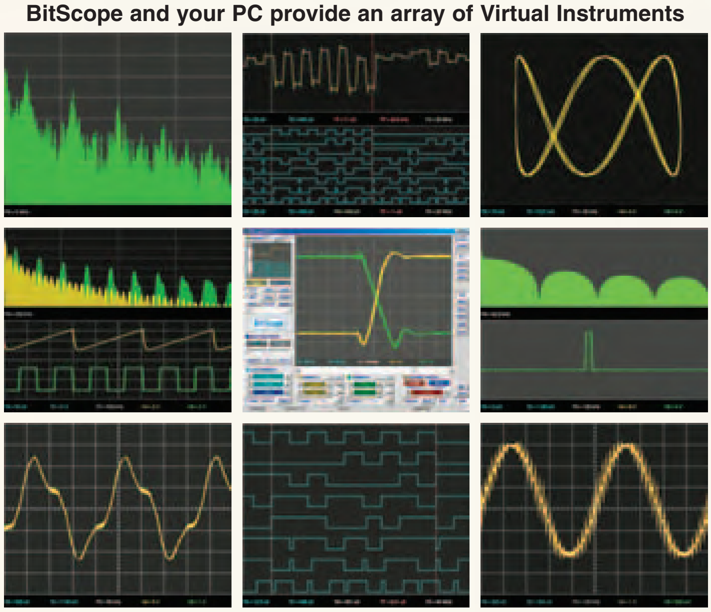
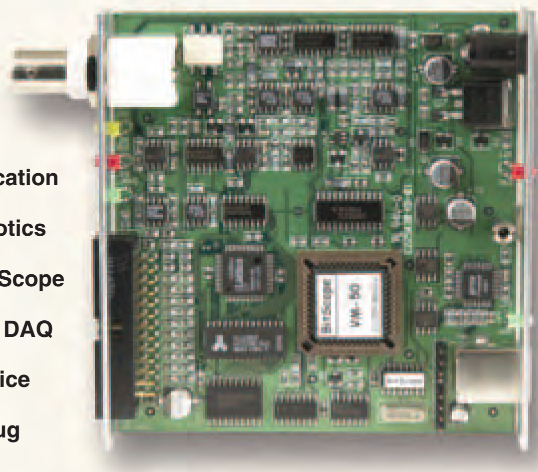


BitScope DSO 1.2 software for Windows and Linux



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Shorter waves — longer faces

Like so many colleagues and, hopefully, *Elektor Electronics* readers, I marvel at the possibilities of simulating electronic circuits on the PC using today's sophisticated software and sleek user interfaces. About 10 years ago, I started out (half-heartedly I must admit) with Electronic Workbench, connecting up a simple logic circuit that was supposed to count six key presses before lighting an LED. It worked on the screen and I could even prove the operation of a 4093 Schmitt trigger gate by applying not so neat input signals. Nothing destroyed, no components to buy and best of all no solder smell or wire clippings on the workshop floor. Next I slapped together some coils and capacitors into what I was certain to represent a pi-filter for a 144-MHz transmitter, using values I knew were correct as they were actually present in my 2-m QRP transmitter. I showed the file to a colleague far more versed in e-simulation and he told me "you'd better breadboard that, there's no such thing as nanohenries and 144 MHz — what's it for anyway?" I insisted on doing a simulation however and was surprised to see the blatant shortcomings of the PC programs when dealing with stray capacitance, inductance and the complex output impedance of a 2N2219A transistor in grounded base mode.

Spurred into finding circuits that would fool the e-simulation programs of the age, friends and colleagues came up with UHF noise generators, Colpitts oscillators, PCB stripline filters, critically coupled inductor pairs and worst of all — a Gunn diode (which has a negative resistance). It was good fun watching the programs either crash or produce downright idiotic results. One program supplier, in response to a critical letter of a good five pages, was honest enough to reply that "our product is intended to cover the needs of mainstream electronics, and cannot reasonably be expected to cater for exotic applications like the ones you suggest". Today's simulation programs have vast component libraries and the ability to mimic non-ideal signals to get much closer to real-life electronics. None the less, the intricacies of RF design are insufficiently covered by most 'wideband' simulation software, which is strange as so much new electronics is wireless in way or another. Now there's a challenge.

Jan Buiting, Editor

32 GBECG

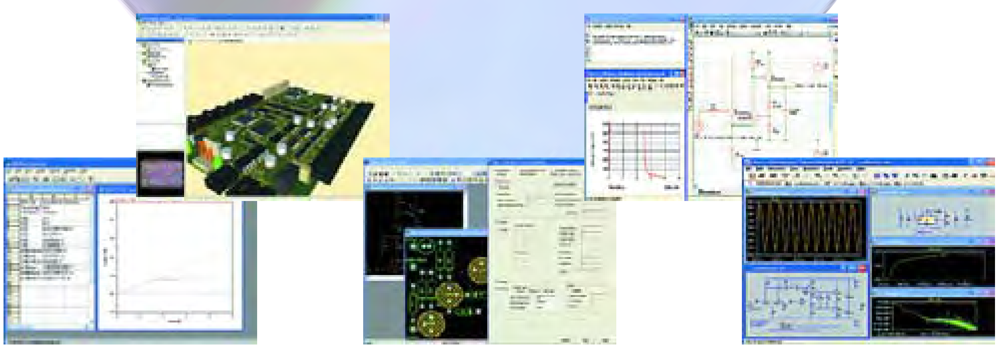
Gameboy Electrocardiograph

Believe us, several problems have to be resolved in order to properly sample the heart's electrical activity. Here we show you how to make your own ECG reading device from a GameBoy games console.

Free DVD!

20 Simulation Programs

Dozens of programs are now available for simulating electronic circuits on the PC. The DVD you get free of charge with this issue allows you to decide which one is best suited for you. In this article we give you an overview with a short description of the programs on the DVD.



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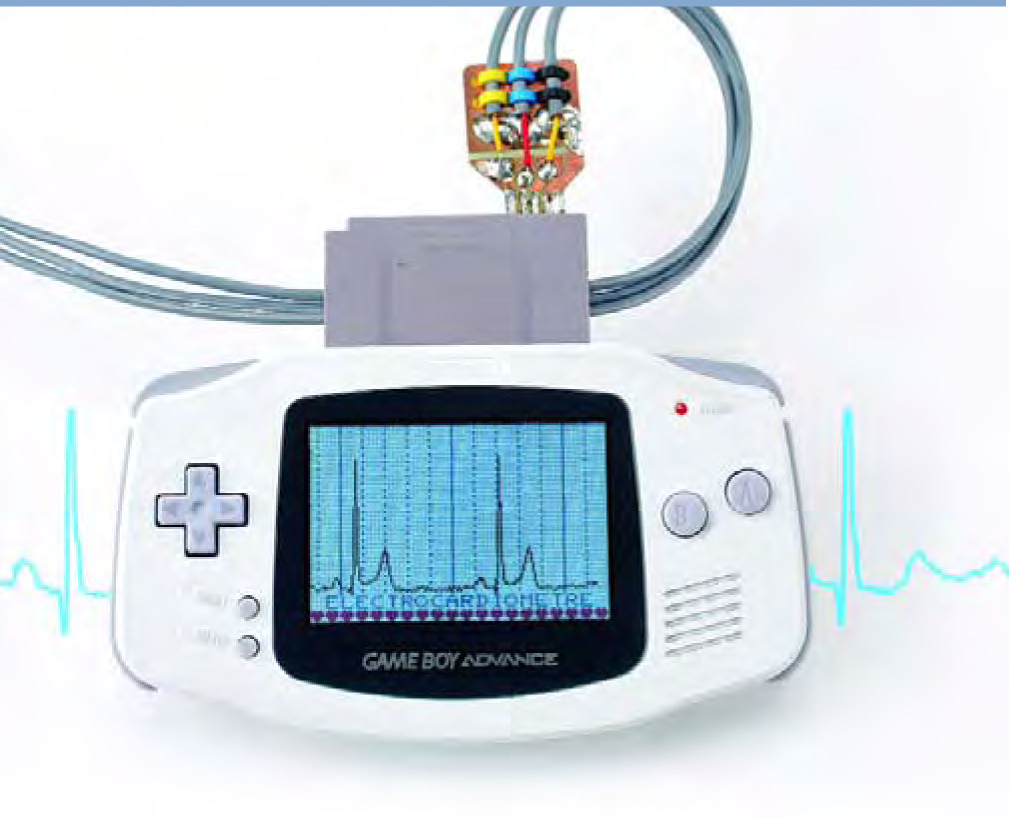
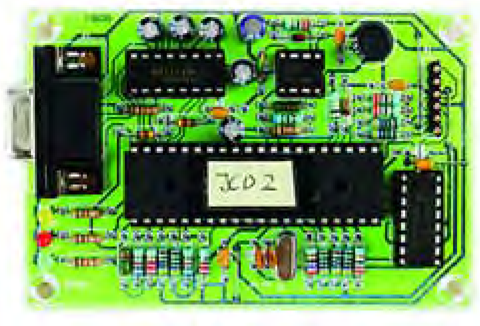
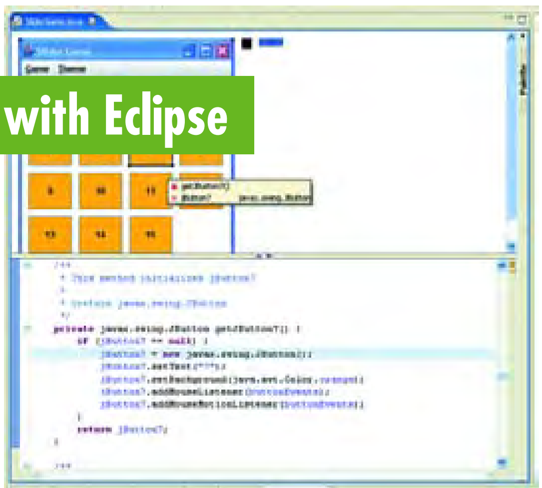


50 PIC In-Circuit Debugger/Programmer



PIC microcontrollers of the 8-bit 16F and 18F family are a favourite of many Elektor Electronics readers. A must for users is a means of loading programs and an In-Circuit Debugger (ICD) for tracking down programming errors. This project shows you how to do it the cheap way.

67 In Control with Eclipse



Eclipse is a modern development environment, which is not only easy to learn but also easily expanded and suitable for the most diverse programming languages. Furthermore, the package is free and open-source!

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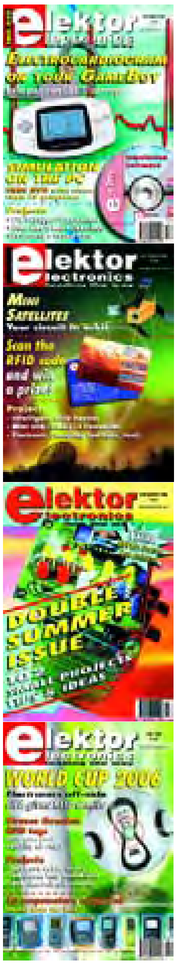

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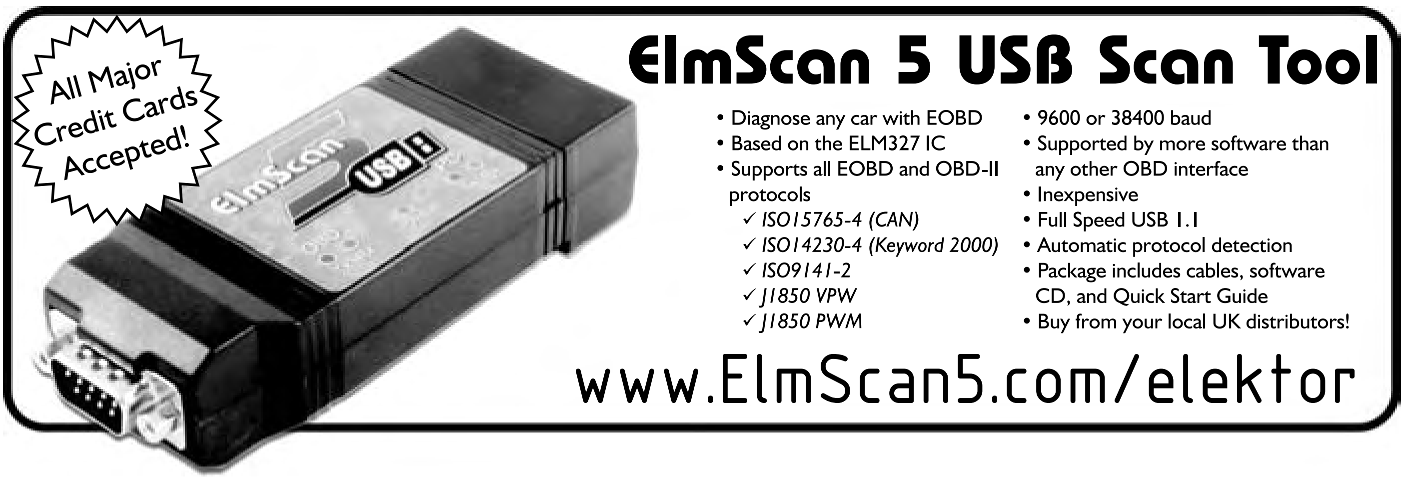

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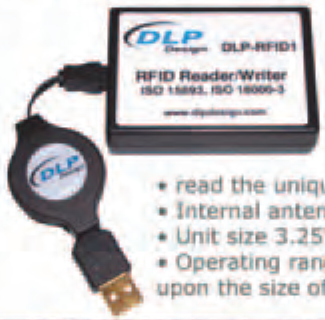
DLP-RFID1 USB - RFID Reader / Writer

£79.50



A low-cost, USB-powered module for reading and writing ISO 15693, ISO 18000-3, and Tag-it™ passive RFID transponder tags.

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£6.99

- Protect your application software with this low cost USB software security dongle
- ChipID Feature returns unique number for every dongle
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- Devise your own encryption scheme
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US232R-10 Premium USB - RS232 Cable

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10cm version

- High tech white gloss enclosure
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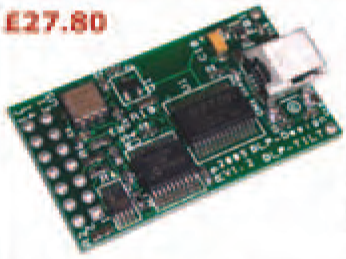
DLP-Tilt USB Accelerometer Module

£27.80



The DLP-TILT USB-to-accelerometer module has four primary application areas:

- vibration analysis
- tilt sensing
- AC signal analysys
- two-button mouse pointing device alternative
- demonstration software provided using FTDI's Virtual COM Port (VCP) drivers

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Better by miles

Dear Elektor — referring to 'Antenna Height and Range' in your latest Summer Circuits edition, sometimes the statute mile and feet works better than the meter. If you use 4/3 earth radius and express the distance *s* in statute miles (1,609 meters) and the height *H* in feet, the formula reads

$s = \sqrt{[2H]}$

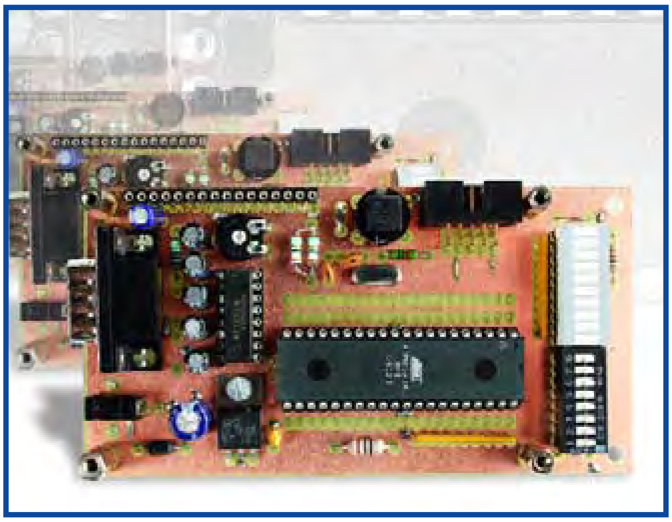
In the example, $H = 15$ meters ≈ 50 feet, and the square root of 100 = 10. Hence the radio horizon is 16 km away. The difference between 16 and 13.8 km is due to the commonly used 4/3 earth profile.
It is true that the distance to the radio horizon varies from these theoretical calculations, but the mile/feet formula is much easier to remember and to calculate.
Have a nice summer and best regards from Knut.
Knut I. Bakke (Denmark)

As a rule we print metrical units in Elektor but Knut's remarks certainly deserve a mention.

Charlieplexing update

Dear Editor — I read with great interest your Elektor Summer Issue. Again full of interesting circuits.
However, I found it disappointing that you had included circuit no. 046, 'Charlieplexing', with incomplete information. That may easily fool someone to try it out with an inappropriate driver.
In order to make such multiplexing work, it is essential that each pin can be tri-stated, i.e. all dark segments are then represented by hi-Z logic state. Otherwise the setup does not work. Maxim's application note correctly addresses that.
Heikki Paananen (Finland)

Thanks for this useful bit of information Heikki.



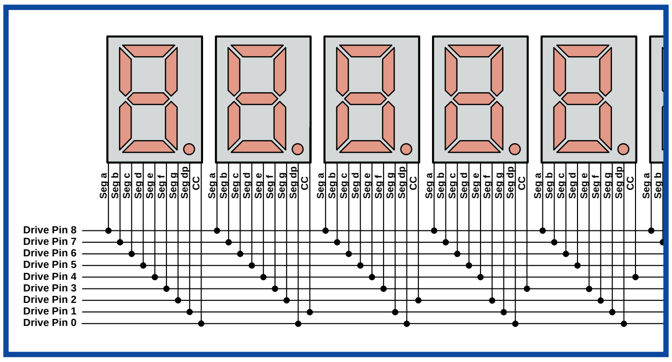
Mini ATMega Board

Dear Jan — I write to question the advisability, from a design perspective, of using JP2 to isolate the R2 resistor array from ground when the switches of S1 are not required. With JP2 open, the resistors become interconnected to all of the pins of PortA. The 8 pins of PortA can be configured independently as either a digital input or output or as an input to a 10-bit A/D converter. The result of interconnecting these PortA pins via the 10-kΩ resistor array elements will be significant 'contamination' of any analogue signal being measured, particularly if its source impedance is not zero, such as from a bridge. If the adjacent PortA pin is configured as an output and toggles between +5 volts and ground, an offset of about 25 mV would be imposed on an analogue signal with a source impedance of 100 ohms. Not 'a good look'.
The broad design objective could be achieved by placing JP2 on the 'hot' side of the S1 switch array instead of the ground side of R2. All of the switches would need to be open when using the A/D converter and a scaling allowance would need to be made for the reduction in the analogue signal due to the voltage divider action of the grounded 10-kΩ resistor with the source impedance of the signal being measured.
Keep up the good work.
Ross McKenzie (Australia)

Thanks for that Ross, our designers fully agree and the word is being passed on.

Multi Colour LEDs

Dear Editor — ref. July/August 2006 issue — project 052 'Multi Colour Flashing LED'. I can't find "i.c.engineering" for supply of LED chips. Can you advise? Many thanks.
Adrian Wood (UK)



We can. See www.fbice.com or order from Conrad Electronics, item code 150700.

AA Cell Characteriser

Dear Jan — several of my colleagues and myself have built this useful piece of equipment (April 2006, *Ed.*) and have found that not only does it check the quality of an AA cell but it also checks the amount of charge that different chargers put into the cells.
I get between 98% and 103% of the rated capacity from my cells but one colleague was only getting 70% or so and blamed his cells. A quick swap of cells and charging on my charger produced in excess of 95%.
The result is that this tester is a good way of checking that your charger is doing what it is required to do. It is pointless getting higher and higher capacity cells if your charger is not fully charging them.
Geoff Moore (UK)

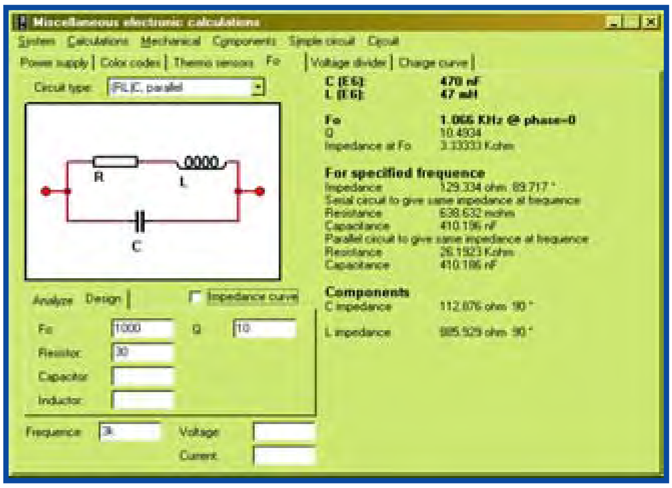
SC Analyser — some feedback

Dear Sir — I just wanted to pass on my experience relating to the Article 'SC Analyser 2005' in the April 2005 issue. My thanks to the author M.Waleczek and Mike Doty of M3 Electronix for their help.
I love your magazine and have built three kits so far:
- DRM Receiver
- Electrosmog Detector
- SC Analyser 2005

All the kits have worked flawlessly. Many thanks. I am a telecom engineer and also teach telecom and electronics related courses at a Engineering Technology polytechnical college in Toronto, Canada.
One of my class projects was for the students to build the SC Analyser. They all

designed their own boards using an LPKF machine and I programmed their PICs for them. I had several problems using my PICSTART programmer. Essentially when I read the hex file, if I just programmed the chip it would not work. If I read the hex file, then reset the configuration bits as the article stated, then the PICSTART would set both code protect bits to zero and no programming was possible. My procedure is to erase the chip, then set the configuration bits and program them first. After this, I then import the hex file then only program the program memory. This works around the code protection bits being set. This is a great project for students learning electronics.
Jeremy Clark (Canada)

Thanks for the feedback Jeremy. All our recent PIC based projects come with configuration bit information as in many cases the default values supplied by Microchip will not work. In case of problems or older projects, do not hesitate to send an email and one of our in-house designers will help you.



Free program for electronic design basics

[Screendump 065075-11U]

Dear Editor — I have seen that you sometimes publish links to interesting electronic programs. I believe my program is in that category:

Please check the webpage for a description of the program:
www.miscel.dk/MiscEl/miscel.html
The program is a hobby of mine, I have been working on it for many years, when I have spare time. Some years ago I decided to share the program with others and put it on the internet, where everyone can get it for free.
Henrik K. Jensen (Denmark)

A useful and easy to use bit of software, Henrik, thanks for making it available to all of us!

Piano playing aid

Dear Sir — I am in the process of designing a system that allows a person to learn playing the piano much faster using a visual aid.
I already own such a system for guitar playing (www.fretlight.com), but a version for the piano does not seem to exist yet.
I have already found some sources that are very close to what I need, but I am still thinking about an LED bar with the electronics built in the case and that consumes almost no power or is powered from an USB port.
Some sources I came across during my research:
www.members.aol.com/decomidi/index_english.htm
and www.midiboutique.com
showing the MDEC64 inter-

face. I am thinking of a system with a LED bar that you can place on a piano. The circuit then shows what buttons you have to press with your left and right hand. USB connectivity would be provided and the possibility to wire up a footswitch.
Johan Pyfferoen (Belgium)

Looking forward to seeing that design Johan!

I want to become famous, too

Dear Editor — I have some circuits ready to share with Elektor. How can I do this? I can send you a .pdf, a .doc file or the original Protel99SE work.
F. M. Gouveia (Portugal)

This is one of the most frequently seen questions forwarded to us by email via the Contact form available on our website. The answer is invariably that our Author Guidelines are available for anyone to read at the SERVICE page of our website (www.elektor-electronics.com). Publication of articles received from free-lance authors is subject to acceptance of the Board of Editors & Designers who meet approximately every month to discuss article proposals.

How many E-Weekly clients?

Dear Jan — just out of curiosity, how many people are subscribing to the E-Weekly newsletter you are sending out? I get mine every Friday and particularly enjoy the pieces you write on what's brewing at Elektor.
Peter McCullough (UK)

Thanks for enquiring Peter. Denis, our web editor tells me that currently 7,200 email addresses are supplied with our free newsletter and that the number is growing at a rate of about 2 percent per month. We recently cleaned our E-Weekly client database addresses, removing duplicate, fake, unresponsive and 'bouncing' email addresses.

Corrections & Updates

Multi-Colour Flashing LED

July/August 2006, p. 83, ref. 0604014-1

The manufacturer of the LED devices discussed in this article has a website at www.fbice.com. Conrad Electronics is a suggested retailer for the product.

Geiger Counter

July/August 2006, p. 130, ref. 040291-1

In the circuit diagram, the junction of C5 and the 220-V winding of TR1 should be connected to the circuit ground line.

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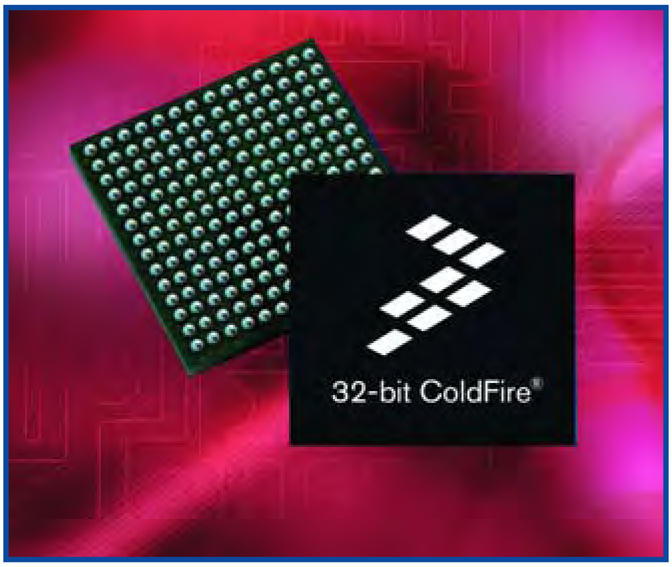
Freescale's ColdFire(R) 32-bit controllers bring wireless connectivity to consumer and industrial applications



Home and industrial automation applications increasingly demand control, connectivity and security. With the release of Media Access Controller (MAC) software that supports the IEEE(R) 802.15.4 protocol on the low-power 32-bit ColdFire(R) architecture, Freescale Semiconductor is creating the broadest portfolio of 802.15.4-enabled solutions in the marketplace.

According to In-Stat, 802.15.4 chipset sales will surpass 150 million units in 2008. Typical applications include home and building automation, industrial monitoring and control, and wireless sensor networks. Designers have struggled to create reliable and secure wireless communication links simply and cost-effectively. Freescale now offers the necessary components for wireless design — microcontroller (MCU), RF and software stack — in 8- and 32-bit chipsets.

Freescale's ColdFire devices are designed to enable gateways for wireless connectivity, helping consumers easily keep an eye on their homes, secure their property from intruders and control household appliances with the click of a mouse.

The ColdFire family of controllers includes devices outfitted with Ethernet MAC/PHY, large amounts of memory and rigorous hardware encryption for security. With a broadband connection, Ethernet gateways based on the ColdFire architecture simply plug into the Ethernet port of current networks to power wireless connectivity.

Freescale offers a wide spectrum of wireless networking solutions, ranging from simple point-to-point and star networks, to sophisticated networks including ZigBee mesh networks. ColdFire MCUs can be coupled with Freescale's MC13191 or MC13201 2.4 GHz RF transceivers and SMAC software for applications that do not require mesh networking or critical timing restrictions. When coupled with MC13192 or MC13202 2.4 GHz RF transceivers and fully compliant IEEE 802.15.4 PHY and MAC software, ColdFire MCUs provide 802.15.4 MAC functionality.

Pricing and availability

The 802.15.4 software is now available for the MCF5282, MCF5213 and MCF5223x processor families. This complimentary embedded software library and the required RF transceivers are available on the Freescale Web site: www.freescale.com/ZigBee.

The M52233DEMO demonstration board is available now for the suggested resale price of $99 (USD). The M52235EVB evaluation board is available for the suggested resale price of $299 (USD). The 13192RFC-A00 and 1320XRFC RF daughter cards are also available for suggested resale pricing of $149 (USD) and $79 (USD) respectively.

Further information on the new products may be found at www.freescale.com/files/pr/cfzigbee-ready.html .

(067192-4)

www.freescale.com

WirelessUSB™ LP evaluation kit showcases low-power 2.4-GHz wireless radio system-on-chip

For design engineers wanting to replace the wires between 'human interface' peripherals such as keyboards, mice, joysticks and games consoles with wireless connections, Cypress Semiconductor's WirelessUSB LP device is a popular choice - it is easy to design in, it's cheap and it doesn't consume much power. For these applications, it has many advantages over industry standards such as Bluetooth and ZigBee.

Now Cypress has launched an eval kit that allows designers to see for themselves how Wire-

lessUSB performs in the real world, and to experiment with module-driven designs.
The CY3630 Evaluation Kit (EVK) showcases the robust, low-power WirelessUSB LP radio, and includes a multiconfiguration microcontroller (MCU) socket, radio modules, LCD displays, a large prototyping area, and MCU programming software. The kit also includes four firmware tutorials as well as a wireless range demo that help users to quickly build familiarity with the features and performance of the radio.
WirelessUSB LP offers an unparalleled feature set to enable superior interference immunity, low bill-of-materials (BOM) costs, higher data rate applications, and faster time-to-market for keyboards, mice, gaming devices, presenter tools, and remotes, as well as other simple, multi-point-to-point wireless applications. It operates between 1.8 and 3.6 volts, using advanced power-saving techniques to extend battery life in devices such as wireless mice. The device uses Cypress's patented frequency agile Direct Sequence Spread Spectrum (DSSS) technology to offer best-in-class interference immunity for a 2.4-GHz radio system. This combination of low power consumption, interference immunity and low cost make it ideal for wireless HID applications.

The CY3630 WirelessUSB LP EVK includes all of the following items:

- Microcontroller modules for driving the radio
- An Emulation module for in-circuit debugging
- WirelessUSB LP radio modules for easy prototyping and evaluation
- MiniProg Programmer for in-system serial programming of any Cypress Flash MCU
- LCD Modules to display application data and provide user feedback
- CD-ROM with complete kit documentation, tutorials, and sample firmware

(067129-6)

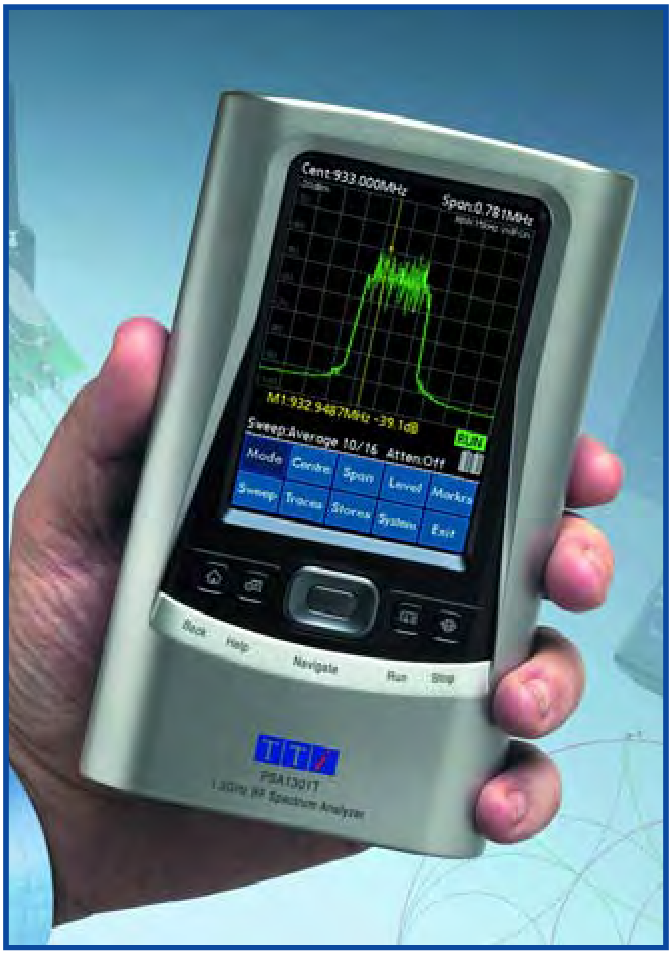
www.cypress.com

Handheld RF spectrum analyzer based on Palm handheld

Thurlby Thandar Instruments has developed a handheld RF spectrum analyzer designed to set a new price point - below € 1200 (approx. £ 850). The analyzer is based around a Palm handheld computer which provides the display, control, calculation, mass storage and external interface capabilities.

The PSA1301T has a high-resolution (480 x 320 pixel) backlit color TFT display capable of displaying 65,000 colors but still has a relatively low power consumption providing more than 4 hours continuous operation from a single charge. For continuous bench top operation it can be operated from its AC adaptor which also recharges the batteries in less than 4 hours.

Frequency range is 150 kHz to 1.3 GHz with selectable resolution bandwidth down to 15 kHz. Sweep modes include continuous, single, peak hold and average (up to 256 sweeps). Sweep parameters can be set in terms of centre plus span or start plus stop to 1 kHz resolution. A zero span mode with AM or FM demodulation is also provided.
Dual markers are incorporated with simultaneous readout of absolute amplitude and frequency plus difference values. Markers can be scrolled manually, or set to automatically find and track peaks.
A reference trace can be displayed simultaneously with the live trace, with the two traces clearly differentiated by color. The reference trace is automatically shifted and scaled to match the current sweep parameters when they are changed.
Any number of waveforms and settings can be stored to permanent memory using an SD or MMC flash memory card. Data can be saved under default or user-entered file names as preferred. bitmap images of the whole screen can also be stored for viewing or printing. The PSA1301T can store three types of data: traces, set-ups and screens. Trace data is stored as tables of amplitude against frequency in a comma delimited format, which can be recalled to the screen as a reference trace. Screens are saved as complete bit-map images of everything visible at the time (traces, graticule, markers and all annotation). These can then be viewed on the Palm itself or transferred to a PC. PSA1301T data files are stored on removable flash memory cards. A USB linked card reader is supplied which allows files to be transferred to or from a PC using simple drag and drop. Where a wireless connection is available (Bluetooth or WiFi), files may be transferred using email attachments or via a wireless communications application.



PSA1301T trace files have a standard comma separated value (.csv) format which can be imported into other applications such as Excel or MathCad. Control of the analyzer is provided by soft keys created on the touch screen. These are large enough to be finger-operated, eliminating the need for a stylus. Alternatively, all functions can be operated using the hard keys of the handheld unit.

To extend battery life the analyzer can also be set to turn off automatically after a user-defined delay from the last key press.

(067129-7)

www.tti-test.com

FTDI's new Vinculum chip ties USB to other technologies

At the Embedded Systems Conference in Taipei, Taiwan, Future Technology Devices International Ltd. (FTDI) announced the release of their Vinculum family of embedded USB Host Controller devices.

The Vinculum USB Host Controller ICs not only handle the USB Host Interface, and data transfer functions but owing to the inbuilt 8 / 32 bit MCU and embedded Flash memory, Vinculum encapsulates the USB device classes as well. When interfacing to mass storage devices such as USB Flash drives, Vinculum also transparently handles the FAT File structure communicating via UART, SPI or parallel FIFO interfaces via a simple to implement command set. Target pricing is $5.00 each @ 10k pieces.
The initial product member of the family is the VNC1L device which features two USB Ports which can be individually configured by firmware as Host or Slave ports.

Key VNC1L features include:

- 8 / 32 bit V-MCU Core
- Dual DMA controllers for hardware acceleration
- 64k Embedded Flash Program Memory
- 4k internal Data SRAM
- 2 x USB 2.0 Slow / Full speed Host / Slave Ports
- UART, SPI and Parallel FIFO interfaces
- PS2 legacy Keyboard and Mouse Interfaces
- Up to 28 GPIO pins depending on configuration
- 3.3V operation with 5V safe inputs
- Low power operation (25mA running / 2mA standby)
- Inbuilt FTDI firmware easily updated in the field
- LQFP-48 ROHS compliant package
- Multi-processor configuration capable

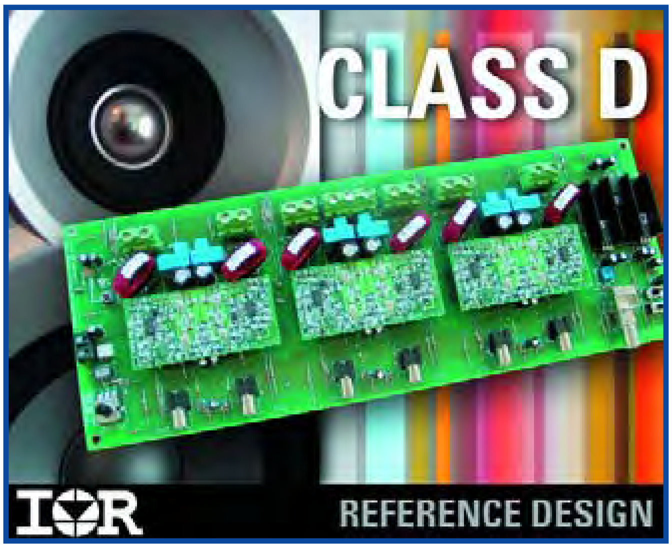
FTDI's CEO, Fred Dart said "Vinculum brings cost effective USB Host capability to products that previously did not have the hardware resources available. We anticipate that these devices will be especially popular for adding USB Flash Drive connectivity to a wide range of consumer and industrial products. As Vinculum comes complete with FTDI's in-house developed firmware, there are no USB software stacks to license, indeed, no knowledge of USB is required to use these devices."
'Vinculum' derived from the Latin word 'vincere' means "an entity that binds/ties objects or expressions together' — in this case, various USB and other technologies.

Complete details for the Vinculum VNC1L are located at www.vinculum.com.
FTDI's full product line can be found on the main web site at: www.ftdichip.com.

(067193-4)

Class-D audio reference design

International Rectifier, recently introduced the IRAUDAMP3 Class-D audio reference design. The new, compact reference design features the IRS20124S high-voltage analog IC and IRF6645 DirectFET® power MOSFETs to complete a six-channel 120W half-bridge Class D audio power amplifier with no heatsink.



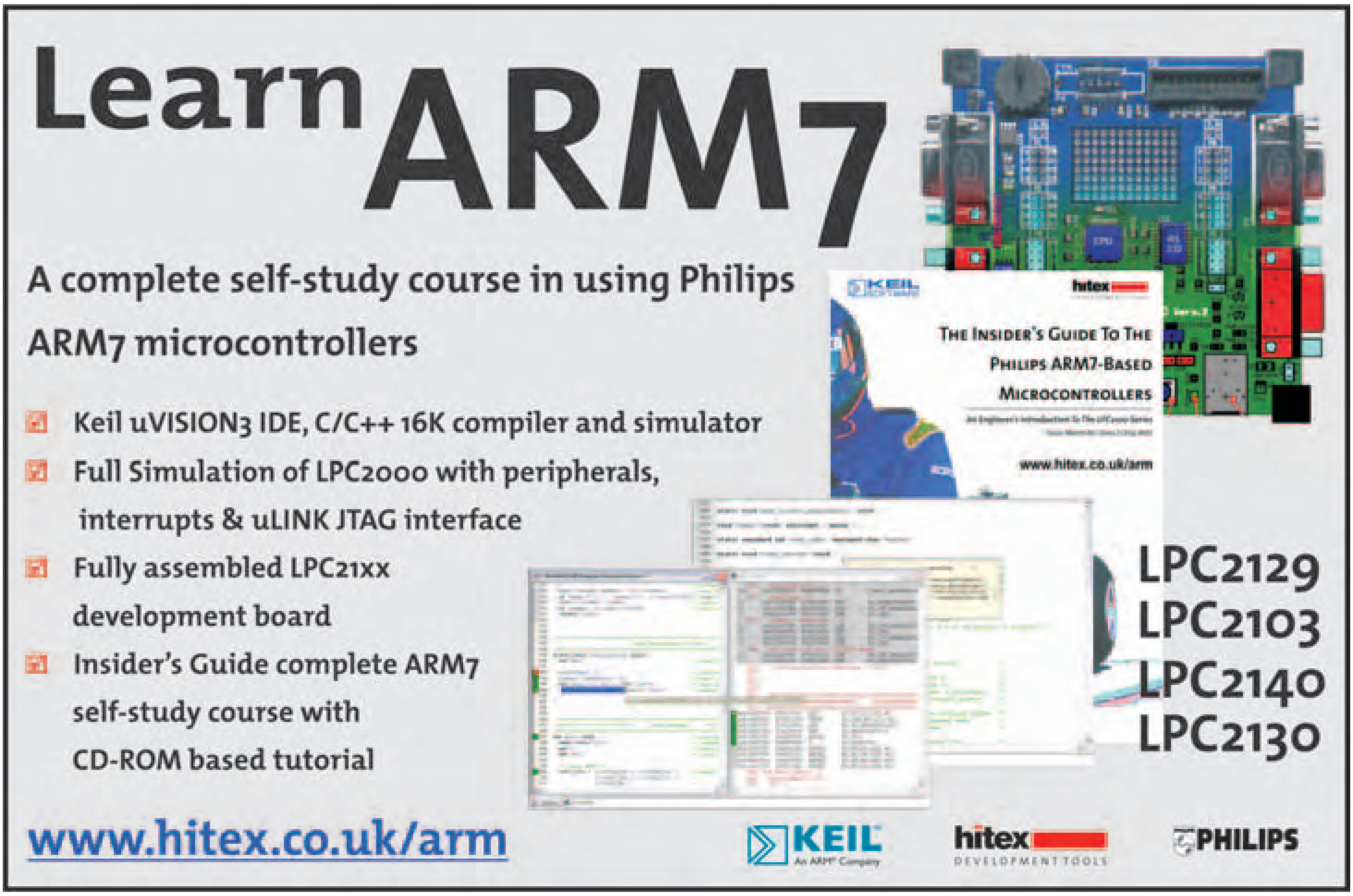
The IRS20124S high-voltage IC incorporated in this reference design features an internal selectable dead-time generation circuit and is immune to noise and supply voltage fluctuations to help achieve a total harmonic distortion (THD) of 0.01% at 60W, 4 Ω and 94% efficiency at 120 W, 4 Ω single channel. Additionally, the IC has built-in bi-directional current sensing and an integrated shutdown function to protect the output MOSFETs when an over-current condition occurs such as a short-circuited speaker wire.

The IRAUDAMP3, which has a footprint of 4.5 square inches for each two channel control and switch function, also utilizes IRF6645 DirectFET power MOSFETs. The innovative DirectFET packaging technology enhances performance in Class-D audio amplifier circuits by reducing lead inductance to improve switching performance and reduce EMI noise.

The higher thermal efficiency enables 120 W operation into 4 ohms, eliminating the need for a heatsink to shrink circuit size, provide greater layout flexibility and reduce overall amplifier system cost.

www.irf.com

(067193-2)



PicoScope	3204	3205	3206
Bandwidth	50MHz	100MHz	200MHz
Sampling rate (repetitive)	2.5GS/s	5GS/s	10GS/s
Sampling rate (single shot)	50MS/s	100MS/s	200MS/s
Channels	2+Ext trigger	2+Ext trigger/Sig gen	2+Ext trigger/Sig gen
Oscilloscope timebases	5ns/div to 50s/div	2ns/div to 50s/div	1ns/div to 50s/div
Timebase accuracy	50ppm	50ppm	50ppm
Spectrum ranges	0 to 25MHz	0 to 50MHz	0 to 100MHz
Buffer memory size	256KB	512KB	1MB
Resolution / accuracy	8 bits / 3%		
Ranges	±100mV to ±20V		
PC Connection	USB2.0 (USB1.1 compatible)		

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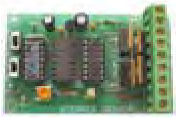
Motor Drivers/Controllers

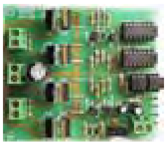
Here are just a few of our controller and driver modules for AC, DC, unipolar/bipolar stepper motors and servo motors. See website for full details.

NEW! PC / Standalone Unipolar Stepper Motor Driver



Drives any 5, 6 or 8-lead unipolar stepper motor rated up to 6 Amps max. Provides speed and direction control. Operates in stand-alone or PC-controlled mode. Up to six 3179 driver boards can be connected to a single parallel port. Supply: 9Vdc. PCB: 80x50mm.
Kit Order Code: 3179KT - **£11.95**
Assembled Order Code: AS3179 - **£19.95**

NEW! Bi-Polar Stepper Motor Driver



Drive any bi-polar stepper motor using externally supplied 5V levels for stepping and direction control. These usually come from software running on a computer.
Supply: 8-30Vdc. PCB: 75x85mm.
Kit Order Code: 3158KT - **£15.95**
Assembled Order Code: AS3158 - **£29.95**

NEW! Bidirectional DC Motor Controller

Controls the speed of most common DC motors (rated up to 16Vdc/5A) in both the forward and reverse direction. The range of control is from fully OFF to fully ON in both directions. The direction and speed are controlled using a single potentiometer. Screw terminal block for connections.
Kit Order Code: 3166KT - **£16.95**
Assembled Order Code: AS3166 - **£25.95**

DC Motor Speed Controller (100V/7.5A)

Control the speed of almost any common DC motor rated up to 100V/7.5A. Pulse width modulation output for maximum motor torque at all speeds. Supply: 5-15Vdc. Box supplied. Dimensions (mm): 60Wx100Lx60H.
Kit Order Code: 3067KT - **£13.95**
Assembled Order Code: AS3067 - **£20.95**

Most items are available in kit form (KT suffix) or assembled and ready for use (AS prefix).

Controllers & Loggers

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

Serial Isolated I/O Relay Module

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

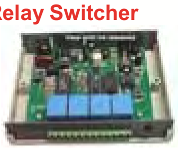
Computer Temperature Data Logger

4-channel temperature logger for serial port. °C or °F. Continuously logs up to 4 separate sensors located 200m+ from board. Wide range of free software applications for storing/using data. PCB just 38x38mm. Powered by PC. Includes one DS1820 sensor and four header cables.
Kit Order Code: 3145KT - **£18.95**
Assembled Order Code: AS3145 - **£25.95**
Additional DS1820 Sensors - **£3.95 each**

Rolling Code 4-Channel UHF Remote

State-of-the-Art. High security. 4 channels. Momentary or latching relay output. Range up to 40m. Up to 15 Tx's can be learnt by one Rx (kit includes one Tx but more available separately). 4 indicator LED 's. Rx: PCB 77x85mm, 12Vdc/6mA (standby). *Two and Ten channel versions also available.*
Kit Order Code: 3180KT - **£44.95**
Assembled Order Code: AS3180 - **£51.95**

NEW! DTMF Telephone Relay Switcher



Call your phone number using a DTMF phone from anywhere in the world and remotely turn on/off any of the 4 relays as desired.
User settable Security Password, Anti-Tamper, Rings to Answer, Auto Hang-up and Lockout. Includes plastic case. Not BT approved. 130x110x30mm. Power: 12Vdc.
Kit Order Code: 3140KT - **£46.95**
Assembled Order Code: AS3140 - **£64.95**

Infrared RC Relay Board

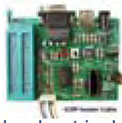
Individually control 12 on-board relays with included infrared remote control unit. Toggle or momentary. 15m+ range. 112x122mm. Supply: 12Vdc/0.5A
Kit Order Code: 3142KT - **£47.95**
Assembled Order Code: AS3142 - **£66.95**

PIC & ATMEL Programmers

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

Programmer Accessories:
40-pin Wide ZIF socket (ZIF40W) £15.00
18Vdc Power supply (PSU010) £19.95
Leads: Parallel (LDC136) £4.95 / Serial (LDC441) £4.95 / USB (LDC644) £2.95

NEW! USB & Serial Port PIC Programmer



USB/Serial connection. Header cable for ICSP. Free Windows XP software. Wide range of supported PICs - see website for complete listing. ZIF Socket/USB lead not included. Supply: 16-18Vdc.
Kit Order Code: 3149EKT - **£37.95**
Assembled Order Code: AS3149E - **£52.95**

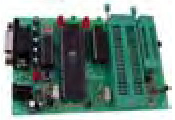
NEW! USB 'All-Flash' PIC Programmer

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

"PICALL" PIC Programmer

"PICALL" will program virtually all 8 to 40 pin *serial-mode* AND *parallel-mode* (PIC16C5x family) programmed PIC micro controllers. Free fully functional software. Blank chip auto detect for super fast bulk programming. Parallel port connection. Supply: 16-18Vdc.
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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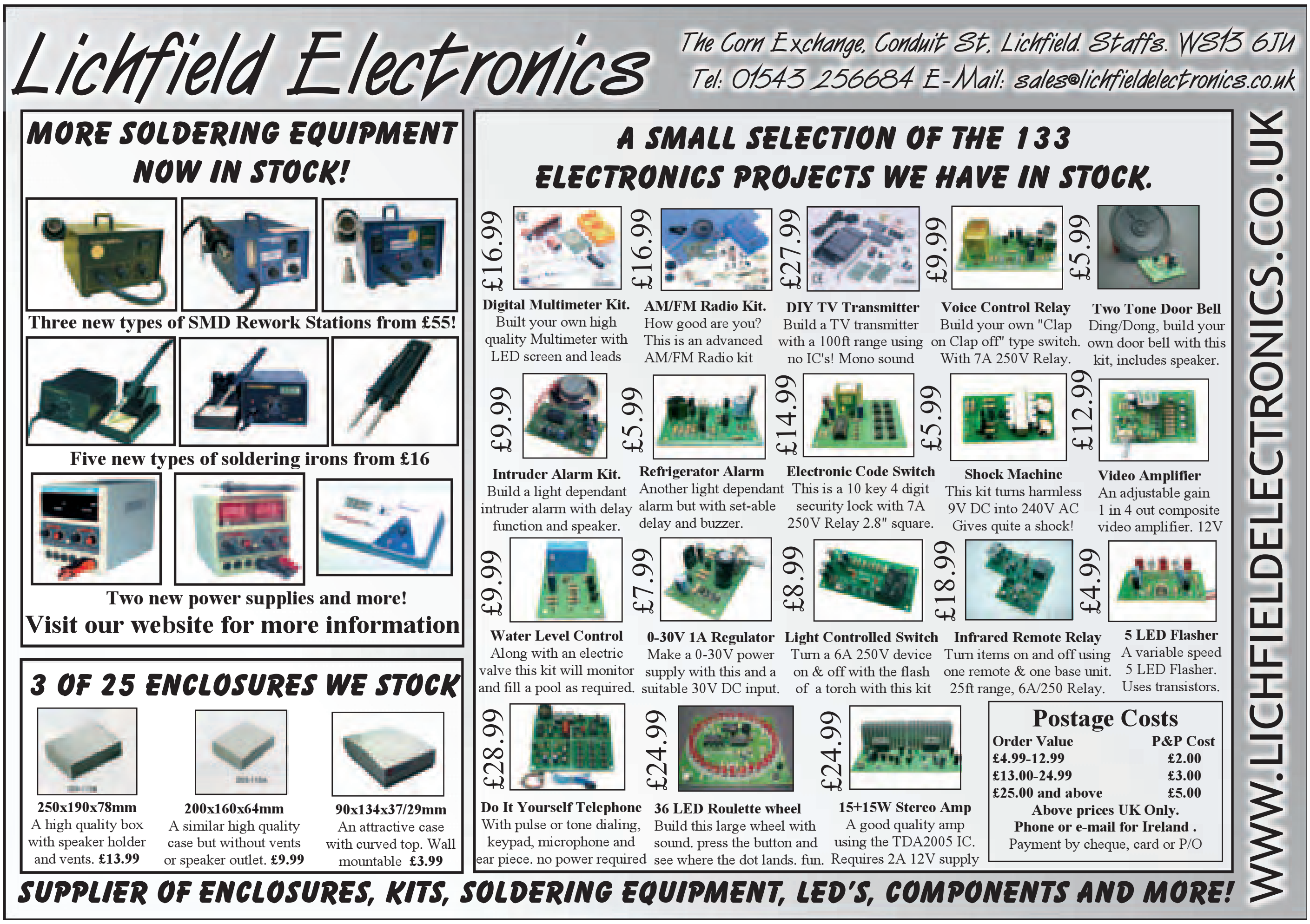

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£9.99 Voice Control Relay Build your own "Clap on Clap off" type switch. With 7A 250V Relay.
£5.99 Two Tone Door Bell Ding/Dong, build your own door bell with this kit, includes speaker.
£9.99 Intruder Alarm Kit. Build a light dependant intruder alarm with delay function and speaker.
£5.99 Refrigerator Alarm Another light dependant alarm but with set-able delay and buzzer.
£14.99 Electronic Code Switch This is a 10 key 4 digit security lock with 7A 250V Relay 2.8" square.
£5.99 Shock Machine This kit turns harmless 9V DC into 240V AC Gives quite a shock!
£12.99 Video Amplifier An adjustable gain 1 in 4 out composite video amplifier. 12V
£9.99 Water Level Control Along with an electric valve this kit will monitor and fill a pool as required.
£7.99 0-30V 1A Regulator Make a 0-30V power supply with this and a suitable 30V DC input.
£8.99 Light Controlled Switch Turn a 6A 250V device on & off with the flash of a torch with this kit
£18.99 Infrared Remote Relay Turn items on and off using one remote & one base unit. 25ft range, 6A/250 Relay.
£4.99 5 LED Flasher A variable speed 5 LED Flasher. Uses transistors.
£28.99 Do It Yourself Telephone With pulse or tone dialing, keypad, microphone and ear piece. no power required
£24.99 36 LED Roulette wheel Build this large wheel with sound. press the button and see where the dot lands. fun.
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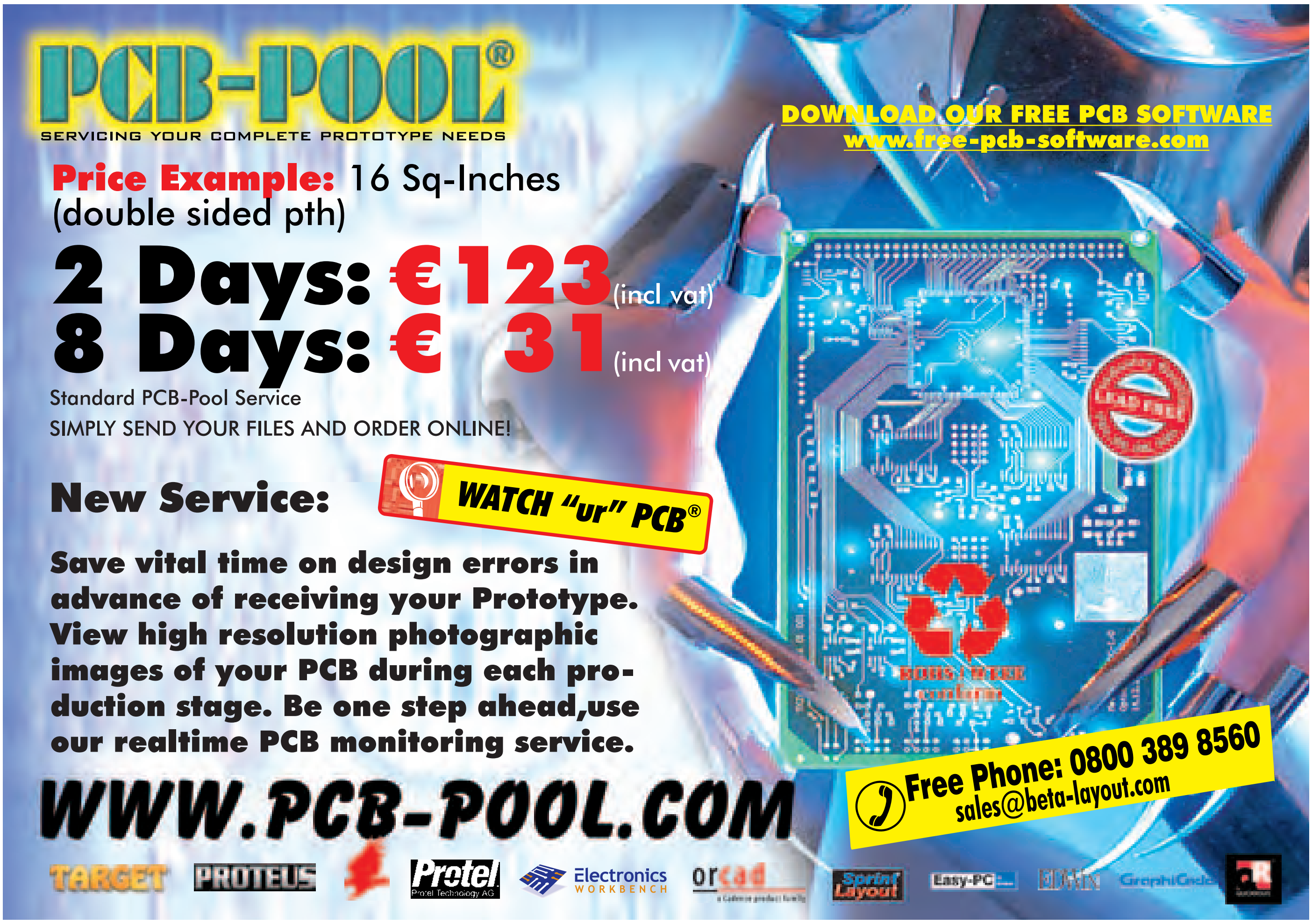

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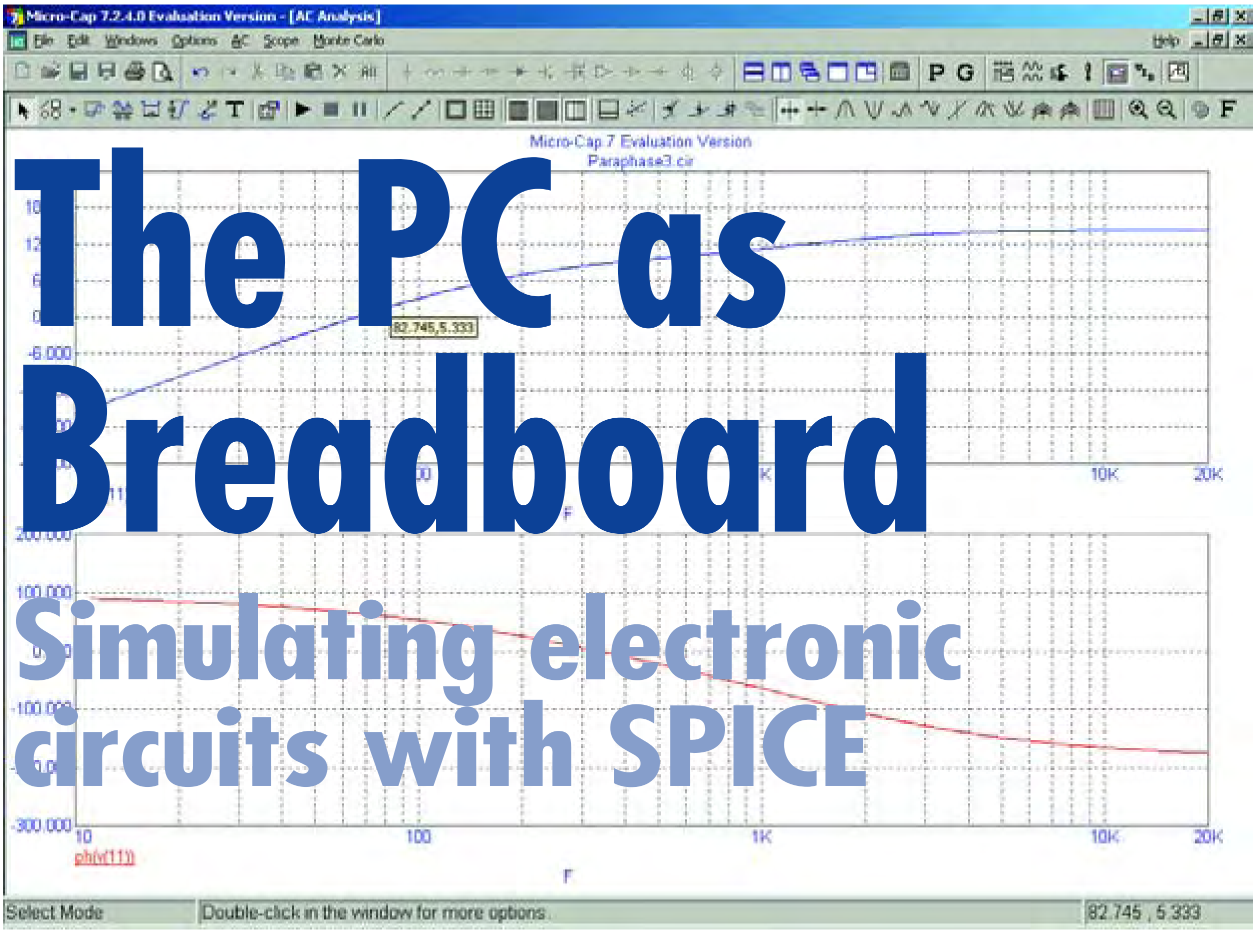
Simulating electronic circuits with SPICE



Kees de Groot

Electronics designers these days spend more time behind their PCs than holding their soldering irons. Thanks to clever software, entire circuits can be simulated without making even a single solder joint. The basis for such simulation software is SPICE, which was developed back in 1972. Here we give a concise description of the way SPICE achieves a realistic simulation of components and circuits.

SPICE is a program you can use to simulate electronic circuits. All voltages and currents can be examined before the circuit has been physically built. There you have it: soldering and experimenting using the PC!

The circuit can be made from all currently known components. That means resistors, capacitors and inductors, but also diodes, transistors and FETs. Many ICs are now also available via libraries. You can define new components yourself, buy them or pick them from the Internet. The results from the simulation generally correspond very well with the real world, even up to very high frequencies.

In addition to analogue circuits, modern simulation software can also simulate digital circuits, such as microcontrollers, RAM and circuits with digital ports, as well as antennas and transmission lines.

Now why would I use SPICE?

For the hobbyist, SPICE offers a tremendous opportunity to experiment with new or (still) unknown components. It is interesting to spend a rainy Sunday afternoon to put together a valve circuit and then drastically lower the supply voltage and examine where problems occur in the circuit. A push-pull audio amplifier power stage with a class-E RF final stage is quite easily slapped up from valves, transistors or FETs. And there is no risk of the accidental demise of expensive components!

The professional electronics designer, too, can benefit a lot from such software. Circuits and changes can be tested without building a new prototype every time. It is also possible to take into account the tolerances and temperature dependency of the components used. In this way it is quick to check if a circuit is reproducible in practice.

How it started

The development of SPICE (Simulation Program with Integrated Circuits Emphasis) dates back to 1972 when Larry Nagel and Donald Pederson of the University of

Berkeley in California wrote the very first version in Fortran. The early versions did not have a graphical user interface, because the programs were carried out on a mainframe computer. This is part of the reason why a rather Spartan description of the circuit is used. This method of description is still used in modern SPICE-models and sub-circuits (**Figure 1**).
Later versions of SPICE, we have now moved forward to 1985, were written in C. The first PC version, PSPICE, was marketed by MicroSim.

These days there are dozens of simulation tools that are more or less based on SPICE. In addition to the commercial versions there are also open-source versions. For educational purposes there are versions which are limited in the size of the circuit that can be simulated or versions with a time limit. Many simulation programs offer the possibility to enter the schematic with a graphical user interface (GUI) and display the simulation results in graphical form on a virtual oscilloscope. It is often also possible to seamlessly convert a virtual circuit into a PCB design.
In addition to the simulation of standard electronic circuits, there are simulators for specialist fields. There are simulators of integrated circuits, microwave circuits and filters, but also radio antennas and even electromagnetic fields. The input can be done in the old-fashioned, numeric way, by naming all the inputs, outputs, nodes, voltages, currents and components. However, many modern simulation programs fortunately make use of graphical input, in which the mouse is used to place components and connect the parts together. For digital circuits a hardware description language like VHDL or Verilog is often used, extended if need be, with an analogue description language.

A completely different area is the simulation of mechanical systems. And what do you think of a simulation program that allows you to build LEGO designs? However, we won't pursue those ones any further here.

How does SPICE work?

SPICE makes use of the Laws of Ohm and Kirchhoff in a clever way.
Ohm's Law gives the relationship between the voltage across a resistor and the current that flows through that resistor. If at a voltage of U = 12 V there is a current of I = 0.5 A through the resistor, then the value of that resistor is 24 Ω ($R = U/I$).
Kirchhoff's Current Law states that at any node the current entering the node is equal to the current leaving the node. For example, connect a few water hoses to a T-coupling. All the water that flows into a hose is certain to leave via the other connected hoses. Not more and not less.

Kirchhoff's Voltage Law states that around a net (a loop through the circuit such that you end at the starting point) the voltages sum to zero. This is analogous to a cycle route through hilly terrain. Whichever route you choose, you can never go only downhill from the camping ground to the pub and then downhill back to the camping ground. You will later go up by the exact same amount as you went down. And you'll know it.

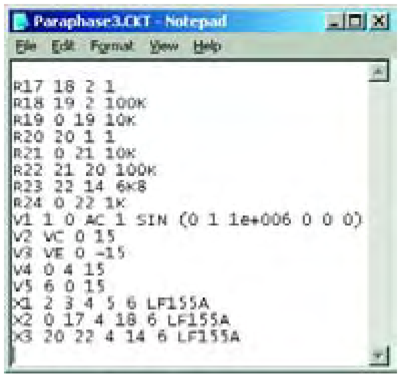
A small example: Assume that we want to charge a penlight (AA) battery of 1.2 V via a resistor of 10 Ω from a voltage source of 12 V. Across the battery there is a moving coil meter with an internal resistance of 100 Ω (**Figure 2**).

Kirchhoff's Voltage Law states

$$U_1 - I_1 \times R_1 + U_2 = 0 \qquad [1]$$
$$U_2 + (I_1 - I_2) \times R_2 = 0 \qquad [2]$$

These two equations can be solved for I_1 and I_2 using some simple algebra. It turns out that I_1 = 1.08 A and I_2 = 1.068 A. The battery will therefore be charged at a current of 1.068 A.

SPICE does it in the same way. At each node Kirchhoff's Current Law is applied and Kirchhoff's Voltage Law for each net. In this way you get a number of equations that are ultimately stored in memory in the form of a matrix of numbers. This matrix is inverted and in this way the set of equations is solved. Any arbitrary number of resistors, voltages sources and current sources can be connected, as long as we tell the computer what is connected


Paraphase3.CKT - Notepad
File Edit Format View Help

```
R17 18 2 1
R18 19 2 100K
R19 0 19 10K
R20 20 1 1
R21 0 21 10K
R22 21 20 100K
R23 22 14 6K8
R24 0 22 1K
V1 1 0 AC 1 SIN (0 1 1e+006 0 0 0)
V2 VC 0 15
V3 VE 0 -15
V4 0 4 15
V5 6 0 15
X1 2 3 4 5 6 LF155A
X2 0 17 4 18 6 LF155A
X3 20 22 4 14 6 LF155A
```

Figure 1.
Part of a SPICE netlist. All components are listed with the node numbers they are connected to, followed by other specific characteristics.

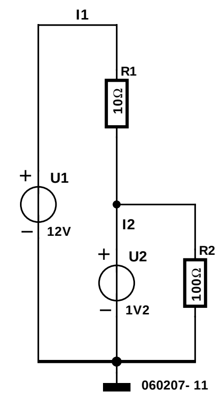


Figure 2.
Replacement schematic of a 12-V power supply which charges a NiCd cell via a 10-Ω resistor. A moving coil meter is in parallel with the battery.

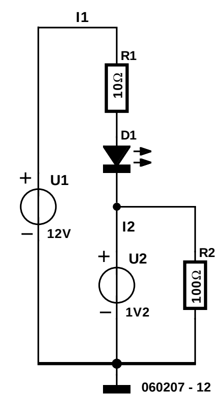


Figure 3.
An indicator LED is added in series with the charging resistor.

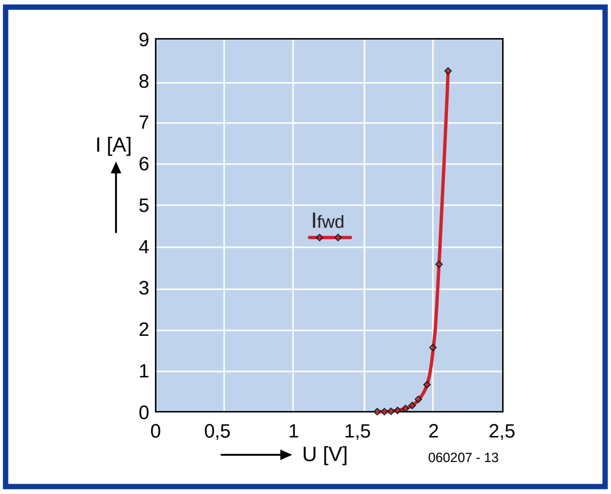


Figure 4. The calculated forward transfer function of the LED.

between the various nodes.

If we now connect an LED in series with R_1 (**Figure 3**), then finding the solution is not quite so easy any more. The LED will cause a reduction in voltage of about 2 V, causing U_1 to drop to about 10 V. Now we can, just as before, calculate the solution for I_1 and I_2, but with that value of 2 V, these will only be a rough approximation. If we want an exact solution, then we need some more maths, because with the LED we are dealing with a non-linear element.
For the current I_{LED} holds:

$$I_{LED} = I_s \times (e^{Ud/N \cdot Ut} - 1)$$

Where $I_s = 5.5 \times 10^{-15}$ A, U_d is the voltage across the diode, $U_t = 25 \times 10^{-3}$ V and $N = 2.3$.
Figure 4 shows what this looks like in the form of a graph. This is the forward voltage characteristic of a diode or LED, as supplied by the manufacturer. If the voltage across the LED is less than about 2 V, then the current is very small. When the voltage is greater than the threshold voltage the current increases quite quickly.

The LED can therefore be replaced by a voltage source U_{LED} with a voltage that depends on the current I_1 in the circuit (**Figure 5**). But we are not there yet. Unfortunately, Kirchhoff's Laws fail when there are non-linearities in the circuit, and a voltage source whose value depends on something else in the circuit cannot be made to fit in the equations. What we can do, is linearise the LED around an arbitrary point. The idea is that with small variations of the voltage or current we can consider the LED to be a linear element. Now we can apply the Laws of Ohm and Kirchhoff again and calculate all the voltages and currents in the circuit. This does not give us the right answer, but it does give us a better approximation. With this better approximation we adjust the parameters of the approximation and then calculate another, better, linear approximation of our diode at this new operating point. It turns out that after only a few iterations we already have a usable result.

We have now seen how SPICE deals with non-linear elements. These are replaced by circuits that are linear around a certain operating point. By repeating the calculations a number of times, SPICE can, in the end, also find a solution for non-linear circuits. An operating point that 'fits' in the circuit.

Inductors and capacitors

If the circuit is powered from AC, then we can consider capacitors and inductors as complex impedances and simply apply Ohm's and Kirchhoff's Laws to determine the voltages and currents in the circuit. But it is not that easy when calculating the initial conditions.
Let us again take a simple circuit as an example: a voltage of 12 V, a resistor of 1 kΩ and a capacitor of 1 nF (**Figure 6**). When the voltage is switched on, there will be a current through R1. This current will charge C1, which causes the voltage across the capacitor to increase. The charging current will be reducing continuously. In the end the capacitor will be charged to 12 V. If we look at the state when the capacitor is charged to 4 V, then at that moment there will be 8 V across resistor R1. The current will be 8 mA. At this time the capacitor can be replaced with a voltage source. The change of voltage is written as

$$dU = dt \times i / C$$

So, if for 0.1 ms there is a current of 8 mA, the voltage across C will increase by

$$1 \times 10^{-7} \times 8 \times 10^{-3} / 1 \times 10^{-9} = 0.8 \text{ V}$$

After this 0.1 ms there is therefore a voltage of 4.8 V across C1 and 7.2 V across R1. We can now use these new values to make the calculations for the next 0.1 ms. In this way we can calculate the curve shown in **Figure 7**.
When using this simple iteration method the time steps have to be kept very small. This means that the PC has to calculate many steps, which could take quite some time. If we make the time step too small, then we could have additional rounding errors.
The time step is often variable. With large changes the steps are made smaller automatically and time steps increase again when changes are small. In practice the formulas in SPICE are a little different (trapezoidal integration is used), but the basic idea is the same.
In this example the capacitor was replaced by a voltage source. But it is also possible to work with a current source and a resistor as with the example of the diode. The principle remains the same: replace the part to be simulated with a combination of linear components and iterate to a solution.

Real-life components

Up to now we've been working with only ideal, theoretical components. Realistic components have a much more complex structure. A resistor is in reality a series circuit of a resistor with a parasitic inductance and both of these in parallel with a capacitance. With a transistor or opamp a large number of additional characteristics are added to that. In SPICE models there is a distinction between theoretical (virtual) and realistic components. The latter are usually sub-circuits where the total behaviour of the real component is replicated as good as possible. The user does not notice any of this, because with a transistor the same symbol always appears on the screen. Only when looking at the internal characteristics of the netlist will you

observe that there is a whole lot more than a theoretical, ideal transistor.
Most semiconductor manufacturers supply SPICE-models for their components, which replicate the characteristics of specific components as best as they are able to. Only with such accurate models is it possible to carry out a simulation whose output corresponds with the behaviour of a real circuit.

Tips and tricks

In SPICE, one node invariably has to be connected to ground. This is the **reference** node. When simulating a circuit, there is always an analysis of the initial conditions first. Things can already go wrong here, for example when you connect three capacitors in series. The middle capacitor can in theory have any arbitrary DC voltage level. This depends only on the initial charge of the capacitors. Even if the initial charge is equal to zero, the middle capacitor can have any arbitrary charge at the end.
When strange errors appear it can often help to swap the location of parts or connect a resistor of a few MΩ from a few strategic locations to ground, provided that is not a problem for the operation of the circuit.
When working with virtual components it is possible that the simulation of the circuit gives an excellent result. If you then use standard parts it may be that the circuit behaves strangely. This could be because the values of the components are not ideal any more, because you had to make a choice from the E12 series, for example. Particularly with filters the transfer function can be significantly different than what was theoretically calculated. The simulation program can help here as well, because with a so-called Monte-Carlo simulation you can specify a tolerance for all the components. In addition you can also subject the circuit to a real heat wave. The circuit will then be simulated with various combinations of component values and temperatures. The final result is shown as a graph with a large number of lines that are hopefully nicely one on top of the other.
When simulating a circuit with 'real' components, interesting things can be observed at higher frequencies. It is then possible that the stray self-inductance of a resistor (the connecting leads) is more significant than the resistance itself. Also, various parasitic capacitances (often only a fraction of a picofarad) can spoil the functionality of the circuit. You can easily add these to the schematic in certain places and then examine what the consequences are on the output signal.
When working with virtual opamps it is possible that the output voltage increases to more than 1 kV when there is a problem with the circuit. 'Real' opamps saturate to one of the power supply rails.
SPICE often has a dislike of transformer outputs that 'float'. So connect one side of the output of the transformer to ground. If that is not possible, a 1 MΩ resistor can often do wonders.
Note carefully: some SPICE programs do not know the difference between m and M, but do understand MEG. A resistor of 1 mΩ has a very small resistance! When in doubt use 1000 kΩ or 1 MEG.
With SPICE it is also possible to build circuits that are not practicable in the real world. Try, for example, to make an inductor with a self-inductance of 100 H and a resistance of only 0.01 Ω. Even transformers with a flux density of 1000 T (tesla) don't pose a problem for SPICE.
Finally: it is possible that an apparently simple circuit does not work. After you have checked all the connections and if it still doesn't work then it may be useful to go to the Internet and ask for help on a forum. Some manufacturers are very helpful. They have a vested interest in knowing what does and doesn't work in practice. Let's be honest here: us users — whether we want to or not — are always participating in one big beta test!

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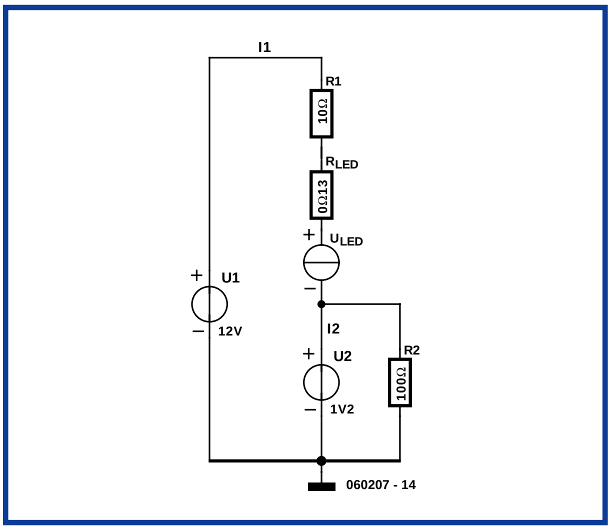


Figure 5. The LED is replaced with a voltage source and internal resistance in order to calculate the voltages and currents in a circuit at a certain operating point.

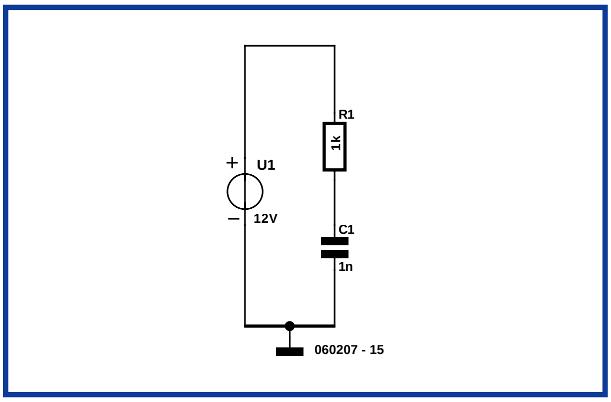


Figure 6. The power-on behaviour is examined based on this simple schematic: a voltage source charges a capacitor via a resistor.

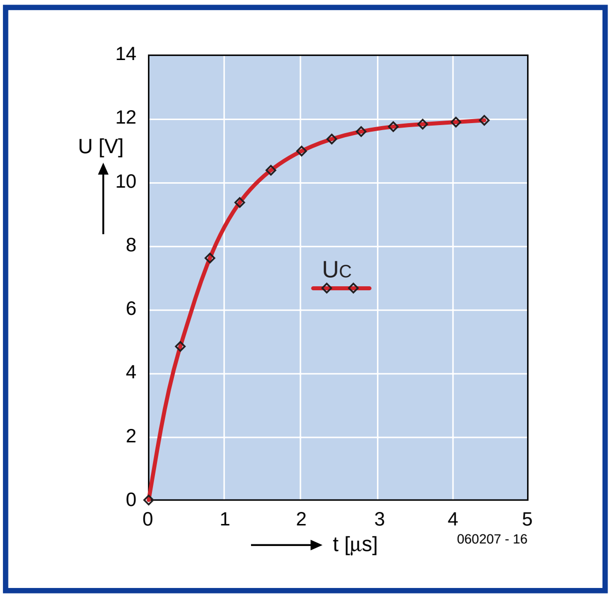


Figure 7. The calculated progress of the voltage across the capacitor.

Simulation

Overview of the simulation programs on the DVD in this issue

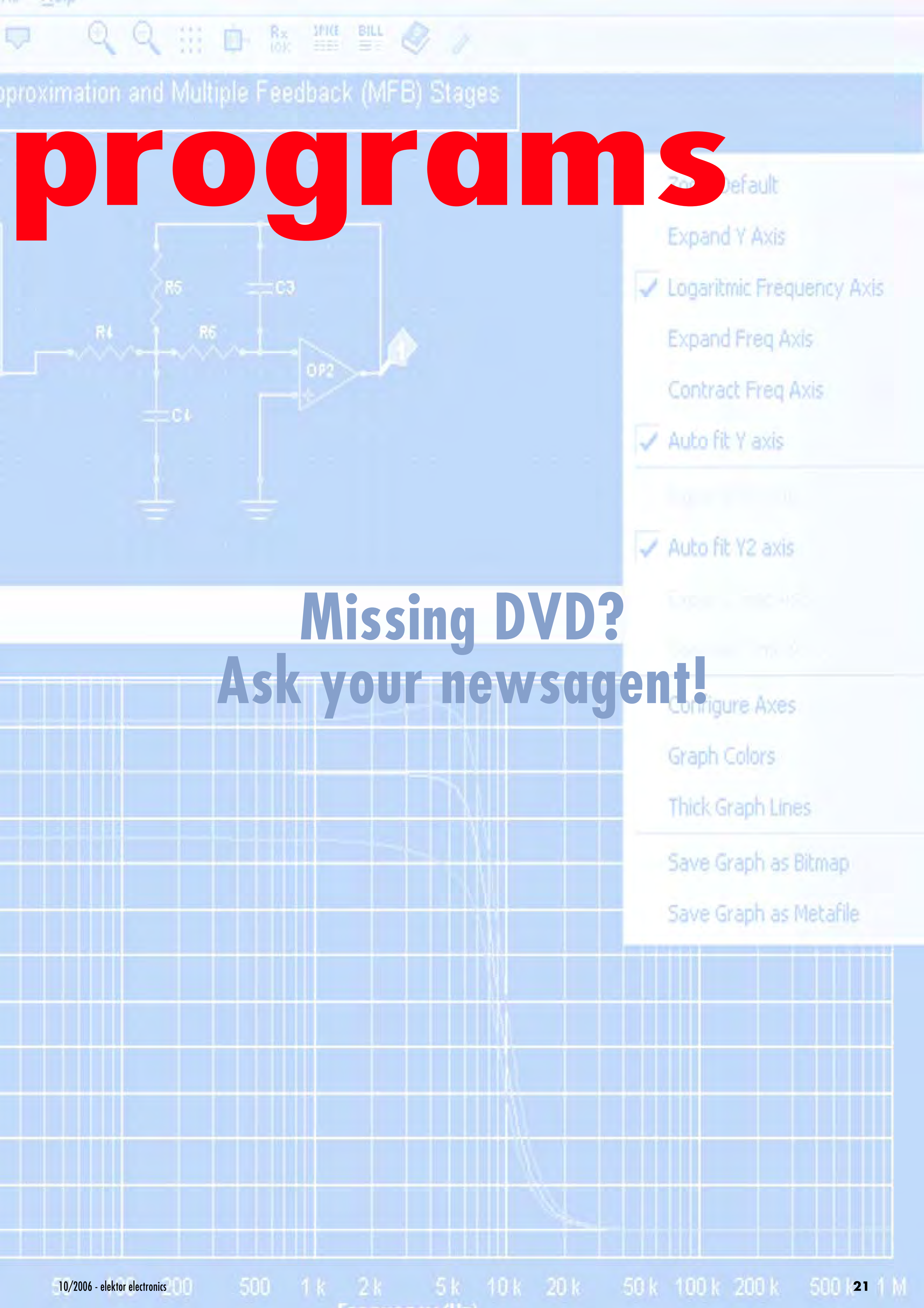
Harry Baggen & Thijs Beckers

The personal computer has played an increasingly important part in the design of electronics circuits. Dozens of programs are now available, not only for creating PCB layouts, but also for simulating circuits. With this issue of Elektor Electronics we offer you a free DVD with a large number of demo, evaluation and even full versions of virtually all the popular simulation programs. With this DVD you can try out various programs on your PC and decide which one is best suited for you. In this article we give you an overview with a short description of the programs on the DVD.

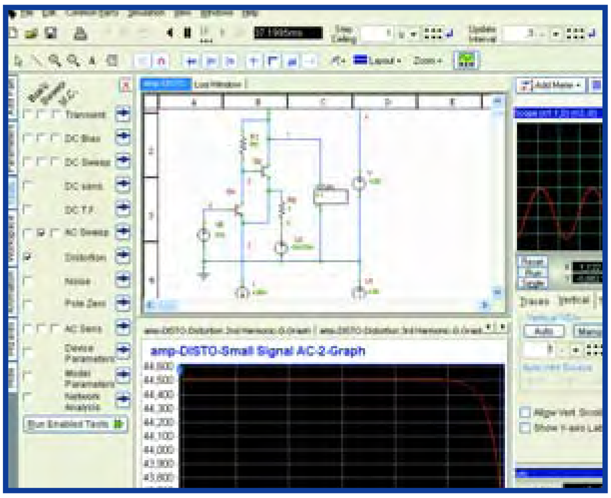
All programs on this DVD are strictly for non-commercial use only!

5Spice 1.22	5 Spice Analysis Software
AIM-Spice 4.3	AIM-Software
B2Spice 5.1.6	Beige Bag Software
Boardmaker 3	Tsien
Cadstar Express 8.0	Zuken
CIRSIM 3.0	Bells-Hill
DesignWorks Professional 4	Capilano Computing
Easy-PC/Easy-Spice 10	Number One Systems
eSketch Pro 1.5	Schematica Software
iSim	Inca Systems
LTSpice/SwitcherCAD 3	Linear Technology
Micro-Cap 8	Spectrum Software
Multisim DesignSuite 9	Electronics Workbench
OrCAD 10.5	Cadence
Profilab-Expert 4.0	Abacom
Proteus 6	Labcenter Electronics
PSIM 7.0	Powersim
SIMetrix 5.2	Catena
SIMWinXP 1.1	Visionix
SMASH 5.7	Dolphin
Sonnet-Lite 10.51	Sonnet
SpiceAge	Those Engineers Ltd
SpiceCreator Pro 5	AMS
Target3001! V12	Ing-Büro Friedrich
TopSPICE/Win32 V7	Penzar Development
Visual Spice 6	Island Logix
Win-Elektronik 3.1	Erwin Rössler

programs



Missing DVD?
Ask your newsagent!



Professional electronics designers have to manage their time very efficiently. Nowadays it is hardly worthwhile to design a circuit on paper and then build one or more prototypes to check that the design functions correctly. The ubiquitous computer (usually a PC) has been promoted a long time ago from a simple calculating tool to an intelligent assistant for circuit design, thanks to a number of clever programs. We already know of PCB CAD programs that simplify the design of boards. They have extensive libraries with package details, place the components onto the board automatically and have autorouters that find the best track layout on the board. Human insight and supervision is of course still a necessity for a successful design, but it is a huge improvement over the manual design of PCB artwork. Engineers also rely more and more on the computer for the design of circuits. The availability of good simulation programs have made it possible to see a realistic simulation of a circuit, once its schematic has been entered. When the circuit in the simulation program functions as expected, it should also do so in practice for 95 to 100% of the time. It is then usually sufficient to make a single prototype for a final test.

These programs are also very useful for students and hobbyists. When you have a brainwave you can quickly input a circuit and check that it behaves as expected, all without touching a soldering iron, components or measuring instruments. Furthermore, you will also gain a better insight in the workings of components and circuits when you create these simulations.

How it all started

The simulation of electronic circuits on computers finds its roots in the creation of SPICE, a program that was developed at Berkeley University. In this issue you'll find an accompanying article (The PC as Breadboard) that tells you more about the history and workings of SPICE. Virtually all current programs are based on this. SPICE can be used to simulate linear and non-linear electronic components. Following this, the Georgia Tech Research Institute developed XSPICE, which is used to create model libraries with extensive component definitions. Both SPICE and XSPICE are completely open source and are therefore ideally suited as a basis for simulation programs. Other well-known developments are Cider (digital simulation) and Ngspice (mixed-mode simulation).

Most of the modern simulation programs work under Windows because this is the most common platform these days. The biggest improvement of these programs has been in the user-friendliness of the interface. In older programs this could be a bit of a nightmare (draw a circuit on paper, number all the nodes, search for the correct models and create netlists, then use a different program module to input what should be calculated at each node, which, if you were lucky, could be shown graphically). These days you can use the mouse with most programs to create a circuit, and a few well-designed menus help you input the simulation settings. This is followed by the display of several clear graphs. The better programs

Special editions

Several suppliers have supplied us with special editions of their programs that have a wider range of functions than their standard demo programs available from their websites.

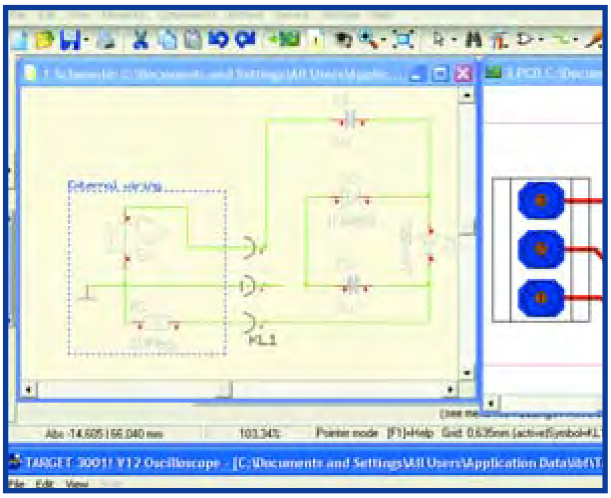
SpiceAge & **Spicycle**, made by the British firm Those Engineers, are on the DVD as special releases with a limited component library. Apart from that they are fully functional and can be used without a time limit (Spicycle Level 1).

Target 3001! from Ing. Büro Friedrich is on the DVD as a special 'light' version with a value of 49 euros (approx. £ 34). This can cope with up to 400 pins/pads and 2 track layers. You won't be able to use the extra component library from Target, but that doesn't matter too much since the included library contains about 1,000 standard components.

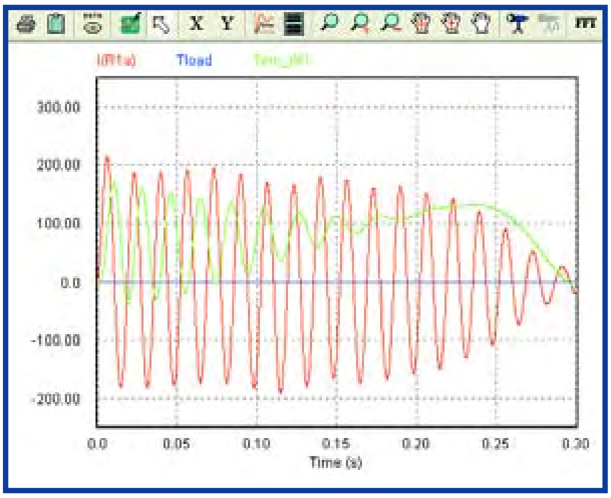
We should remind you that all programs are strictly for non-commercial use only.

With thanks to...

We would like to thank all suppliers for their help in making this DVD, in particular Linear Technology for allowing us to include LTSpice/SwitcherCAD, and Those Engineers and Ing. Büro Friedrich for their special editions.



also have extensive component libraries, which contain the properties of most semiconductors made by the larger manufacturers. There is no longer a need to study for days just to find out how a simulation program works. After a few hours you should be able to use it fairly well. Most programs are so-called mixed-mode simulators, which can be used to simulate analogue, digital and mixed circuits.



Types of programs

There are several types of simulation program available, and you'll find some of each on the DVD.
There are complete design suites that take care of the schematic input, simulation and track layout, such as MultiSim. With these packages you don't need any other software. These programs are usually fairly expensive because of their complexity, but the advantage is that there is a close integration of the various sections, which are controlled sequentially from one program and support is obtained from a single source.
Then there are pure simulation programs. Some have a full graphical input and output, such as Micro-Cap, others don't have the graphical input facility but instead make use of a separate schematic capture program (e.g. AIM-Spice). Some programs have been designed in such a way that they can be integrated with an existing PCB program (e.g. Easy-Spice in Easy-PC). Lastly, there are interface programs, such as iSim, which translate the output of a schematic capture program into a form that can be used by a SPICE program.

The DVD

We have tried to include as many simulation programs on the DVD as possible. We obtained permission from various suppliers to distribute about 30 programs on our DVD.
The programs on the DVD have been stored in several different folders. The largest number can be found in the Windows folder. Almost all these programs can run under Windows 98/ME/XP. The majority of the programs have an English user interface and a few offer a choice of languages.
The Linux folder contains a few interesting simulation programs for Linux, as the name suggests. A few programs from the Windows folder are also found here because they have been made available as a Linux version as well. A separate open-source Windows folder contains programs that can be freely used and distributed.
The final folder called Extra contains a few special programs that deviate from normal simulation programs, such as a program to simulate magnetic fields and a program to help calculate component values in filters and timers.

We'll now give you a short description of the major programs on the DVD, along with any restrictions of the supplied version and the amount of space each program takes up on your hard drive.

We hope you enjoy trying out the various programs!

Now it's your turn!

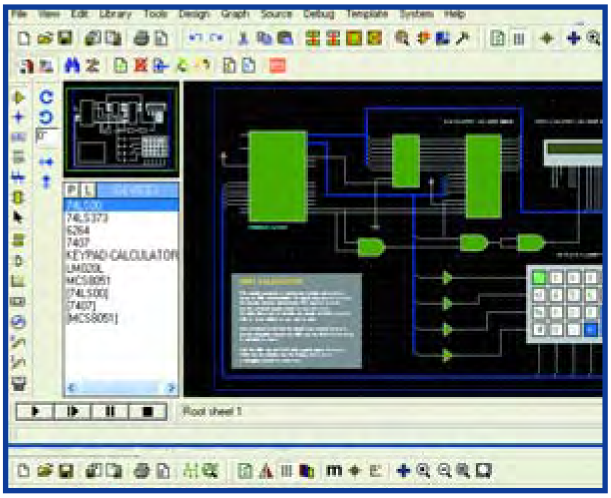
We have done our best to include the most recent versions of the programs on our DVD, but suppliers continually strive to improve their programs. If you are interested in a specific program it is always advisable to look on the supplier's website to see if a more recent version is available.

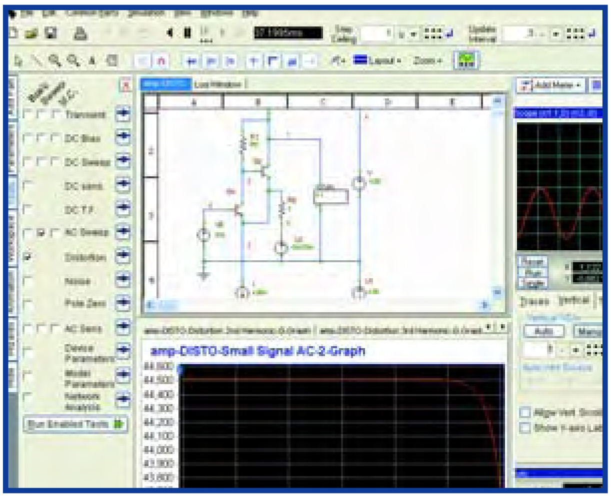
We have included a list of other interesting products that haven't made it to the DVD for one reason or other (e.g. no permission was given to distribute the software). It's certainly worthwhile to have a look at these as well.

The larger suppliers usually have a national distributor or an organisation that can give you further information about their products, which is more convenient since you can talk to them in your own language. They can also give you details of pricing and support for their software.

Finally, we thought we should include the well-known disclaimer: we have tested all Windows programs on several PCs, but we can't guarantee that they will run faultlessly on your system. Should you have problems with the installation or running of programs, please contact the relevant supplier directly. We are unlikely to be able to help you out in these matters!

Now it's your turn to try out the collection of software on this DVD and see what potential they have. Simulation is the future, that much is certain. And this DVD is a perfect introduction to this subject. Brought to you free of charge by Elektor Electronics.



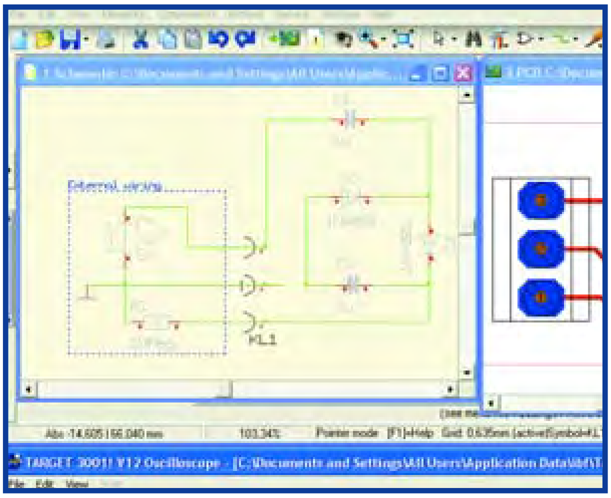


5Spice 1.22 (14 MB)

This program is a graphical shell built around a traditional Spice emulation engine. A schematic editor is used to enter the electronic design, which can then be simulated using Spice version 3f4/3f5.
The operation is quite simple. The program is not very comprehensive, but can still simulate most types of circuit. The size of the schematic is restricted in the demo version and the numerical output of several types of analysis is not possible. Another restriction is that schematics with logic gates cannot be stored and a demo text is added to all other schematics.

AIM-Spice 4.3 (10 MB)

This program doesn't have a schematic input, but is just a SPICE-simulator. The software 'suite' consists of two programs: AIM-Spice, with a text editor for editing the Spice netlist and simulation options, and AIM-Postprocessor, which is used to display stored data files graphically. Once you've become used to the textual input for a schematic the program will be easier to use. A large number of simulation parameters can be adjusted.
The student version is limited to 150 nodes and a maximum of 30 transistors per circuit.



B2Spice V5.1.6 (131 MB)

This program is of particular interest to Eagle users because Eagle schematics can be directly imported and simulated. You can also draw the schematic with B2Spice itself. The user interface of this program is clear and intuitive. Simulating is very easy. Virtual instruments are used to place probes onto the schematic in real-time.
The trial version can be used without restrictions for 45 days.

Boardmaker 3 (134 MB)

Boardmaker 3 is a complete CAD package. You can draw schematics, simulate and create print layouts. PCB layouts can even be shown in 3D.
The operation of the program is quite complex, mainly due to the many functions it can perform. There are tutorials in PDF format (they're stored in the same folder where the program was installed, but strangely enough there are no shortcuts to them in the start menu). It is strongly recommended that you go through these before you start using the program. The demo version can't print or store schematics, nor can it output Gerber files.

CIRSIM2006 (5 MB)

CIRSIM is a fairly straightforward program that is only suitable for simulations with continuous input signals. The description of the schematic can only be entered using SPICE-code, i.e. there is no graphical input. Because the program has only a few functions, its operation is self-evident. Registration of the program is just £10.
The demo version of the program is severely restricted, with only six nodes maximum.

DesignWorks Professional 4 (38 MB)

With DesignWorks Professional you can simulate digital circuits in a simple manner. The design can be input as either a schematic or using VHDL. The operation has an intuitive and logical feel to it. However, if you get stuck you can refer to an excellent manual in PDF format. DesignWorks can also be used to create analogue schematics, but these can't be simulated.
The demo version has full functionality for 30 days.

Easy-Spice (& Easy-PC)

Easy-Spice is an enhancement for the print layout program Easy-PC (both are on the DVD). You should install Easy-PC first, then Easy-Spice.
Easy-PC can be used to draw electronic schematics and PCBs, set simulation parameters and start a simulation. The program then creates a netlist and starts Easy-Spice. Easy-Spice automatically opens the netlist and uses it for the simulation.
The folder ...\Easy-PC Demo\Examples\SPICE contains a few examples. Both analogue and digital circuits can be simulated. The demo version of Easy-PC can't store files or create CAM outputs. There are no known restrictions in the demo version of Easy-Spice. Both programs require a password to function, which is kp69ny31 for Easy-PC and wa32pk65 for Easy-Spice.

eSketch (5 MB)

This (small) program has a polished look and is very easy to use. You can draw passive analogue schematics

with it and simulate them. Unfortunately you can't use it to enter logic gates, transistors, diodes or other active elements.
You can try out the free version for 15 days without restrictions.

LTSpice/SwitcherCAD III (77 MB)

The program SwitcherCAD III supplied by Linear Technology can be used to simulate (almost) every switchmode regulator made by LT. The simulation even includes the power-up cycle. Several useful example circuits are included and you can of course input your own circuit as well. The program may not have a polished look, but its functionality leaves nothing to be desired.
LTSpice/SwitcherCAD III is completely free of charge.

Micro-Cap 8 (22 MB)

Micro-Cap is a well-designed simulation program with a schematic capture and a well-sized standard component library. The abbreviations used in the simulation setup are a little bit confusing at the beginning, but once you're used to them they are very easy to work with.
The evaluation version of Micro-Cap is limited to 50 components and 100 equations (nodes, inductors and signal sources). The simulation speed is slower and the number of optimisations, filter designs and 3D plots has been reduced.

Multisim 9 (191 MB)

Multisim is a complete design suite that comprises schematic capture, simulations and PCB design (Ultiboard). It's one of the most comprehensive packages that we've come across. Smart virtual instruments can be placed onto the schematic, which then show the simulated signals. The component library of Multisim is very extensive. The program is now also capable of exchanging measurement and simulation data with LabView.

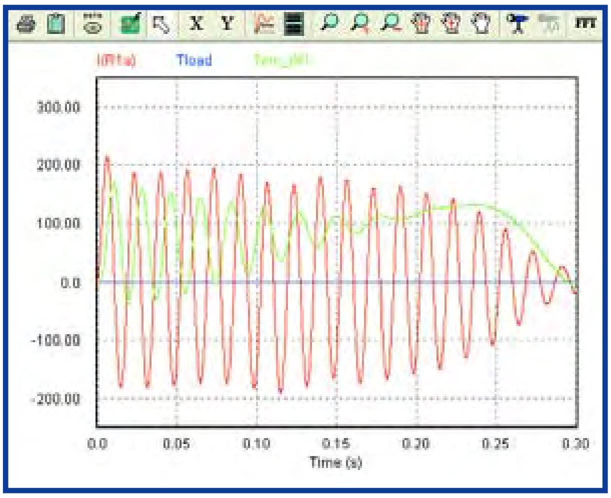
The freeware version requires an Internet connection to simulate a circuit. After 45 days the simulation and autorouting functions stop working. Furthermore, the designs are limited to 50 components, 750 pins and 2 layers.

OrCAD 10.5 (707 MB)

This is another comprehensive design suite! OrCAD creates a number of shortcuts for the various programs in the package. The main program is Capture CIS. This program acts as a type of manager for all the files that make up a design. There is also a tutorial (OrCAD-directory\OrCAD_10.5_Demo\tools\capture\tutorial\CAPTUTOR.EXE). The simulation section (PSpice A/D) isn't controlled directly by Capture CIS and so you need to point it to your project manually. The many functions of the package make it somewhat difficult to use, so a bit of training is to be expected before you can fully use it.
There is no time limit in the demo version, but there are restrictions on the size of designs.

ProfiLab Expert 4 (17 MB)

ProfiLab Expert looks similar to Labview, but is a lot simpler. Various dials, displays and other functional blocks can be added to a design via a clear, well-designed



screen. The simulation then shows the results for your design.
The demo version can be used with a maximum of 10 components. You can't store or compile your designs and the simulation time is limited to 30 seconds.

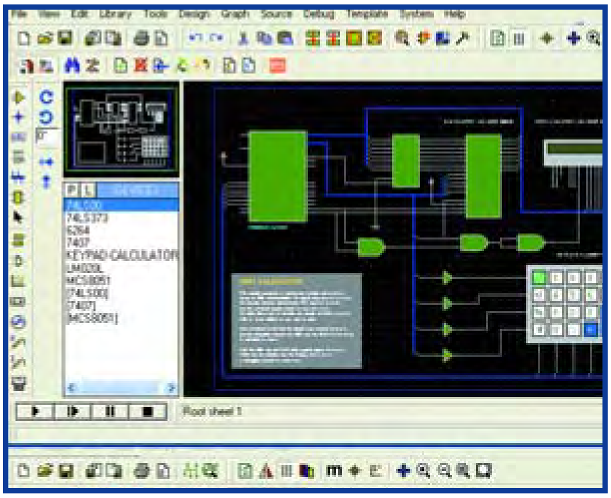
Proteus 6 (112 MB)

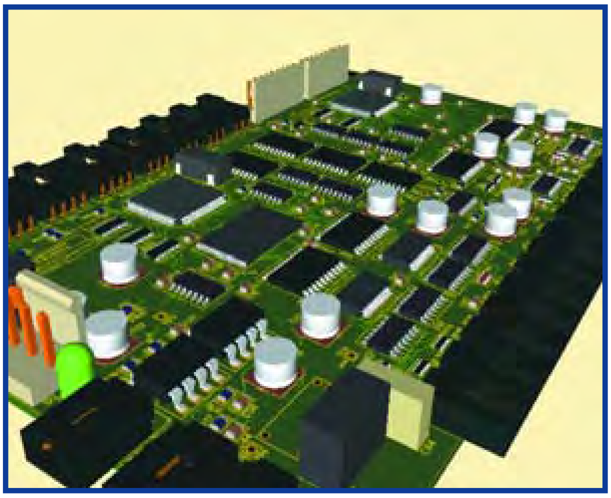
Proteus 6 consists of 2 programs: ISIS 6 and ARES 6. ISIS is used to draw schematics and simulate them; ARES is used to design the PCB layout. It is very easy to simulate a circuit with ISIS (play button at the bottom-left). The help files included are very clear, as is the comprehensive user interface. What makes Proteus special is that mixed-mode simulations can include microprocessors, which have their code executed during the simulation.

The demo version does not allow printouts or saving of files. Neither can you input your own microcontroller designs, but you can modify the examples included.

SIMetrix 5.2 (34 MB)

SIMetrix can be used to input and simulate analogue and digital circuits. Despite the separate program windows the package is easy to use. The various settings are





quickly and intuitively found.
When installing the program you should choose SIMetrix Intro. SIMetrix uses five characters for extensions and so avoids any potential problems with other programs.
The demo version is only limited to the number of components that can be used.

Suppliers' websites

5 Spice Analysis Software	www.5spice.com
Abacom	www.abacom-online.de
AIM-Software	www.aimspice.com
AMS	www.advancedmsinc.com
Beige Bag Software	www.beigebag.com
	Benelux: www.franklin-industries.com
Bells-Hill	www.bells-hill.freeserve.co.uk
Cadence	www.cadence.com/orcad
Cadmigos	www.cadmigos.com
Capilano Computing	www.capilano.com
Catena	www.catena.uk.com
Dolphin	www.dolphin.fr
Electronics Workbench	www.electronicsworkbench.com
Erwin Rössler	www.win-elektronik.de
Inca Systems	www.incasystems.fi
Ing-Büro Friedrich	www.ibfriedrich.com
Island Logix	www.islandlogix.com
Labcenter Electronics	www.labcenter.co.uk
Linear Technology	www.linear.com
Number One Systems	www.numberone.com
Penzar Development	http://penzar.com
Powersim	www.powersimtech.com
Schematica Software	www.schematica.com
Sonnet	www.sonnetusa.com
Spectrum Software	www.spectrum-soft.com
Those Engineers Ltd	www.spiceage.com
Tsien	www.tsien.info
Visionix	www.visionics.a.se
Zuken	www.zuken.com

If you want to use the program for switchmode supplies you should choose the SIMetrix/SIMPLIS option during installation. SIMPLIS is between 10 and 50 times faster in simulating these, compared to the extensive Spice simulation of SIMetrix.

SIMWinXP 1.10 (261 MB)

SIMWinXP is the little brother of the EDWinXP design suite. It is a standalone program for drawing the circuits that can then be simulated using the included mixed-mode or EDSpice simulator. With EDSpice you can also simulate circuits that have been created in Spice. SIMWinXP can cope with both analogue as well as digital designs.
To install SIMWinXP you should run Setup.exe from the SIMWinXP folder.
The evaluation version is fully functional, but works for only 30 days.

Smash 5.7.0 (424 MB)

Smash is a powerful mixed-mode simulation program without a schematic capture input. The program has some unusual features, such as estimating the power consumption of digital circuits and a mixed-mode facility of SPICE and VHDL-AMS.
The required netlists can be loaded as .cir, .nsx or .sp files. The program can work with several other popular programs from e.g. Matlab, Keil and National Instruments.
We were pleasantly surprised by the large number of PDF documents that were included, with details of various design problems and simulation methods.
The evaluation version has a limit of 25 analogue nodes.

SpiceAge & Spicycle (49 MB)

Before you can install SpiceAge (simulation) and Spicycle (schematic capture) you should copy the complete SpiceAge folder from the DVD to the C:\ drive, including the folder structure.
Spicycle is used to draw schematics and PCB layouts. You can start a simulation from Spicycle that is then run in SpiceAge. From SpiceAge you can set many more parameters and can also start different simulations. The user interface is clear and well designed. Most of the control icons can be reached via the menu bar.
The demo versions have been specially provided for Elektor Electronics and have a limited component library, but are otherwise fully functional and don't have a time limit.

Spice Creator Pro V5.12 (39 MB) & Visual Spice (39 MB)

These two programs are like peas in a pod.
Spice Creator and Visual Spice are used to create and simulate analogue and digital circuits. There is a useful help-browser, which makes it easy to find instructions on using the program. The main program screen overflows with icons, but this can fortunately be reduced.
The trial versions have quite a number of restrictions: there is no undo, save, export, print, copy/paste and simulation of edited circuits.

Target 3001! V12 (61 MB)

Target 3001! is a CAD program with various extra features. In the first instance it is a program designed for inputting schematics and creating print layouts. The design can be simulated and it can also check for EMC issues. It also offers the facility for the design of front panels.

To use all of the features to their full potential you will have to read the manual first. Although it is possible to use the program straight from the box, you'll need a bit of study and practice before you can grasp the finer points of this program.
A special version has been made available to *Elektor Electronics*, which offers more than the standard demo version: Target 3001! V12 'light' (400 pins/pads, 2 track layers, costing 49 Euro), which can't access the component library on the Target server.

TopSPICE 7.09g (23 MB)

TopSPICE can be used to open both schematic diagrams as well as Spice netlists. Simulations are fast and easy. It is self-evident how to use the program, but if you should get stuck you'll find many 'help' and 'getting started' documents to help you out.
There are several limits imposed in the demo version, such as on the size of the schematic, the number of nodes, transistors, top-level components, data points per plot and a maximum data memory of 1 MB.

Win-Elektronik 3.1 (1 MB)

This simple (German language) program is perfect for checking how an analogue network functions. It is mainly intended for students and schools. It has a limited set of features.
The demo version has a maximum of 8 components and 1 opamp.

Extras

-iSim (14 MB) (& CADStar Express 8 & PSpice A/D 10.5)

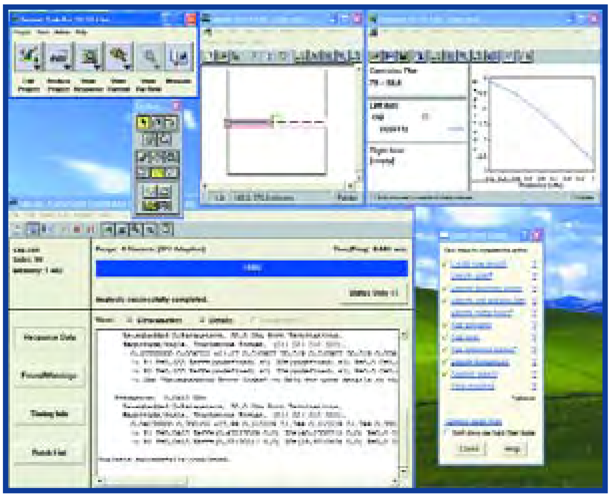
iSim is an interface between schematics drawn with CADStar and the SPICE simulations in PSpice A/D. You can run iSim from within CADStar Express to start the simulations. The results are then shown by PSpice A/D. This plug-in has been well designed and leaves nothing to be desired. The demo version is limited for use with up to 50 components.

PSIM (22 MB)

PSIM is intended mainly for simulating power circuits and motor drivers. It consists of two programs: PSIM and SimView. PSIM is used to draw the schematic and to start a simulation. SimView then automatically takes over and shows the simulation graphs.
The operation of the programs doesn't really require an explanation. The examples that come with the programs are very useful as they give you a quick insight how the programs work and what they're capable of.

Sonnet Lite 10.51 (91 MB)

The Sonnet software is suitable for (nearly) all calculations and simulations that are concerned with RF electromagnetic interference. A few examples of the capabilities of the program are the analysis of PCB track crosstalk, microstrips and coupled transmission lines. The free Lite version has a few restrictions compared with the full version, but you can still evaluate the latter for 30 days. You can find more information on the supplier's website.



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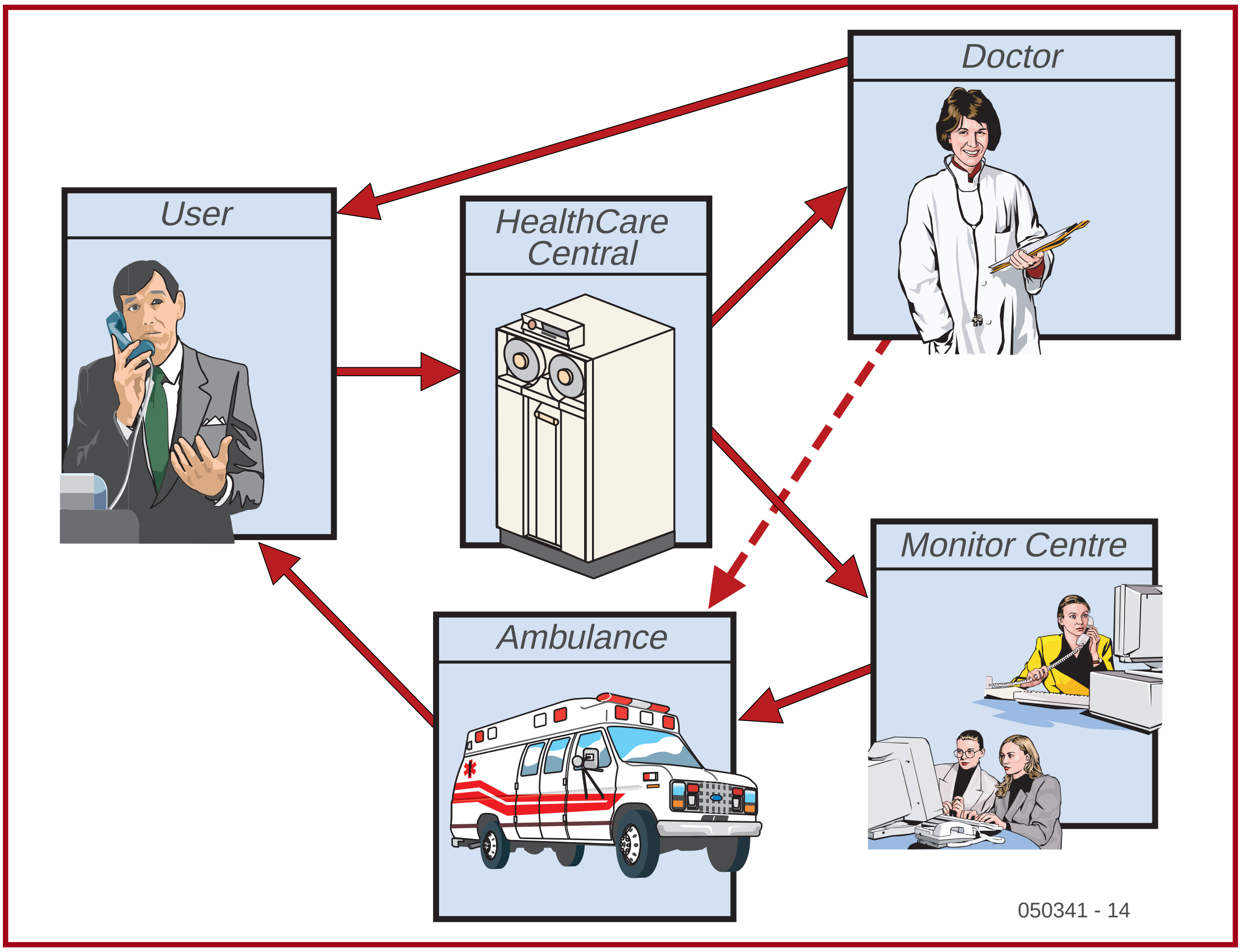
Interesting links

Altium Designer	www.altium.com/Products/AltiumDesigner/
Tina Pro 6	www.designwareinc.com/index.shtml
NGSpice	http://ngspice.sourceforge.net/relapp.html
AnaSoft SuperSpice	www.anasoft.co.uk/
APLAC	www.aplac.hut.fi/aplac/
AKNM Circuit Magic	www.circuit-magic.com/
Intusoft ICAP/4	www.intusoft.com/demos.htm
PC-ECAP	www.cdquickcache.com/pcecap.htm
Digital Simulator	www.mit.edu/people/ara/ds.html
Spice+	http://spicep.sourceforge.net/
WinEcad	www.winecad.com/winecad.htm
DxAnalog	www.mentor.com/products/pcb/expedition/analysis_verification/dx_analog/index.cfm
NGSpice	http://ngspice.sourceforge.net/
+ GSpiceUI	www.geda.seul.org/tools/gspiceui/index.html
PSpice 3f4	www.ee.washington.edu/circuit_archive/software/spice3f4.tar.gz
Spice3f4 (Mac)	www.kivadesigngroupe.com/Kiva%20Professional/professionalpage.htm
MacSpice 3f5 (Mac)	http://newton.ex.ac.uk/teaching/CDHW/MacSpice
Pulsonix	www.pulsonix.com/index.asp
CSiEDA	www.csieda.com/
Crocodile Technology 6.01	www.crocodile-clips.com/crocodile/technology/index601.jsp
Qucs	http://qucs.sourceforge.net/news.html
Simplorer Student Version	www.ansoft.com/about/academics/simplorer_sv/index.cfm

The Electronic

Haider Karomi

A quick and precise diagnosis of a serious medical condition is vital — if a doctor can perform this remotely it saves both time and money. The Star Trek gadget may not yet be reality but remote patient monitoring is and brings with it some fears of data protection.



Telemedicine diagram (Source: Paxiva Service / Personal HealthCare Telemedicine)

It was back in the late 1940s when NASA were planning to put an astronaut into orbit that they began to experiment with primates and developed the first system for remotely monitoring vital signs during launch and re-entry into the atmosphere (but rarely, alas, after impact). The term 'Telemedicine' was coined to describe these early monitoring systems which were further refined and went on to provide telemetry data when astronauts finally ventured into space and later from the moon.

Now, half a century later the installation of wide bandwidth telecommunications channels in the home and availability of convenient, precision sensors makes it possible for doctors to monitor the health of their patients over great distances. A decision on the patient's course of treatment can be made by experts almost instantaneously; specialist doctors are able to determine if anomalies in ECG (Electro Cardiogram) readings taken at home indicate that a patient requires emergency treatment or just a change in their medication.

Telemedicine offers the possibility of not just diagnosis but also remote therapy and consultation between doctors. 'TeleHome care' is one branch of telemedicine and uses

Doctor

"Tricorder reading Dr McCoy?..."

the Internet to pass physiological readings (Pulse rate, Blood pressure etc.) taken in the patients home to a doctor using video conferencing facilities. The table shows how 'TeleHome care' can impact on different aspects of patient care and administration.

For and against

The 'TeleHome care' system offers a drastically reduced diagnosis response time which in some cases (e.g. heart failure) is vital to the outcome of an episode and can be a life saver. The system offers better efficiency and cost-effectiveness by allowing doctors and health care personnel to care for more patients in the community without the need for time-consuming routine home visits which can prove costly especially in rural areas. In a society where the numbers of chronically sick and care-dependant are growing the distinction between sickness and health is becoming ever more blurred. Improvements to the quality of life of each individual must be the main goal of health care providers but at the same time the dramatic increase in costs mean that it is vital to be more efficient and target support more precisely so that available funds are not wasted [1].

The concept of 'TeleHome care' also raises questions regarding data protection and the possible misuse of personal information which previously had only passed between doctor and patient but modern encryption techniques used for data transfer offer a high degree of security and provide good protection against third-party eavesdropping.

The impact of Tele Home Care

'Clinical'	Availability in emergencies. Remote medical advice. Remote consultations. Remote diagnosis. Remote treatment. Monitoring of patient parameters (e.g. ECG).
Care & Information	Health support Disease prevention. Self help. Training.
Administration	Electronic patient management. Patient records. Coordination.

Coronary care sets the pace

Coronary heart disease is the biggest killer in the UK and most European countries, many risk factors have been identified as contributing to the development of the disease. 'TeleHome care' is particularly well suited to identify and manage lifestyle induced risks and remotely supervise the rehabilitation process while enabling the

The pros and cons of Tele Home Care

Patient monitoring

- Improvement in the quality and quantity of patient monitoring data.
- More patients can be monitored with fewer resources.
- Automated diagnostic tools can be used to interpret patient data.

Therapy management

- Improvement of doctor-patient communication.
- Faster response time for therapy evaluation.
- Support for patient self-treatment.

Remote caring

- Fewer hospital/surgery visits.
- Simplification of patient information collection.
- Patients generally find the autonomy empowering.
- Reduction of short and long term complications.

Tele Home Care requires organisational changes

- The new service requires modifications to existing clinical routine and protocols.
- Increased workload for medical personnel in the first stage of implementation.
- More patients and Data: Integration of specialised tools/software to analyse data.
- Disadvantage: The patient is not in a controlled environment.

Source: Telemedizinführer Deutschland 2004 (www.telemedizinfuehrer.de)

patient to retain their independence and mobility.
In recent years several studies have been conducted on heart patients to asses the feasibility and effectiveness of automatic (remote) monitoring of the progress of their condition (telecardiology) and corrective therapy using communication channels provided by modern telecommunications. The conclusions broadly indicate that remote patient monitoring is technically possible but relies on close patient cooperation and agreement. Remote monitoring has the potential to offer the patient a better understanding of their condition, providing them with more precise information on the progress of their disease and the remedial effects of medication and therapy which often results in a higher level of patient satisfaction.

Standardisation

Many competing systems are currently being trialled by health authorities around the world (even the term 'telemedicine' is undergoing a 21st Century makeover and has been called 'e-health'). Personal HealthCare Telemedicine is currently working closely with clinics and health care providers to establish their Paxiva system for the remote monitoring and care of heart patients [2]. This system gives the patient the possibility of taking an ECG (Electro Cardiogram) of their heart at home either on a regular basis or as required and sending the readings over a phone line to the monitoring centre where a diagnosis can be made and appropriate remedial treatment recommended without necessarily troubling their own doctor. The patients know that the Paxiva monitoring centre is continually manned so this tends to remove the initial reluctance to contact a doctor or call out a paramedic when the first symptoms of a change in their condition occur. Precious minutes can be saved if it turns out that the condition requires emergency treatment.

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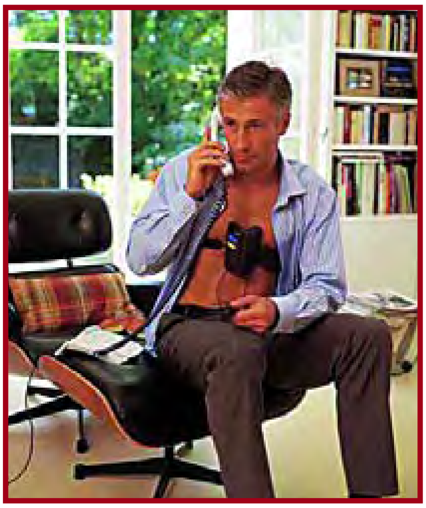


Weblinks

[1] Canadian report 'Office of Health and the Information Highway'
http://dsp-psd.pwgsc.gc.ca/Collection/H21-168-1998E.pdf

[2] System Paxiva:
www.medical.philips.com/main/news/assets/docs/medicamundi/mm_vol46_no2/mampuya.pdf

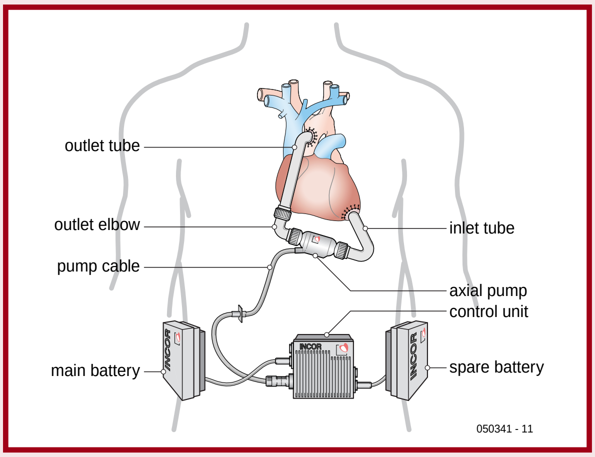


Figure A. Heart function support system INCOR from the company Berlin Heart AG. Blood flow through the implanted pump is managed by the control unit. (illustration: Berlin Heart AG)

Telemedicine technology

an example

The author developed the telematik module in the final year of his degree. The unit can be used by a heart patient fitted with a heart support device either in or on their body and allows remote diagnosis/monitoring over the Internet. The unit is currently undergoing further development by the company Berlin Heart AG and should be ready for the market next year.

The microprocessor controlled unit reads data from the heart support system (**Figure A**). The information including flow rate and pressure difference across the implanted pump together with data from any anomalous heart 'event' are then sent daily using either the analogue modem, Ethernet, RS232, Bluetooth or GPRS (General Packet Radio Service for mobile phone use) port shown in **Figure B**. A PC interface is provided to enable the unit to be configured (IP Address etc.); it is anticipated that future developments will allow data to be displayed on the patients PC or laptop. **Figure C** shows the internals of the unit, **Figure D** is the cased prototype.

Following much market research and product assessment the RCM3200 core module from Rabbit Semiconductor was chosen for the unit, it offers a cost-effective solution with good functionality and sufficient memory capacity for this application. Dynamic C from Z World was the chosen development environment.

The RCM3200 Module (**Figure E**) has an integrated 10/100Base T Ethernet interface and a 3.3 V core with 5 V tolerant input/output. Six serial ports are also available. The module is based on the Rabbit 3000 8-bit microprocessor running at a clock frequency of 44.2 MHz. It has a 512 Kbyte flash memory, 512 Kbyte program execution SRAM and 256 Kbyte data SRAM, quadrature decoder, PWM outputs and pulse-capture capability. The module

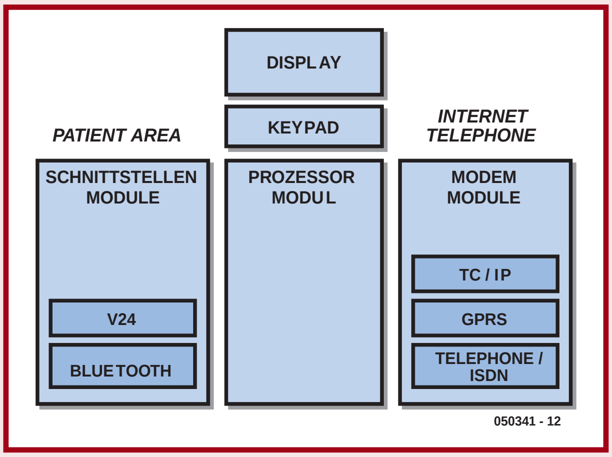


Figure B. Interfaces of the Telematik module.

Figure C. Main blocks of the Telematik unit.

also contains a real time clock which can be fitted with a backup battery and has a low power 'sleep' mode. Built-in features including a clock-frequency spectrum spreader ensure that EMI (Electro Magnetic Interference) problems are virtually eliminated.

Dynamic C is a user-friendly C language program development environment comprising of an editor, compiler and debugger. A programming cable is used to transfer the application software to the target system and is also used for debugging without the need for a separate emulator. Dynamic C comes with an extensive library of routines (TCP/IP stack, serial interface etc.) which helps cuts down program development time.

The author can demonstrate the viability of monitoring patients fitted with heart function support devices. It is important to co-operate with the patient and provide basic training in the use of the monitoring unit (cable connections, familiarisation of keypad and the most important error messages etc.). It is also necessary to determine if data can be reliably transferred over a potentially unpredictable Internet connection available at the patient's home.

Figure D. The housed unit.

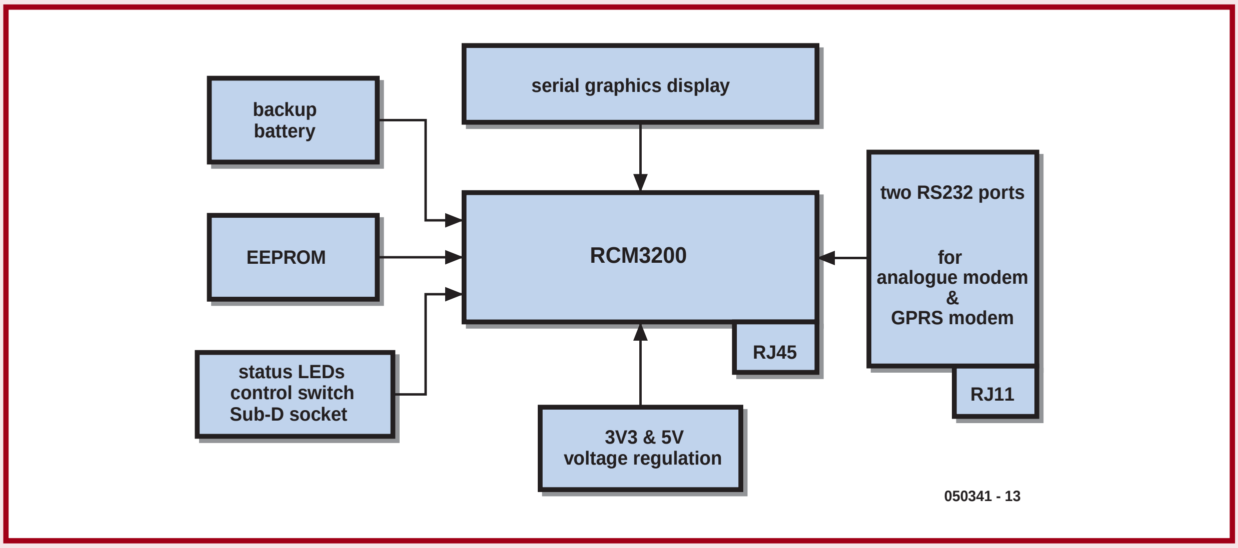
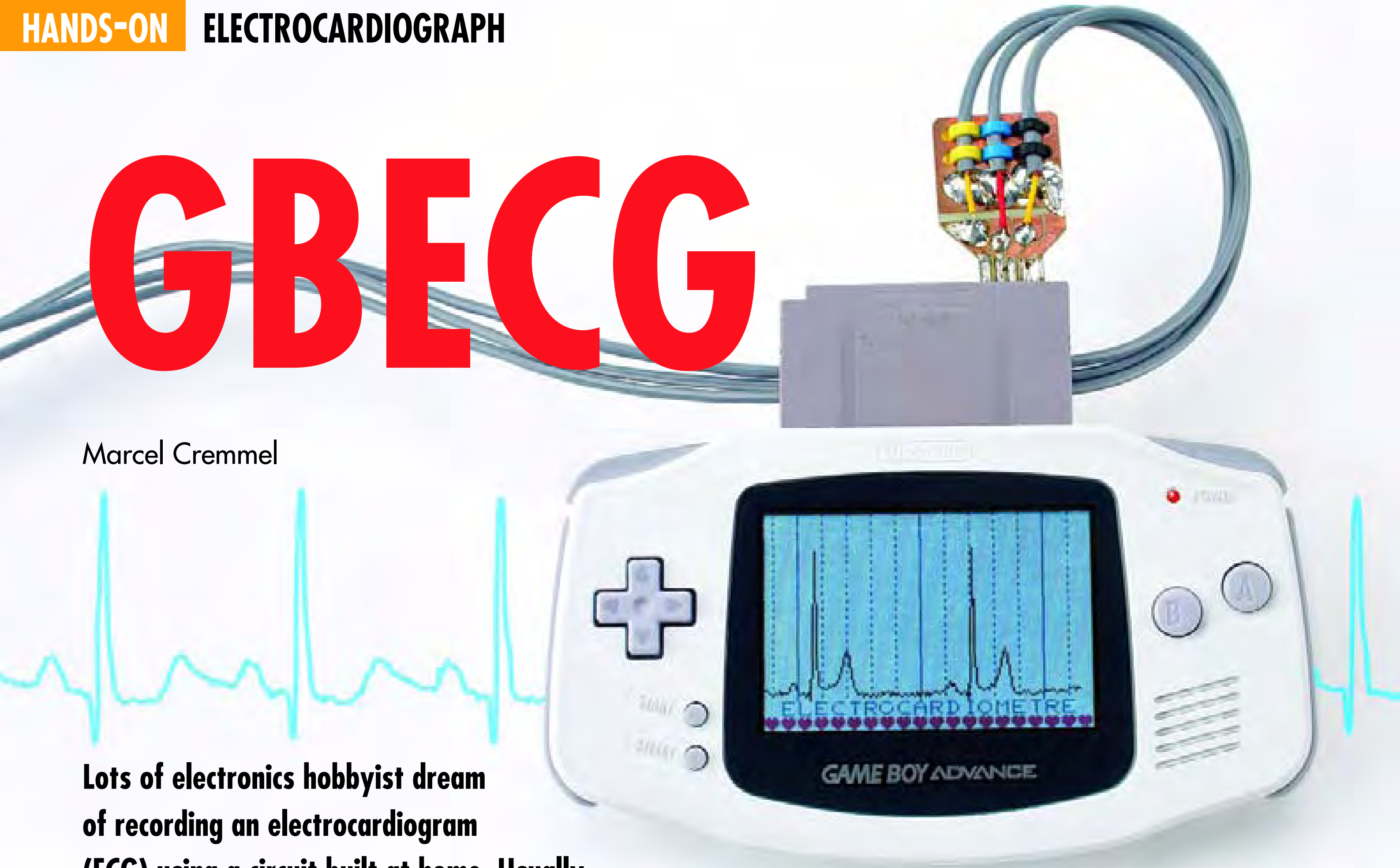


Figure E. A Rabbit microprocessor is at the heart of the unit.

GBECG



Marcel Cremmel

Lots of electronics hobbyist dream of recording an electrocardiogram (ECG) using a circuit built at home. Usually out of technical curiosity, as numerous problems have to be resolved in order to properly sample the heart's electrical activity. Alternatively, some people require personal medical monitoring while under a cardiologist's care. And then it's great to be able to make your own ECG and show it to your GP or clinical staff.

The idea of using a Nintendo Gameboy games console equipped with a special cartridge was inspired by the world-famous Elektor GBDSO [1] (a big thank you goes out to Steve Willis for his help with this project).

Our electrocardiograph utilizes three electrodes: one on each wrist, the third on the left leg. The electronic device, built on a cartridge that slips into any Gameboy model, processes the sampled signals and produces a very high quality ECG scrolling across the LCD (see the various illustrations).

The electrocardiogram implements the method of M. Einthoven (see the inset on the next page). It only uses two active electrodes, a third being used to set the no-signal level of the first two. All leads are single-ended. Despite this simplicity, the results are noticeable and even recognized as usable by a cardiologist. The electrocardiograph easily meets the initial specifications for which it was designed: to monitor tolerance to the anti-malaria medication.

To do that, we measure the QT interval (see **Figure 1**) which should remain 'normal'. Figure 1 [2] matches up the electrical activity sampled and the cardiac cycle phases, as follows:

P-Wave: Auricular contraction; the blood coming from the veins is pushed into the ventricles.

QRS Complex: Ventricular contraction; the blood contained inside is pushed into the arteries.

Both of these waves produce the 'lub-dub' heartbeat sounds.

T-Wave: Repolarisation of the ventricles; the ventricular muscle returns to rest.

The electronics!

After this little 'dose' of general knowledge, let's deal with our favourite subject: describing the GBECG electronic structures and making the board.

Just as with the **GBDSO** [1] (*Elektor Electronics* October and November 2000), the specific electronics and software (in Flash memory) are grouped onto a cartridge that slips into the console's connector. In this way, the Gameboy is transformed into a powerful electrocardiograph!

The electronic device processes the very low voltages sampled between the two active electrodes. The single-ended leads are designated DI, DII and DIII according to their localisation (see drawing in **Figure 2**).

The most common lead is DI.

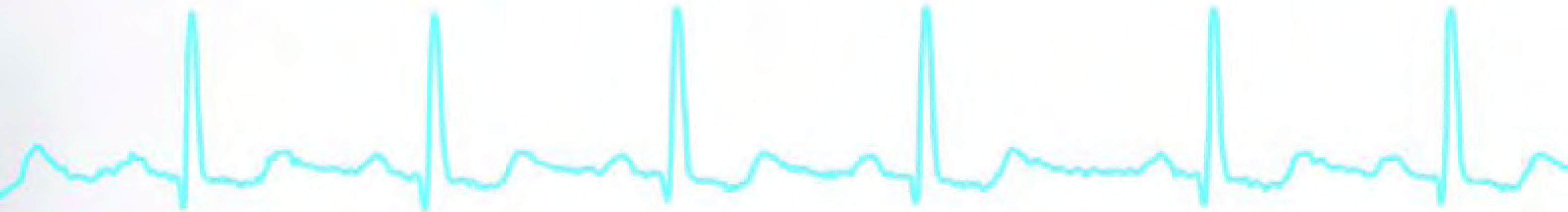
Due to its low peak-to-peak amplitude (of the order of one mV), the EMF (electromotive force) measured is considerably amplified (about 1000×) before it can be converted to 8-bit digital. The sampling frequency selected is 477.84 Hz, compatible with the spectrum of an ECG signal.

The digital signal is then taken care of by the console processor. It is then placed in an 8 kBytes cyclic buffer

GameBoy ElectroCardioGraph

Characteristics:

- Cartridge compatible with Nintendo Gameboy consoles type Classic, Pocket, Colour or Advance
- Single-ended connections using 3 electrodes
- Sensitivity: 1.6 mV full scale
- Common mode rejection: 100 dB
- Trace memory : 68 s
- Scrolling display
- Temporal window: 2.6 s in acquisition mode (1.3 s or 2.6 s in consultation mode)
- Heartbeat indicator
- Battery power supply required
- Approx. 2 hours use from battery power



The Electrocardiogram (ECG)

It is practically impossible to grasp the operation of this home-made electrocardiograph instrument without a minimum of medical knowledge. We deal with the heart of the subject. First of all...

A bit of history...

In passing, let us pay homage to Willem Einthoven who discovered the relationship between electrical phenomena and muscular contraction of the human heart about 100 years ago. He received the Nobel Prize in 1924 for that discovery.

Willem Einthoven, inventor of the electrocardiograph.

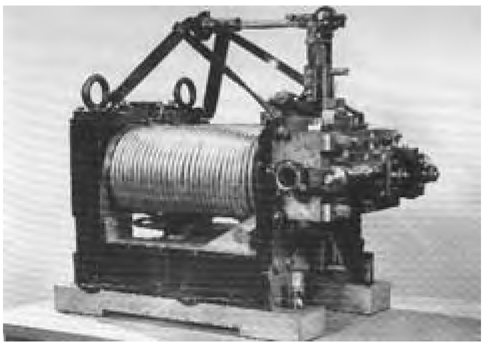
and a bit of biology...

The heart is an autonomous muscle: it is the only one not controlled by the brain. The 'sinus node', located in the right auricle, triggers nerve flows that control the heart muscles. These contract ('depolarisation' in medical lingo) and relax ('polarisation') in order to make up the blood pump that gives us life. The contraction is caused by a change in electrical polarity on each side of the cellular membranes. During the relaxation phases, the electrical charges find their state of equilibrium before being stimulated again.

The resulting potentials are transmitted to the skin surface. They can then be sampled by cutaneous electrodes, as the human skin is sufficiently conductive.

A wise placement of the electrodes allows a cardiologist to deduce the heart's mechanical behaviour (and its defects!) by analysing the electrical activity.

Technology has greatly evolved since the 1920s. The first patients dipped their hands and feet in basins full of very salty water!



String galvanometer, The U-shaped magnet ends are enveloped in water cooling tubes (well before PCs!) *Photos : Stichting Einthoven Foundation*

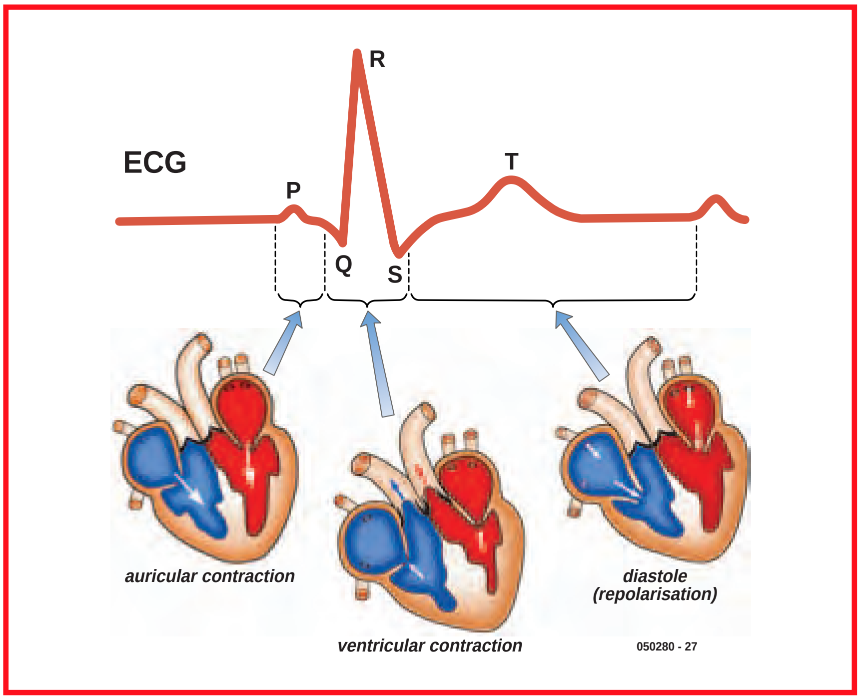


Figure 1. Relationship between the measured electrical activity and the cardiac cycle phases.

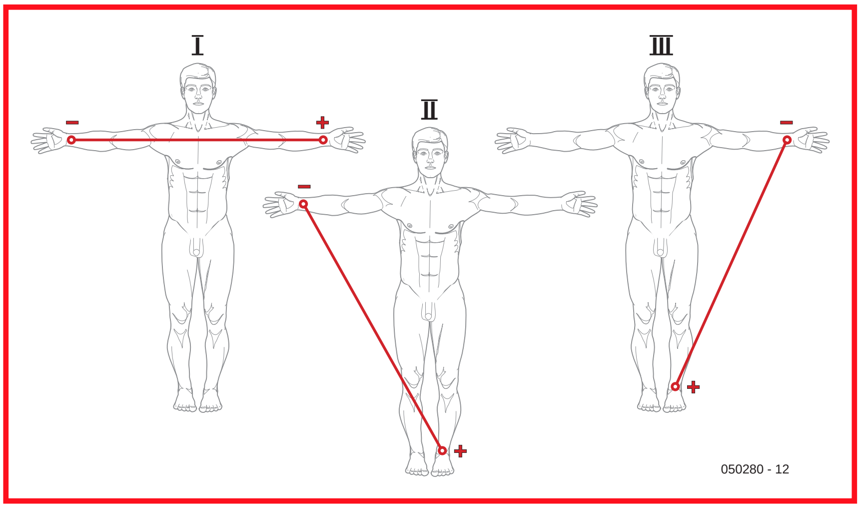


Figure 2. These single-pole leads are used to implement the electrocardiograph.

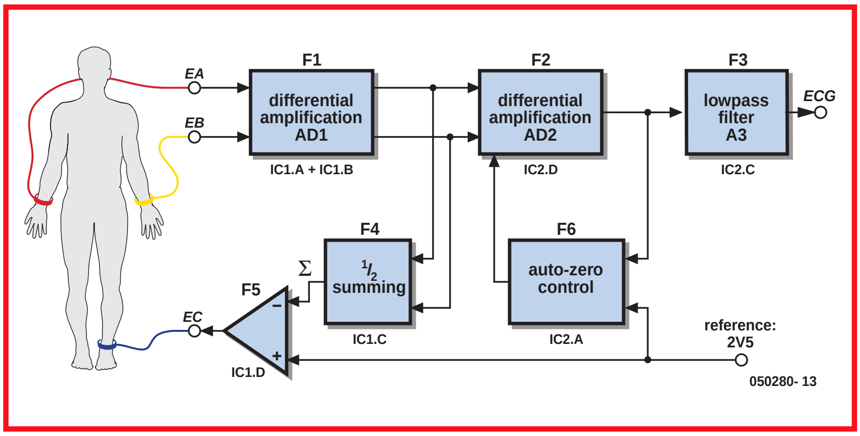


Figure 3. Block diagram of the analogue part of the circuit.

memory and reread to show the ECG in real time on the screen, in 'scrolling' mode.

The analogue part

Presenting an adequate signal to the input of the digital analogue converter presents a challenge to the electronics engineer because there are a number of technical problems to analyse and resolve.

Differential amplifier

The peak-to-peak amplitude of the signals sampled between the electrodes is very low at just 2 mV max.

Also, both the human body and the connecting wires to the electrodes are strongly influenced by high noise levels radiated by mains wires and other power carrying leads inside buildings. Capacitive coupling, although very low, produces a relatively high voltage (often over 1 V) to appear with respect to ground, despite the relatively low frequency of just 50 Hz or 60 Hz.

To begin with, it would seem difficult to isolate the useful signal because its amplitude is 1,000 times lower than all the interference around! Moreover, the mains frequency is included in the useful spectrum; so the filtering solution does not work here.

However, considering the wavelength of the mains voltage (6,000 km!), it is safe to assume that that each point on the skin receives the same induced potential thanks to its conductivity. Therefore, a common-mode voltage is developed with respect to the electrodes.

In this case, the solution becomes obvious: we're going to use a differential instrumentation amplifier with an adequate common-mode rejection ratio (CMRR):

$$CMRR \geq \left[\frac{S_p}{S_{ECG}}\right]_{dB} + \left[\frac{S}{N}\right]_{dB}$$

In this formula:

S_P = amplitude of the interference: 1 V

S_{ECG} = ECG amplitude: 1 mV

S/N= signal to noise ratio: 40 dB

Or : CMRR ≥ 100 dB.

In addition, the amplifier must be characterised by a very high input impedance (> 10 MΩ) and a low offset voltage.

Numerous integrated instrumentation amplifiers exist (the AD624, for exam-

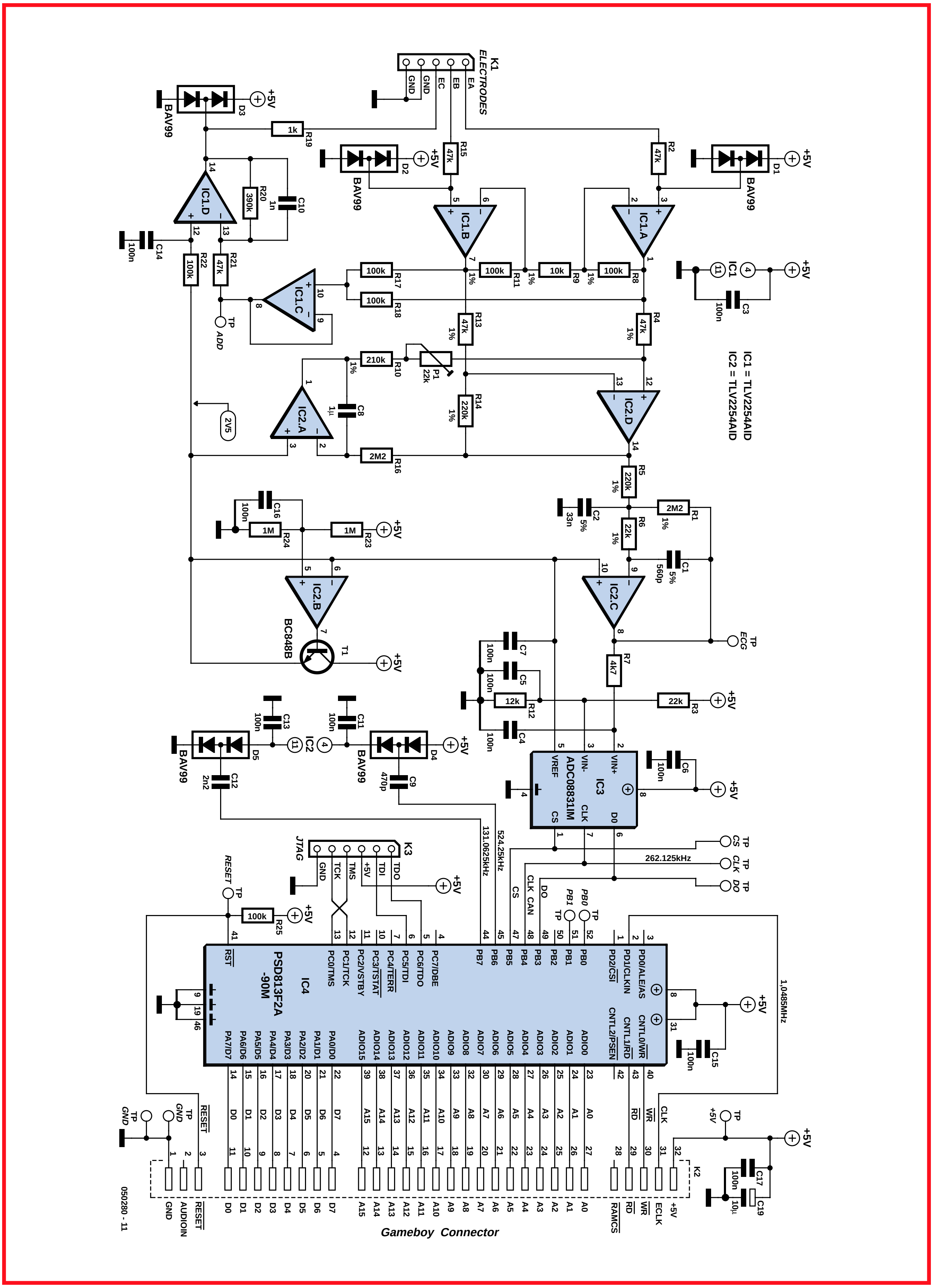


Figure 4. The bulk of the work is handled by the ISP flash memory, IC4 and IC3, an A/D converter, Serial I/O. The Gameboy processor handles the processing.

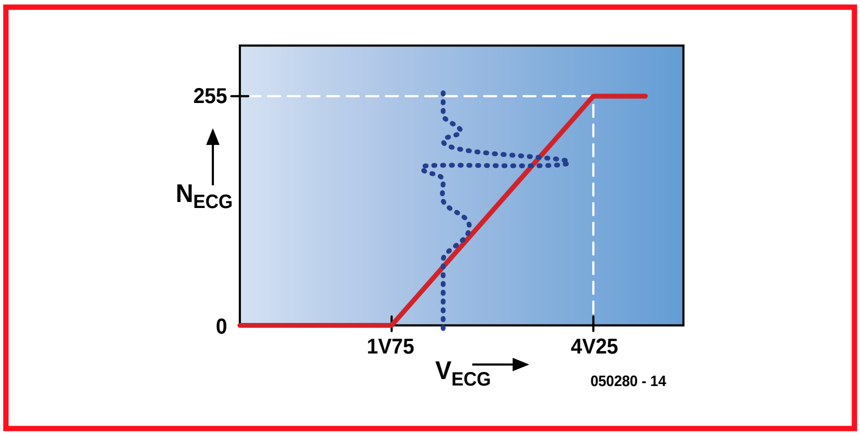
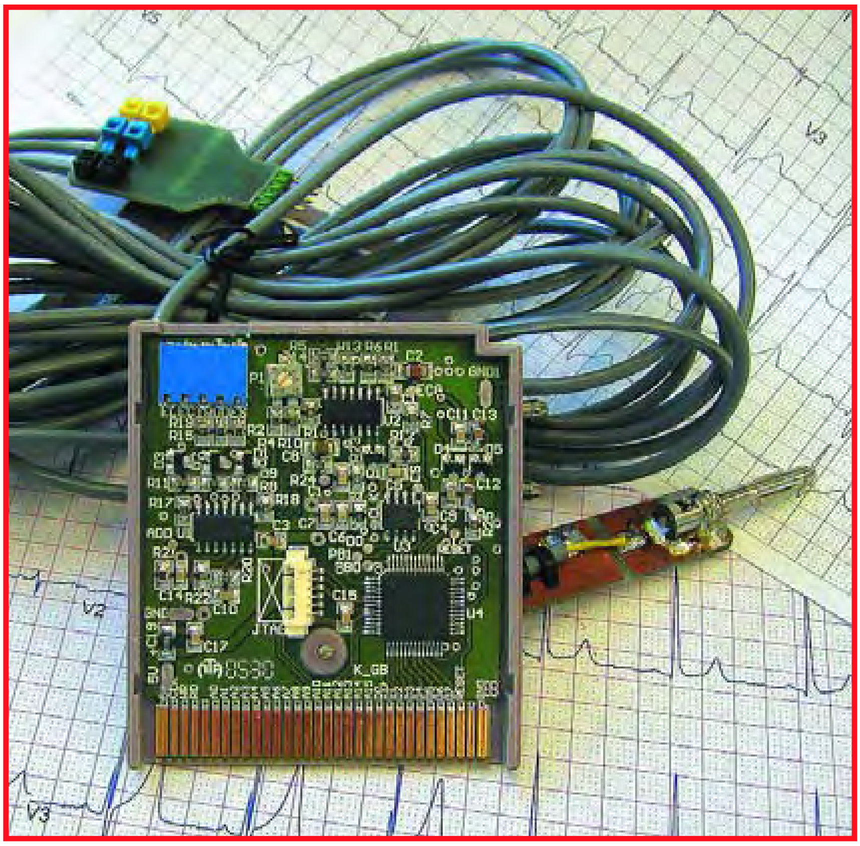


Figure 5. The transfer function is determined by divider bridge R3/R12.



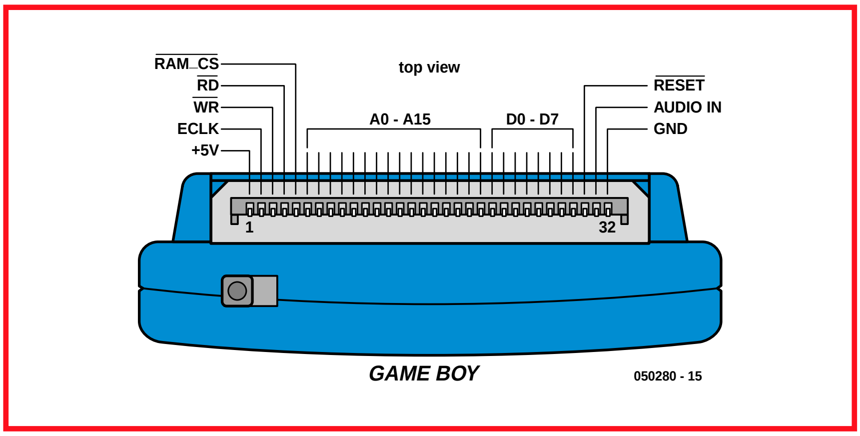


Figure 6. Connector pinout for the Gameboy cartridge (view from above).

ple). These are very high-performance devices and need no adjustment. But quality comes at a cost.

We decided to make the differential amplifier using more economical operational amplifiers. This also allows significant savings in cost and power consumption. Moreover, these opamps function perfectly with a single 5 V power supply (this is not the case for the AD624). The disadvantage is the presence of an adjustable potentiometer to optimise the CMRR.

Block diagram and wiring diagram

Figures 3 and **4** respectively give the block diagrams for the analogue part and the complete circuit diagram. The references associated with each function (ICx.y) identify the operational amplifiers for the structural diagrams that show the functionality.

The instrumentation amplifier is made up of functions F1 and F2. Function F3 is a 2nd order low pass filter with a roll-off of 170 Hz and a damping factor *m* of 0.73 (i.e., near Butterworth). It will faithfully attenuate all unwanted components outside of the useful frequency spectrum and replaces the anti-aliasing filter for the DAC (digital/analogue converter) that follows it.

The gain distribution in the circuit is as follows: A1 = 21×, A2 = 4.7× and A3 = 10×. The total amplification is 987, in compliance with our objectives. The other functions (F4, F5 and F6) assist the instrumentation amplifier in order to ensure its proper operation. In fact, the operational amplifiers have a supply voltage of between 0 V and 5 V. The ideal no-signal voltage on each of the terminals is 2.5 V. Setting this level is not a problem in most cases: a divider bridge with two resistors is appropriate (R23 and R24). It is harder for the two input amps because we must take care not to compromise their input impedances.

The problem is solved using the third, common, ECG electrode (see **Figure 3**) and the functions of F4 and F5.

It can be shown that the voltage S equals half the sum of the voltage (EA + EB). It is compared to the '2.5-V' setting, and the error voltage is amplified to produce an ECG signal that can be processed. As there is no current flow in the electrodes, voltages EA and EB are equal to EC (give or take a few mV). In this way, the human skin actually helps to keep EA and EB equal to the target level of 2.5 V. That is the goal

we are seeking: the no-signal voltage of the opamps is as desired without reducing the input impedance.
Moreover, a natural, but very annoying phenomenon occurs when we place the electrodes: an electromotive force (EMF) contact potential is produced between the skin and the electrode metal. This 'micro-cell' is very weak (a few mV) but it is not eliminated by the instrumentation amplifier. On the contrary, it is amplified!
Functions F4 and F5 partially reduce this effect, but the offset in S1 and S2 may still reach 1 V in differential mode. This value is unacceptable and is therefore compensated by function F6. F6 compares the average S3 signal value with the 2.5 V setting. The error voltage is integrated (time constant R16C8 = 2.2 s) in order to produce the ZERO signal. This continuous voltage offsets the S3 signal until its average value is stabilised at 2.5 V.
To increase the amplitude of this compensation, two diode pumps C9-D4-C11 and C12-D5-C13 produce –3 V and +8 V supply voltages for IC2.

The digital part

The digital-analogue conversion is performed by IC3. It integrates a real differential amplifier, but requires an external reference voltage. This is simply derived from the 5 V power supply using a potential divider (R23/R24) buffered by T1. The precision and the stability are average at best, but still sufficient for this application. The divider R3/R12 determines the transfer function (see **Figure 4**).
The asymmetry with respect to 2.5 V is justified by the asymmetrical shape of an ECG in relation to its average value.
The DAC provides its NECG results in 'serial' format. It is controlled by the CS and CLK signals — the first triggers the conversion (its frequency is 477.84 Hz) and the second clocks the data output (on DO).

The PSD813F2

A Gameboy cartridge plugs into a connector which accommodates the console's microprocessor buses:

- Addresses: A15 to A0
- Data: D7 to D0
- Check: ECLK, $\overline{\text{WR}}$, $\overline{\text{RD}}$ and $\overline{\text{RESET}}$

The first Gameboy games consoles on the market from about 1989 had a microprocessor similar to the old Z80, which explains the size of the buses.
The most recent consoles are equipped with much more powerful CPUs, but for commercial reasons the old cartridges (and even older than those) still operate on the current Gameboys. That is also the case for our electrocardiograph!
The PSD813F2 is an integrated circuit that's perfectly adapted for making a cartridge for a Gameboy console. Unfortunately, we do not have enough space in this article to describe its complete functionality (see [3]). In summary, the PSD813F2 includes:

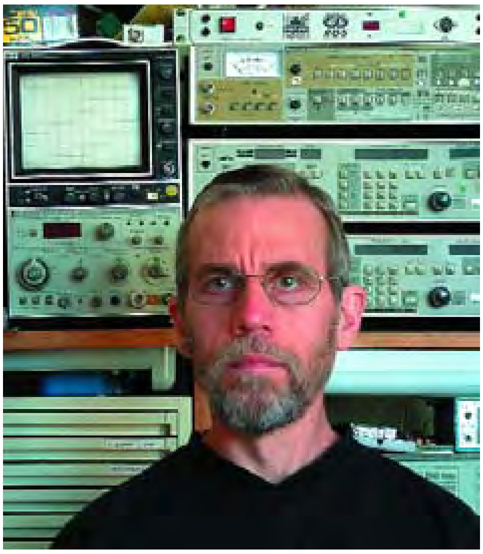
- a configurable microprocessor interface that can be adapted to all 8-bit microprocessors on the market, including the vintage Z80;
- 128 kBytes of Flash memory (only 32 kBytes are utilised by the electrocardiograph object code, which leaves space for extensions or other things...);
- a complex programmable logic device (PLD) that takes care of the address decoding;
- a 16-cell sequential Complex Programmable Logic Device (CPLD). It is responsible for the serial-to-parallel conversion of the DAC frames to relieve the CPU and produce the squarewave signals required for the diode pumps;
- 27 I/O configurable ports;
- 2 kBbytes RAM (not used).

Moreover, a JTAG interface is used to completely configure the 'on circuit' component via connector K3, which should not fail to interest all of you electronics hobbyists. The PSDSoftExpress development environment can be downloaded for free on the manufacturer's website.
As you can see from the diagram (Figure 4), the connection between the console bus and the PSD813 is simple: the signals of the same name are connected.
The only particularity that could be interpreted as an error: the data bus connections are crossed! That enabled us to simplify the board layout and the binary file of the GBECG control program was changed to suit.

The software

The software is entirely written in assembly language. The author used the 'Gameboy Assembler Studio' environment by Nicklas Larsson (freeware available on the web [4]).
The assembly language was necessary because the specifications require a 'scrolling' display in real time. That

The author



The author, Marcel Cremmel, has been a qualified teacher in Electrical Engineering (with Electronics option) since 1979 (French National Education state diploma).

After having initially taught at the Mohammedia de Rabat Engineering School in Morocco as a participant in the Cooperation program, he was assigned to the Louis Couffignal High School in Strasbourg in 1982, in the BTS EL section (Certificate, Senior Electronics Technician).

Although his profession forces him to deal with all domains of electronics Marcel has a preference for telecommunications, video, microcontrollers (MSP430 and PIC) and programmable logic circuits (Altera). In addition to electronics, his other passion is motorcycles in all forms: touring, races, etc.

His personal website is at http://electronique.marcel.free.fr/

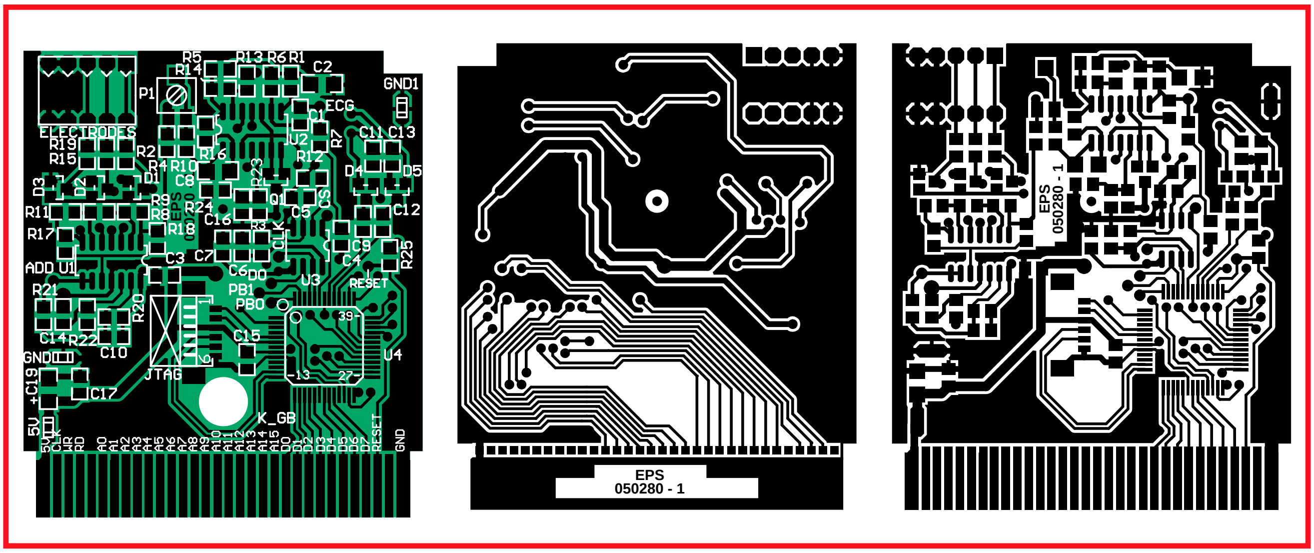


Figure 7. Copper track layout and component mounting plan of the double-sided board designed for the GBECG. Soldering of IC3 is particularly difficult, so we're supplying the board with all components pre-soldered.

occupies the CPU of the first consoles at a level of 80% due to the 'old' manner in which the screen memory is organised (separate screen memory and character memory).
The software can be thought of as handling four tasks:

1. Initialisations
This task is executed at switch-on or after a reset,

- Initial assignment of variables.
- Configuration of I/O ports.
- Initialisation of the LCD. The screen has 160 x 144 pixels, but for technical reasons, the useful part is reduced to 160 x 96 pixels. The lower part (160 x 48) is utilised for fixed messages.
- Internal timer: this is programmed to produce interrupts at a rate of 477.84 Hz (sampling frequency).
- Sound generator: this is pre-programmed to produce a cardiac 'beep' when required.

2. Main loop
The main loop simply detects the action of certain keyboard keys and modifies the operating mode:

- Start: **acquisition** mode
- Select : **stop** mode
- △: zoom _1 in stop mode
- ▽: zoom _2 in stop mode

3. Timer interrupt program
This task is executed a rate of 477.84 times per second. It carries out the following functions:

- Debounced readout of the keyboard state.

In **run** mode:

- triggers a new conversion;
- acquisition of the last sample (result of the previous conversion);
- all 4 samples (or 119.46 times per second);
- calculation of the 'average sample'

COMPONENT LIST

(all SMD, except K1)

Resistors
(all 0805 case)
R1 = 2MΩ2 1%
R2,R15,R21 = 47kΩ
R3 = 22kΩ
R4,R13 = 47kΩ 1%
R5,R14 = 220kΩ 1%
R6 = 22 kΩ 1%
R7 = 4kΩ7
R8,R11 = 100kΩ 1%
R9 = 10kΩ
R10 = 210kΩ 1%
R12 = 12kΩ
R16 = 2MΩ2
R17,R18,R22,R25 = 100kΩ
R19 = 1kΩ
R20 = 390kΩ
R23,R24 = 1MΩ
P1 = 22 kΩ preset (Bourns 3314G)

Capacitors
(all 0805 case except C8 and C19)
C1 = 560pF 5%
C2 = 33nF 5%
C3-C7,C11,C13-C17= 100nF
C8 = 1µF (1208)
C9 = 470pF
C10 = 1nF
C12 = 2nF2
C18 = not fitted
C19 = 10µF (1208P)

Semiconductors
IC1,IC2 = TLV2254AID
IC3 = ADC08831IM (Analog Devices) or TLC0831CD (Texas Instruments)
IC4 = PSD813F2A-90M (STMicroelectronics), programmed, order code **050280-41**
D1-D5 = BAV99
T1 = BC848B

Miscellaneous
K1 = Molex connector, 5-way, Dubox 89882-405, Digikey # 90148-1102-ND

Programming connections:
K3 = Molex connector, 6-way, 1.25mm lead pitch, type 53261-0671 (Digikey # WM7624CT-ND)

Optionally: FlashLink programming connection:
Molex 6-way connector, 1.25mm lead pitch, female (Digikey # WM1724-ND)
6 wires with pin terminations for Molex connector (Digikey # WM1775-ND)

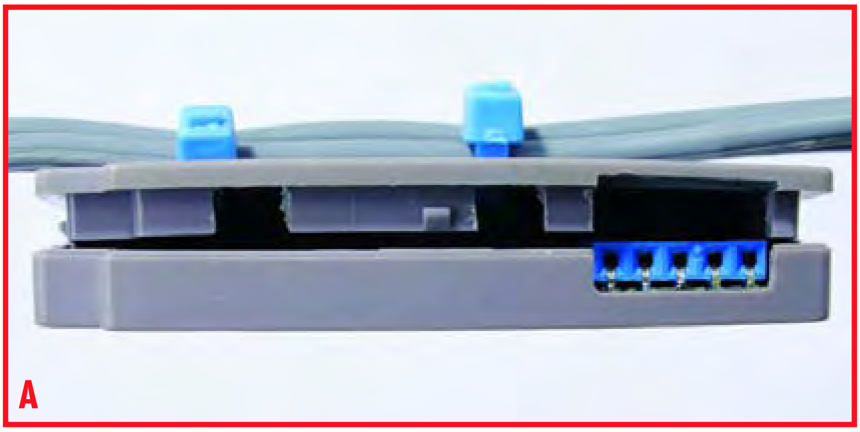
Electrodes:
Cutaneous probes or clips are available from medical supplies outlets
5-way SIL pinheader
4 mm plate (3x)
6 m screened audio cable
PCB, with all components ready fitted, tested, order code **050280-91**

= average of the last 4 samples;
- detection of the R-wave in order to trigger the cardiac 'beep';
- loading the 8 kBytes cyclic buffer with the average sample.

4. Interrupt program, V-Blank
This interrupt is produced at the end of each LCD vertical sweep. The rate is: f_v = 59.73 Hz; or every two averaged samples.

The program also takes care of refreshing the display.
- **Run** mode: the LCD shows the last samples (or 320 averaged sampled values on the cyclic buffer), which traces the last 2.68 s on the screen width.
- **Stop** mode: depending on the zoom value: ×1 or ×2, the LCD shows the last 320 or 160 samples, which traces the last 2.68 s or 1.34 s on the screen width.

In **stop** mode, the program also detects action on the ▷ or ◁ keys allowing the use to move around within the screen memory.
During the display of the ECG trace, the program draws the vertical and horizontal scales. The latter moves with the trace in order to improve readability. The source code file of the GBECG control program is available as a free download from the *Elektor Electronics* website, the file number is **050580-11.zip**, see under month of publication. Improvements and additions are welcome.


A

Building it

The use of SMD components is unavoidable. In fact, the underside of the board must be perfectly smooth (therefore, no through wires or pins) so that it can slip into the cartridge case. To save you the trouble of struggling with (and losing) those tiny SMD parts, we are supplying the GBECG printed circuit board with all components already soldered in place, and the PSD813 programmed, all at an affordable price (see the inset). The order code is **050280-91**.
All that is left to do is find an old Gameboy cartridge case and clear out the two half-shells a little. **Photo A** illustrates the cutouts to make.
The wider cutout in the upper half-shell is due to potentiometer P1 which otherwise prevents closing the case.

Adjustment

The only adjustment consists in optimising the CMRR of the differential

The electrodes

A good ECG can only be obtained with good, well-placed and properly-wired electrodes.

To limit the effect of undesirable signals, it is recommended that you use shielded cables. Electronically, 'audio' cables are perfectly suited to this function. In practice however they are much too fragile, We therefore propose making small adaptors on which the cable clasps eliminate practically all risk of breaking (see **Figure F**),

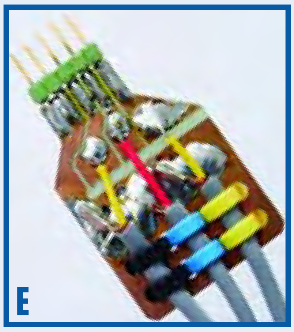
You will see that the shielding is only connected at the cartridge side and that it is isolated on the electrode side in order to avoid any contact with the skin.

'4 mm' type plugs make it possible to use commercially available electrodes (**Figure G**).

The clip is very practical and adapted for children. But the price of these two electrodes may discourage many readers (more than £6 each and you will need three off!)

Homebrew electrodes can be made from coins as illustrated in the opposite photo. The author used French Florin (FF) coins which are made from nickel. Solder a 4-mm socket and the electrode (**Figure H** is ready to use.

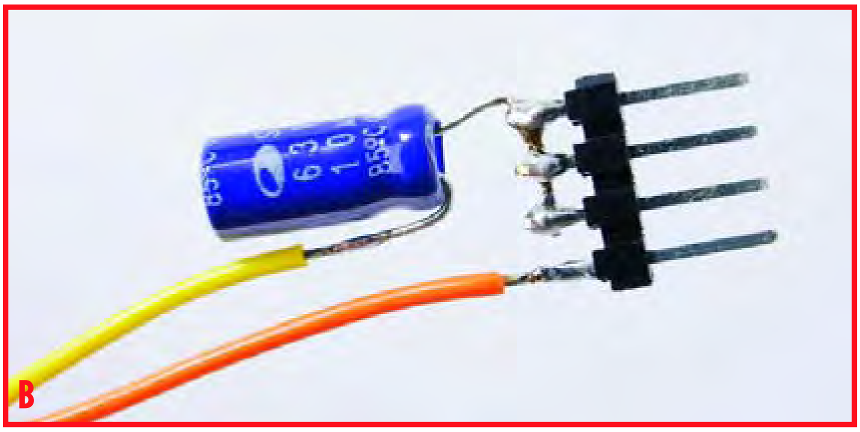
Three rubber bracelets keep them in place on the wrists and the lower calf. These bracelets can be made by cutting ribbon for straps to the proper length and gluing them to the self-adhesive 'Velcro' tape at both ends. We can also use sections from air chambers from a motorcycle or a scooter.


E

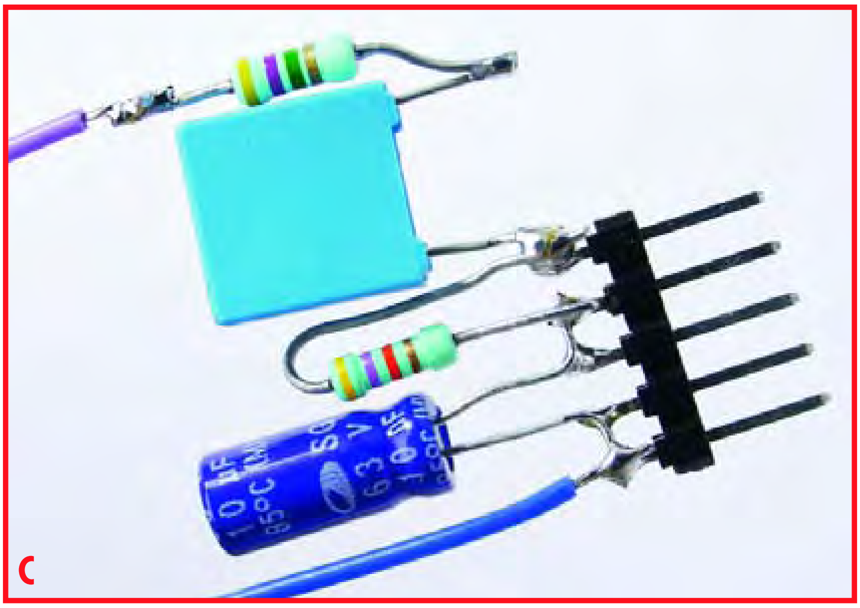

F


G


H



B



C

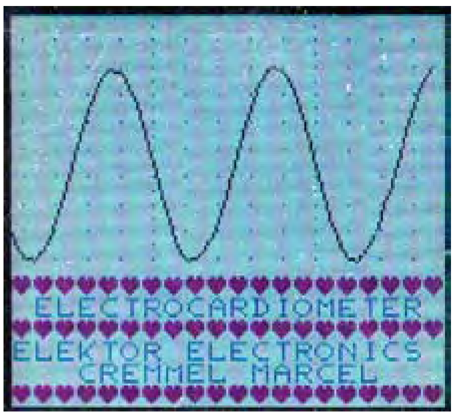
amplifier. For that, you need a function generator and an oscilloscope or an AC voltmeter. Begin by making the measurement circuit in **Figure B** (the capacitor has a capacitance of 10 μF). Top to bottom: EA, EB, EC, GND.
Plug the device into the fixed connector K1, observing the orientation, and only then connect the generator. In this way, we inject a common-mode test signal. Adjust the generator: 50 Hz sine wave with amplitude 1 V. Insert the cartridge in the Gameboy with the upper half-shell removed in order to access the ECG test point. Turn on the power and measure the AC component of the ECG signal. Then adjust P1 to minimise the peak-to-peak amplitude. It should be less than 25 mV in order to obtain an S/N ratio in excess of 40 dB.

Final check

This step is not strictly required. Its purpose is to ensure proper operation of the electrocardiograph by injecting a signal and by verifying the result on the screen.
Most benchtop signal generators are incapable of reliably producing the very low levels required for this check. Therefore, we must greatly attenuate the GBF signal. That is what the device shown in **Figure C** does.
The signal is effectively divided by 100. In this way, we inject a 1 Hz sinusoidal signal and a 140-mV DC amplitude signal. These should result in an image on the LCD screen similar to that in **Figure D.**
The sinewave is aligned with the first dotted line and has a DC amplitude of 7 divisions, or 7×200 μV = 1.4 mV.
The fixed connector K1 on the cartridge is not very sturdy. To limit the risk of deformation or of it being torn out, restrain the three shielded cables on the cartridge cover with two cable ties, as illustrated in **photo E.**
The cable ties we used on our prototype of the GBECG do not touch the internal components. They require four 2 mm holes to be drilled which do not significantly weaken the shell.

(050280-1)

We would like to extend our thanks to Professors Schalij and Maan, Leiden University Hospital, the Netherlands, for their valuable assistance.



D

Bibliography

[1] GBDSO — Gameboy Digital Storage Oscilloscope, Elektor Electronics October and November 2000.

Internet references and links

[1] http://chem.ch.huji.ac.il/~eugeniik/history/einthoven.html

Attention

The GBECG electrocardiograph described in this article has not received medical approval and is therefore not intended for professional use. The instrument must always be powered by batteries in order to respect protection category III.

Operating instructions

Placement of the electrodes

It is absolutely necessary to clean the skin and the electrodes well with a cotton and ether or alcohol, In this way, the electromotive force EMF on the contacts, which may saturate the amplifiers, are limited considerably.

The standard lead is 'DI':

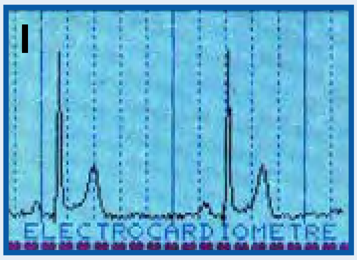
- EA electrode: right wrist
- EB electrode: left wrist
- EC electrode: left foot (lower calf)

Utilisation of 'contact' products based on potassium chloride considerably improve the quality of the measurements.

The best ECGs are obtained when the patient is calm and lying down so that the only muscle in action is the heart.

Operation

- Live start-up: welcome screen is displayed.
- Go to the acquisition screen: press Start, A, B or Select.



- ECG acquisition: if the electrodes are properly placed and the patient is calm, the reading should be stabilised in a few seconds and look like the one illustrated in **Figure I**.

Do not use this ECG as a reference; the shapes may vary appreciably from one individual to another.

If no trace appears after thirty seconds, clean the skin below the electrodes using a pad and ether or alcohol.

Irregularity of the trace may be reduced by using a 'contact' product.

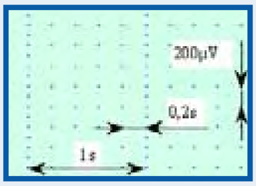
- Stop mode: pressing the Select button stops the acquisition. You can then analyse the memory which contains 68.6 s worth of ECG.

△: zoom x 1

▽: zoom x 2 (see below)

▷: Move ahead

◁: Move backwards



Scales (zoom 1x)

A beep sound will be heard each time an R wave is detected. The volume can be adjusted with the volume button on the console.

Attention: The screen memory is erased when power is removed.

[2] http://www.e-cardiologie.com/examens/ex-electro2.shtml

[3] http://www.st.com/stonline/products/

[4] http://www.devrs.com/gb/

Additional documents and program sources on

http://www.elektor.com

http://www.infoscience.fr/histoire/biograph/biograph.php3?Ref=128

PSD813 datasheet

http://www.st.com/stonline/products/literature/ds/7833.pdf

ADC08831IM datasheet

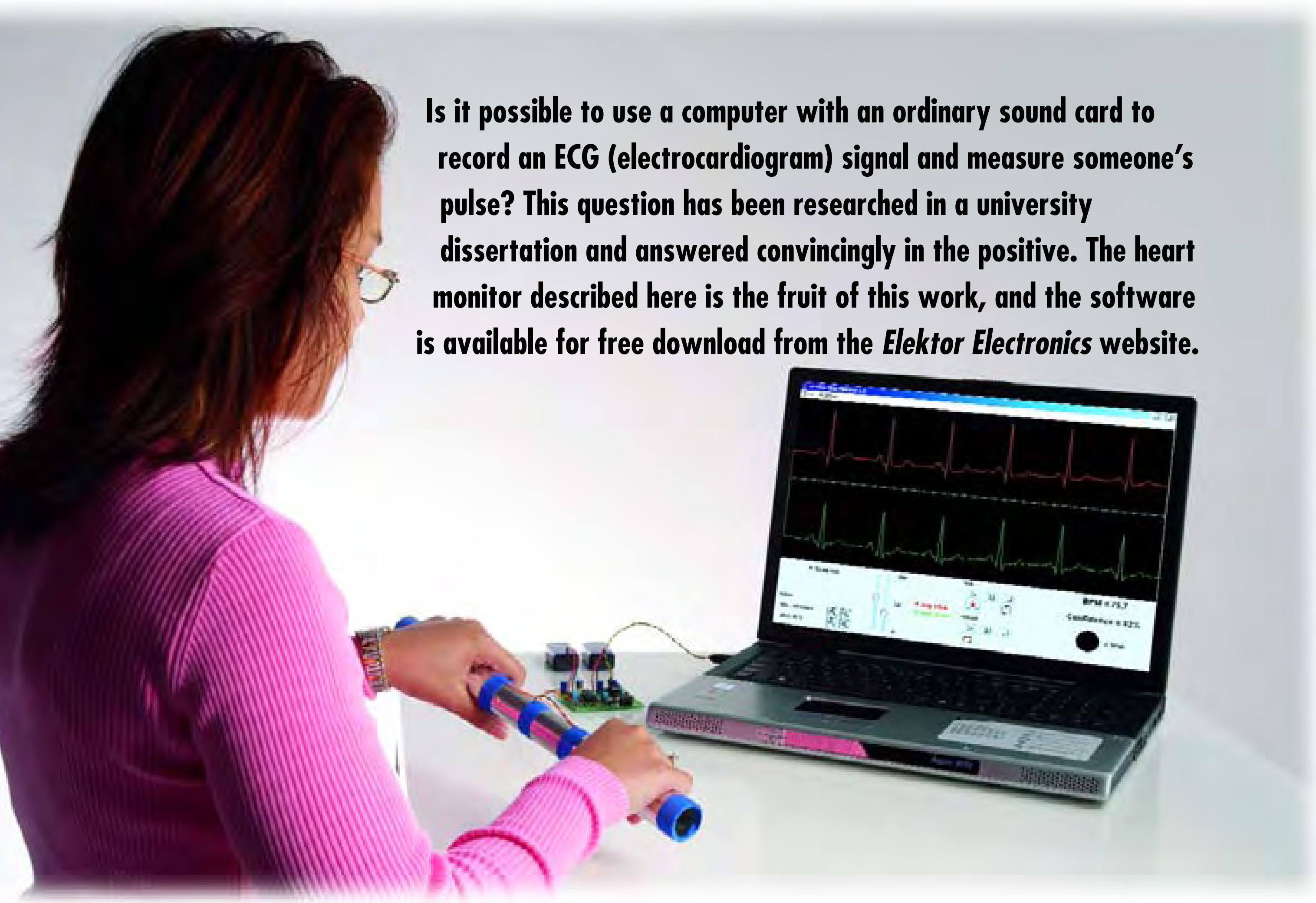
http://www.ortodoxism.ro/datasheets2/6/0rcoik1yuwhx1dj2ogg8wid7sfcy.pdf

ECG using a Soun

Medical signal processing on a PC

Martin Klaper

Is it possible to use a computer with an ordinary sound card to record an ECG (electrocardiogram) signal and measure someone's pulse? This question has been researched in a university dissertation and answered convincingly in the positive. The heart monitor described here is the fruit of this work, and the software is available for free download from the *Elektor Electronics* website.



Elsewhere in this issue we describe how to record an ECG signal using a Gameboy games console fitted with a special insertion card. Here we show how it can be done in a more experimental way using an ordinary sound card or the audio input of a laptop computer. For this we need a sensor (see **Figure 1**), which in the simplest case can be just a tube with contact surfaces at either end that can be gripped like the handlebars of a bicycle. The weak signal that is picked up is amplified by a factor of 1,000 and presented to the audio input of the computer.

Subsequent processing is carried out using a Java program. It conditions the signal using a digital filter, stores it and displays it on the screen. The program also monitors the pulse and automatically calculates the pulse rate with a digital display and audio output. The individual readings can be stored in a

d Card

Specifications

Input impedance:	> 1 MΩ
Input dynamic range:	5 mV_{pp}
Amplifier current consumption:	approximately 11 mA
Optocoupler current consumption:	approx. 2.2 mA
Common mode rejection ratio (CMRR):	> 70 dB
Gain:	approx. 1,000 (60 dB)
Bandwidth:	approx. 0.4 Hz to 35 Hz (depending on sound card)
Recording rate:	in practice unlimited, typically 60 kbyte per minute

file for later analysis. Test data sets are also available on the Internet [1] from medical databases, and these can also be processed and displayed using the program.

ECG

As described in detail in the Gameboy ECG article elsewhere in this issue, the heart muscle is controlled by electric currents. This electrical activity can be measured on the surface of the body using electrodes. The resulting plot against time is called an electrocardiogram, or ECG. **Figure 2** shows a typical ECG plot: the exact form of the curve is an important diagnostic aid. We will leave the job of diagnosis to the specialists, and concentrate here on making the measurements.

ECGs are normally displayed with 25 millimetres on the horizontal axis representing one second, or 40 milliseconds per millimetre. The vertical axis is usually 10 millimetres per millivolt. This means that a 1 mm square on the plot represents 0.04 s in time and 0.1 mV in voltage. There are conventions for labelling certain characteristic points on the ECG curve with letters [2]. The distance from one of the prominent 'R' peaks to the next represents exactly the time between two heartbeats: this lets us readily determine the pulse rate.
This rate, expressed in beats per minute (or BPM) is displayed by the computer, and the pulse itself can optionally be output as an audio signal. An interesting project would be to compare the measured rate against a preset value and use this to control the braking on an exercise bicycle, in order to maintain a constant pulse rate while exercising.

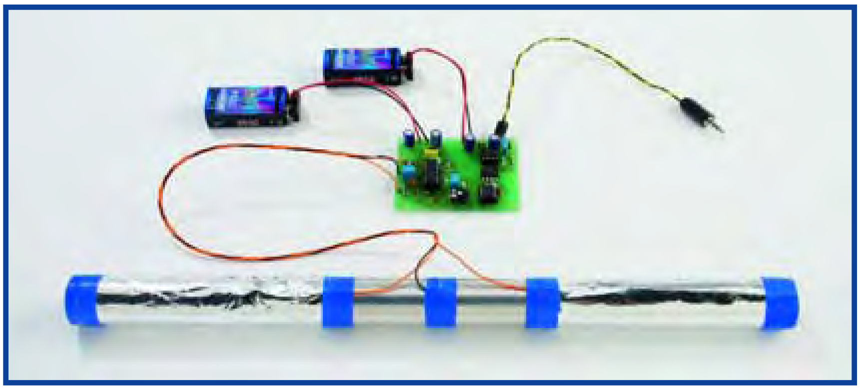


Figure 1. This simple sensor for heart signals consists of a pipe with a contact surface at either end.

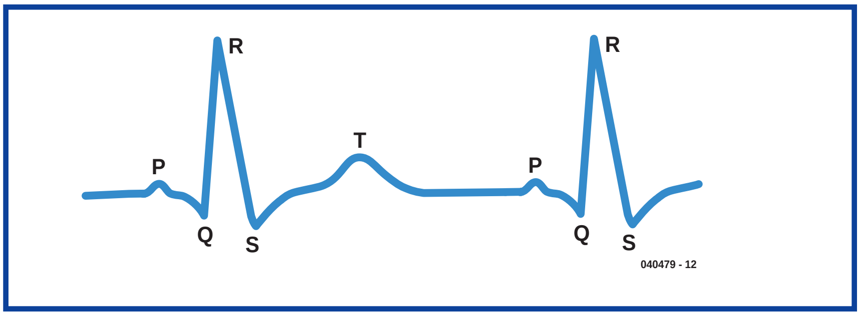


Figure 2. The interval between two consecutive points marked 'R' in the ECG trace gives the time between heartbeats.

Safety

The circuit and software are not approved and/or licensed for medical use. They are for private use only, for example for experimental purposes.

The circuit must only be used with a battery supply. This also applies to the connected computer whose sound card input is being used: the computer **must not be connected to the mains supply**. In practice this means that a notebook or laptop PC must be used, running on battery power. The mains adaptor must be disconnected!

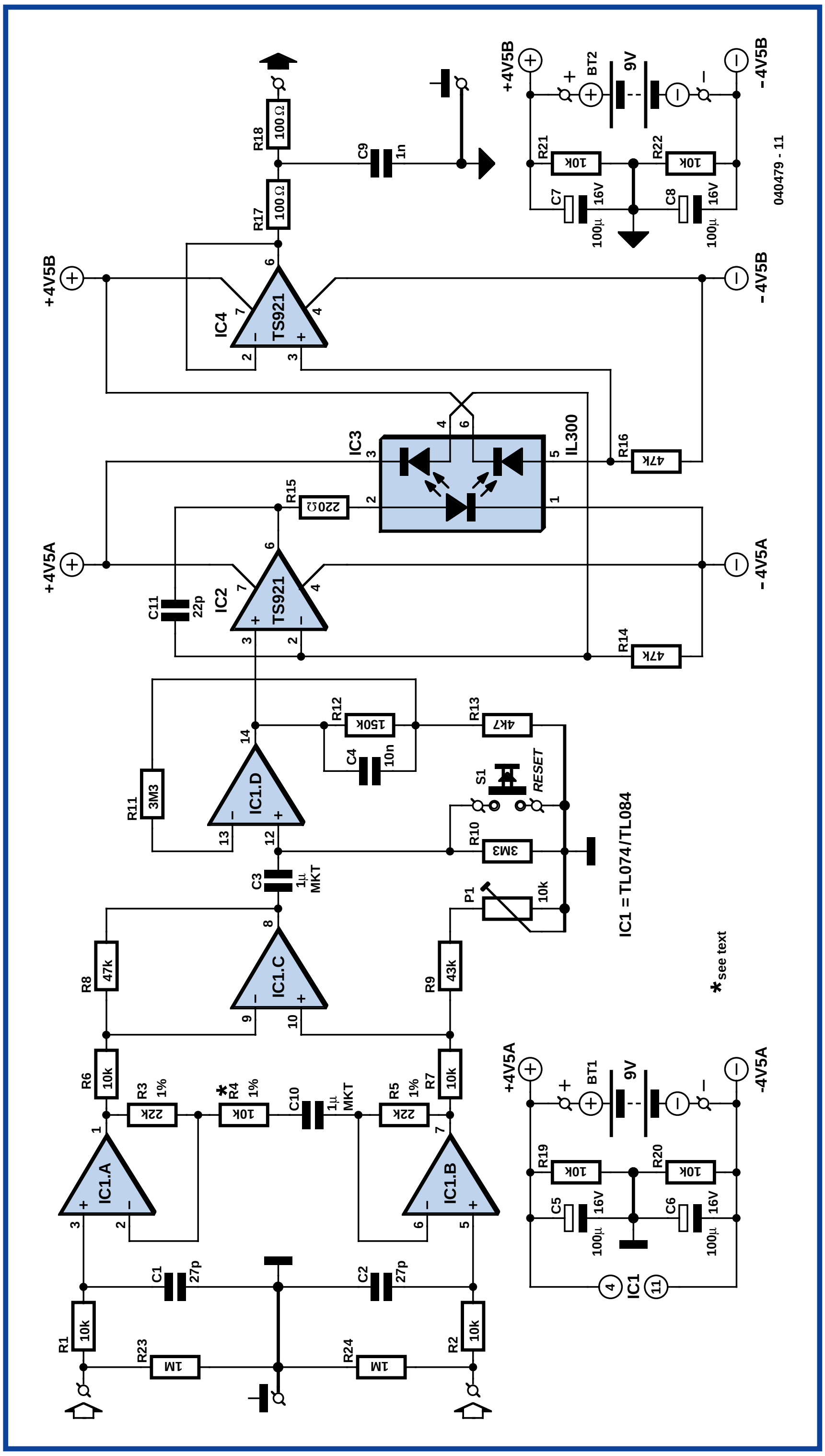


Figure 3. Circuit of the instrumentation amplifier, with galvanical isolation between input and output provided by an optocoupler.

Signal processing

Measuring an ECG using a computer requires demanding real-time processing, most of which is carried out in software. The hardware takes the form of an instrumentation amplifier (**Figure 3**) and has the job of amplifying the weak signal from the sensor (which has an amplitude of approximately 1 mV) by a factor of around 1,000, and attenuating DC, common-mode, and high-frequency components.

To obtain an (at least relatively) clean ECG signal it is necessary carefully to filter out any interference. This is done in software using a biquad infinite impulse response filter. The filter can be configured for any of the required responses: low-pass, high-pass, band-pass and notch. A 50-Hz rejection filter removes interference originating from the mains, and other interference is attenuated using a further high-pass filter. Since the signal is obtained from electrodes on the skin it is possible that there will be a slowly-varying offset voltage: this is removed using a DC blocking filter. The main pulse of the ECG can be extracted using a band-pass filter, giving a signal from which it is straightforward to measure the pulse rate. The Java program allows display of either the original signal or the filtered version. The various filter functions can be selected and configured by the user, and the effect on the processed signal can be clearly seen. The pulse rate is calculated from its autocorrelation function, determining the period by comparing the signal against itself with a time offset.

Instrumentation amplifier

The circuit (Figure 3) can be divided into two blocks: the instrumentation amplifier itself at the input and the optocoupled isolation amplifier at the output.

The signal is amplified by quad operational amplifier IC1, type TL084 (or the lower-noise TL074). IC1.A and IC1.B are non-inverting amplifiers, feeding the inputs of differential amplifier IC1.C. This arrangement is known as an ‘instrumentation amplifier’. P1 allows adjustment to obtain best common-mode rejection. Coupling capacitor C3 at the input to the next stage, built around IC1.D, blocks the DC component of the output of the instrumentation amplifier. To minimise the effect on low-frequency signals the time constant of the RC network formed by C3 and R10 is more than three seconds. This means that it will take at least this long for the voltage across the capacitor to stabilise when power is applied: this delay can be avoided by pressing reset button S1.
Optocoupler IC3 is driven by IC2. The type TS921 used is a ‘rail to rail’ opamp, which means that it can be driven to either extreme of its supply voltage range. Its output can deliver

COMPONENTS LIST

Resistors
R1,R2,R4,R6,R7,R19-22 = 10kΩ
R3,R5 = 22kΩ 1%
R8 = 47kΩ
R9 = 42kΩ2
R10,R11 = 3MΩ3
R12 = 150kΩ
R13 = 4kΩ7
R14,R16 = 47kΩ
R15 = 220Ω
R17,R18 = 100Ω
R23, R24 = 1MΩ
P1 = 10kΩ preset

Capacitors
C1,C2 = 27pF
C3,C10 = 1µF 63V, 5mm lead pitch (no electrolytic cap)
C4 = 100nF
C5-C8 = 100µF 16V radial
C9 = 1nF
C11 = 22pF

Semiconductors
IC1 = TL074 DIP14
IC2,IC4 = TS921 or TL071 DIP8
IC3 = IL300

Miscellaneous
Two wire links
Two 9-V PP3 batteries with connecting clips
Two DIL8 IC sockets
One DIL14 IC socket
PCB, order code **040479-1**
CD-ROM, contains PC software and source code, order code **040479-81** or free download from www.elektor.com

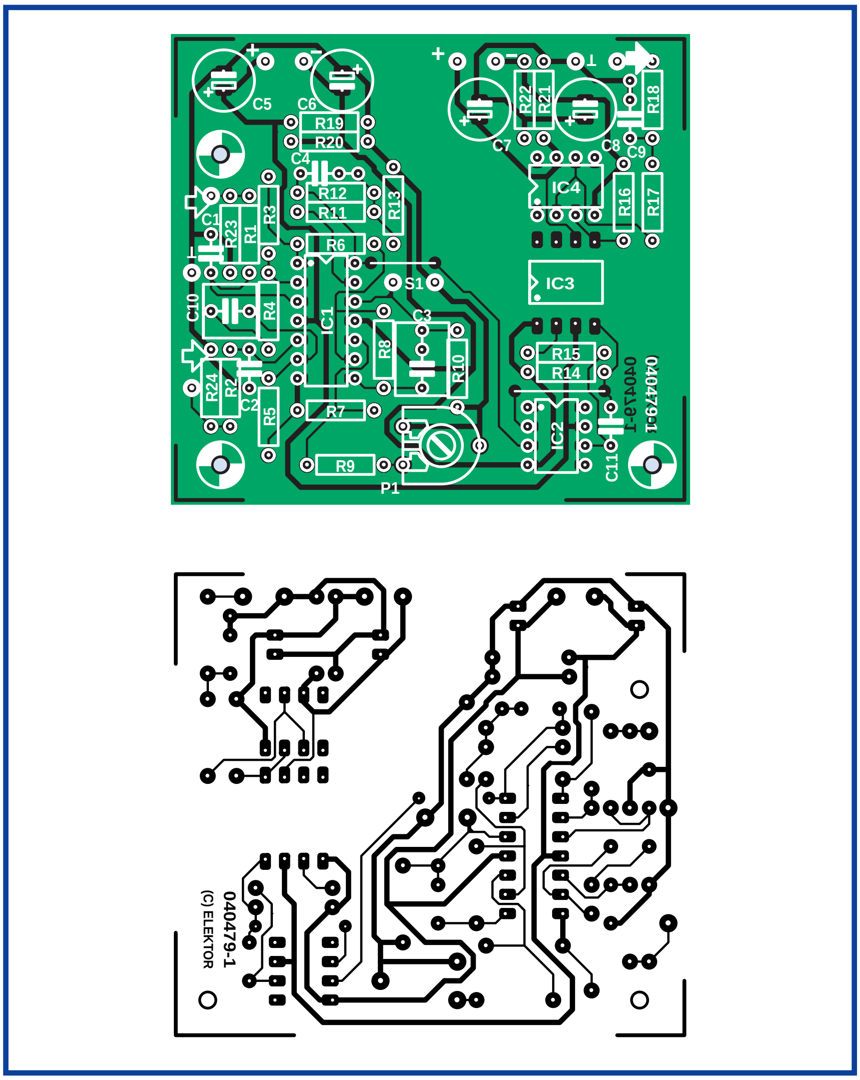


Figure 4. There are no SMDs on the single-sided printed circuit board, and so assembly is straightforward.

up to 80 mA, although only approximately 2.2 mA is needed to drive the transmit LED in the optocoupler. The current through the transmit LED is controlled using feedback from one of the receiver diodes in the optocoupler fed in to the inverting input of the operational amplifier. The result is that the voltage across R16 (the bias resistor for the second receiver diode) is equal to that across R14 and hence to the voltage at the non-inverting input to IC2. In other words, the voltage at the output of IC1.D appears across R16, but with galvanic isolation. C11 prevents high-frequency oscillation of the driver.

The final opamp at the output of the circuit acts as a buffer amplifier. This makes for a low-impedance output, which is also short-circuit proof thanks to the 100 Ω resistors R17 and R18, forming a low-pass filter at the output in combination with C9.

About the author

Martin Klaper studied electronic engineering at the Swiss Federal Institute of Technology in Zurich and worked in various positions in the telecommunications industry over a period of 20 years. Since 2000 he has been a lecturer in computing and telecommunications, until 2005 at the University of Applied Sciences of Northwestern Switzerland (FHSO), and since October 2005 at the School of Engineering and Architecture (HTA) in Horw, near Lucerne. This project was begun at FHSO and continued at HTA.

The author is also a keen radio amateur (callsign HB9ARK) and is currently interested in the ideas behind software defined radio. He is married with two sons.

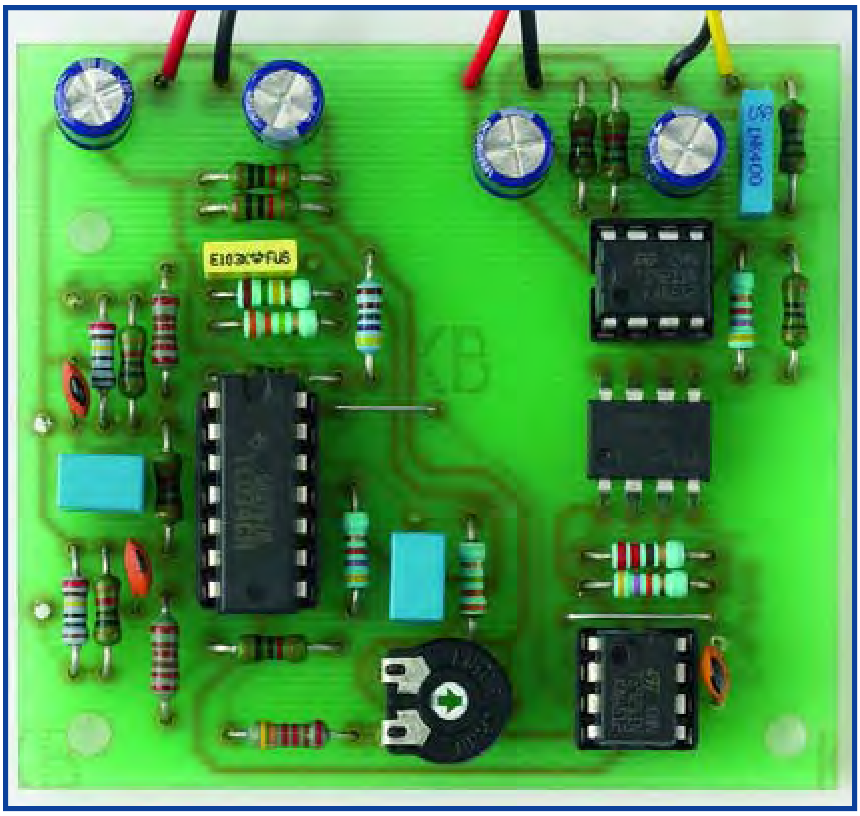


Figure 5. The populated *Elektor Electronics* prototype board. The IC not fitted in a socket is the optocoupler, whose pins are splayed out for mounting in order to increase the isolation gap.

The complete galvanic isolation between input and output of the circuit provides for extra safety (see the 'Safety' text box). The instrumentation amplifier and the output stage should be powered from separate batteries.

Components and construction

We look first at component selection. For resistors R3, R4 and R5 low-noise metal film types are recommended. C10 provides DC decoupling for the input amplifiers, which, if the sensor shown in Figure 1 is used, prevents weak muscle signals from swamping the signal from the heart. If disposable self-adhesive ECG electrodes are used instead, the capacitor can be replaced by a wire link.

If the TS921 should prove hard to obtain, a type TL071 can be substituted at the cost of reducing the dynamic range of the circuit somewhat. The 43 kΩ resistor (value from the E24 series) can also be replaced by a different value, adjustment of P1 compensating for the difference.

Assembly of the printed circuit board (**Figure 4**) should commence with the wire links, since these are easy to overlook if left to a later stage of construction.

IC3 is supplied with its pins bent at a right angle. To fit the circuit board they should be bent apart (see **Figure 5**): this is necessary in order to guarantee the necessary isolation gap.

P1 can be adjusted for best common-mode rejection. Start with it set to its mid-position: the adjustment is not critical and so this will often be adequate. For best results connect the inputs of the instrumentation amplifier together and adjust P1 to minimise the amplitude at the output of the 50 Hz signal picked up by the circuit. This measurement can be done using the Java program (see **Figure 7**).

The heart signal sensor used by the author consists of two short pieces of conducting tube (zinc- or chrome-plated steel, for example from a vacuum cleaner head, or a length of water pipe) joined using a piece of insulating pipe. The *Elektor Electronics* prototype used a longer piece of conducting pipe with insulating tape wound around either end for a distance of about 10 cm. We then wrapped this insulating layer with aluminium foil to provide the two contact surfaces. Tinned copper wires wound around the two pieces of foil provide connection to the inputs of the instrumentation amplifier. This sensor construction, illustrated in Figure 1, has the advantage of not requiring any drilling or sawing.

Screened audio cable can be used to wire the output of the circuit to a plug suitable for connecting in to an audio line input (or microphone input) of a computer. Most computers use a 3.5 mm stereo jack.

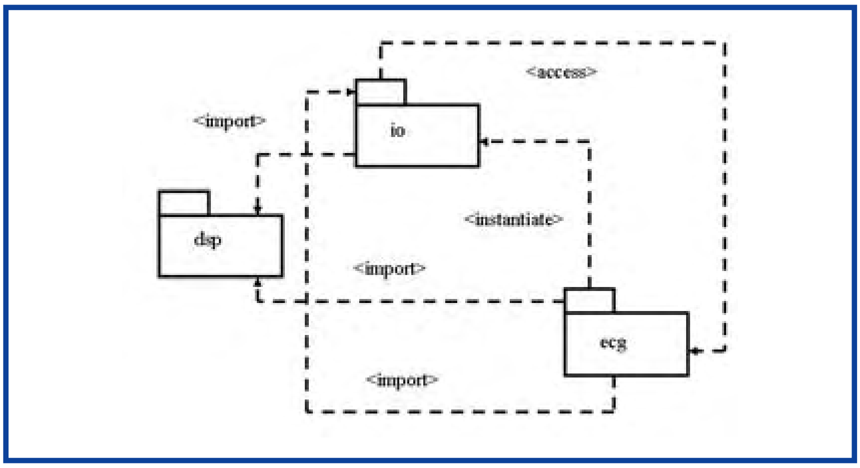


Figure 6. The module structure of the PC-based Java signal processing software.

Software

The Windows-based software is written entirely in Java. The modular structure of the software (see **Figure 6**) is designed to provide the following functions:

- capture the signal from the sound card (labelled 'io');
- signal conditioning and filtering to

remove interference ('dsp');
- user interface ('ecg').

Figure 7 shows the appearance of the user interface, showing the main program window with the original signal plotted at the top and the processed signal plotted below. The time axis is shown in between the two plots. The BPM meter in the lower right corner of the window shows the pulse rate and the program's confidence in the displayed value. The audio output can also be enabled here. The program has many other features which we do not have space to describe here.

The source code is available for download from the *Elektor Electronics* website. There are several files in the download. The PC program is called 'EKG-MonitorV1.0.jar' and can be run with a double click of the mouse. The '.jar' extension indicates that this is a Java executable, analogous to a '.exe' file under Windows. A Java runtime system is required to execute the program: this can be found at [3]. You will need the version of the JRE (Java Runtime Environment) suitable for your operating system.

In practice

The circuit is suitable for use only with sound cards that have a frequency response that extends down to at least 0.1 Hz (at –3 dB). This should not present a problem if the input is DC coupled; however, many are provided with inputs that are AC coupled (i.e., with an input capacitor). In our laboratory the prototype worked perfectly with the audio input of an elderly laptop. In case of doubt the frequency response of the sound card can be measured using the free program RMAA [6].

Best results are obtained using commercial disposable ECG electrodes, but they can be tricky to attach to the skin. The pipe sensor described above and shown in Figure 1 is rather easier to use.

The filter (**Figure 8**) can be configured to minimise interference, and there is plenty of scope for experimentation, improvement, and research. Readers are encouraged to publish their improvements, and the Java software for the project is released under the GNU public licence.

As well as compiled hex code and source code, a User Guide is also available for download from the *Elektor Electronics* website. Look for archive file 040479-11.zip under month of publication.

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Figure 7. The main program window shows the original signal (above) and the processed signal (below).

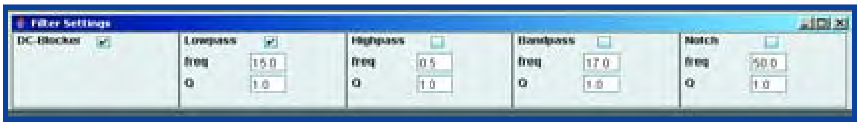

Figure 8. The 'Filter Settings' window allows configuration of the infinite impulse response biquad filter, implemented in software.

Links:

[1] www.physionet.org/physiobank/ ECG sample data

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

[3] http://java.sun.com/javase/downloads/index.jsp
Java compiler and development environment. The Java Runtime Environment (JRE), current version 5.0, is required to run the program and the J2SE Development Kit (JDK), current version 5.0, is required to compile modified versions of the program.

[4] www.bluej.org/download/download.html
Simple Java development environment with tutorial, ideal for beginners.

[5] www.eclipse.org/downloads/
Eclipse is a full-featured Java development environment for professionals.

[6] http://audio.rightmark.org/download.shtml
RMAA (RightMark Audio Analyser).

[7] www.dspguru.com; www.musicdsp.org/archive.php?classid=0
Various topics in DSP.

EMC DIRECTIVE

From 1 January 1996, home-made equipment must take into account emc Directive 89/336/eec (emc = ElectroMagnetic Compatibility). Basically, the directive states that no equipment may cause, or be susceptible to, external interference. Here, interference means many phenomena, such as electromagnetic fields, static discharge, mains pollution in the widest sense of the word.

Legislation

Home-made equipment may be taken into use only when it is certain that it complies with the directive. In the United Kingdom, the dti (Department of Trade and Industry) will, in general, only take action against offenders when a complaint has been made. If the equipment appears not to comply with the directive, the constructor may be sued for damages.

ce label

Home constructors need not affix a ce label to their equipment.

Elektor Electronics and the Directive

The publishers of Elektor Electronics intend that designs published in the magazine comply with the directive. Where necessary, additional guidelines will be given in the article. However, the publishers are neither obliged to do so, nor can they be held liable for any consequences if the constructed design does not comply with the directive. This column gives a number of measures that can be taken to ensure that EE-designed equipment complies with the directive. However, these are needed only in some designs. Other measures, particularly in case of audio equipment, are not new and have been applied for some time.

Why emc?

The important long-term benefit for the user is that all electrical and electronic equipment in a domestic, business and industrial environment can work harmoniously together.

Radiation

The best known form of emc is radiation that is emitted spuriously by an apparatus, either through its case or its cabling. Apart from limiting such radiation, the directive also requires that the apparatus does not impart spurious energy to the mains—not even in the low-frequency range.

Ferrite through-filters as illustrated are used for feeding cables through a panel.

Immunity

The requirements regarding immunity of an equipment to emc are new. Within certain limits of ambient interference, the apparatus must be able to continue working faultlessly. The requirements are fairly extensive and extend to a wide range of possible sources of interference.

Computers

Computers form the prime group for application of the directive. They, and microprocessors, are notorious sources of interfering radiation. Moreover, owing to the way in which their internal instructions are carried out sequentially, they are also very sensitive to interference. The notorious crash is but one manifestation of this.

Enclosures

A home-made computer system can comply with the emc directive only if it is housed in a metal enclosure. A minimum requirement is that the underside and rear of the enclosure is an l-shaped frame. All cabling must converge on this area or be filtered. If there are connectors on the front panel, a u-shaped metal frame should be used.

Even better results are obtained if a 20 mm wide, 1 mm thick copper strip is fixed along the whole width of the rear wall with screws at 50 mm intervals. The strip should have solder tags at regular distances for use as earthing points.

A closed case is, of course, better than an l-shaped or u-shaped frame. It is important that all its seams are immune to radiation ingress.

Power supplies

In any mains power supply, account should be taken of incoming and outgoing interference. It is good practice to use a standard mains filter whose metal case is in direct contact electrical contact with the enclosure or metal frame. Such a filter is not easily built at home. It is advisable to buy one with integral mains entry, fuse holder and on/off switch. This also benefits electrical safety in general. Make sure that the primary of the filter is terminated into its characteristic impedance—normally a series network of a 50 Ω, 1 W resistor and a 10 nF, 250 V capacitor.

Mains transformers must be provided with rc-networks at the primary and secondary side. Bridge rectifiers must be filtered by rc-networks. The peak charging current into the reservoir capacitor must be limited by the internal resistance of the transformer or by additional series resistors. It is advisable to use a 250 V, 2 W varistor between the live and neutral mains lines. At the secondary side, it is sometimes necessary to use a transient suppressor, preferably following the reservoir capacitor.

If the supply is used with digital systems, a common-mode inductor in the secondary a.c. lines may prove beneficial for limiting radiation. For audio applications, an earth screen between primary and secondary is advisable. This screen must be linked via a short wire with the earthing strip.

The supply must be able to cope with a mains failure lasting four periods and with mains supply variations of +10% and –20%.
Peripheral equipment and earthing
All cables to and from peripheral apparatus, such as measurement sensors, control relays, must be fed through the metal wall of the enclosure or frame. The earth lines of such cables must be connected directly to the earthing strip at the inside of the enclosure or frame via a wire not longer than 50 mm. When plugs are used, the cable earth, if any, must be connected to the earth pin or the metal surround of the connector.

Basically, all non-screened signal lines must be provided with a filter consisting of not less than a 30 mm ferrite bead around the cable or bunch of wires. This bead may be outside the enclosure (for instance, around the pc-to-monitor cable).

Leads that may have a resistance of 150 Ω must be provided with a 150 Ω series resistor at the inside of the connector shell. If technically feasible, there should also be a capacitor from this point to earth. Commercial feed-through t-filters or π-filters may, of course, be used. In all other cases, screened cable must be used for connections within the enclosure. Symmetrical lines must consist of twisted screened cable and be earthed at both ends.

The earth plane of printed-circuit boards must be linked as firmly as feasible with the earthing strip, for instance, via a flexible flat metal strip or flatcable.

Electrostatic discharge (esd)

All parts of an equipment that can be touched from outside must preferably be made from insulating, antistatic material. All parts that can be touched and enter the enclosure, such as potentiometer and switch spindles, must be earthed securely. All inputs and outputs whose wires or connector pins can be touched must be provided with an earth shield, for instance, an earthed metal surround via which any electrostatic discharge are diverted. This is most conveniently done by the use of connectors with sunken pins, such as found in sub-d connectors, and a metal case.

Audio equipment

Immunity to radiation is the most important requirement of audio equipment. It is advisable to use screened cables throughout. This is not always possible in case of loudspeaker cables and these must, therefore, be filtered. For this purpose, there are special high-current t-filters or π-filters that do not affect bass reproduction. Such a filter must be fitted in each loudspeaker lead and mounted in the wall of a metal screening box placed around the loudspeaker connections.

Low-frequency magnetic fields

Screened cables in the enclosure do not provide screening against the low-frequency (< a few kHz) radiation of the mains transformer. Therefore, these cables must run as close as possible to the walls of the enclosure. Moreover, their braid should be linked at one end to the earthing strip. In extreme cases, the power supply should be fitted in a self-contained steel enclosure. Special transformers with a shading ring that reduce the stray field can lower the hum even further.

High-frequency fields

High-frequency fields must not be allowed to penetrate the metal enclosure. All external audio cables must be screened and the screening must be terminated outside the enclosure. This again necessitates the use of all-metal connectors. All cable braids must be linked to the earthing strip inside the enclosure.

Owing to the skin effect, it is important to choose an enclosure with a wall thickness ≥ 2 mm to ensure that internal and external fields are kept separate. Any holes must be either small (<20 mm) or be covered with a metal mesh.

Heat sinks

Heat sinks should preferably be inside the enclosure and be earthed at several points. Non-earthed heat sinks in switch-mode power supplies often create problems. If possible, place an earth screen between transistor and heat sink. Ventilation holes must be covered with metal mesh unless they are smaller than 20 mm. Ventilators should be fitted inside the case.

Standard mains filters built into a mains entry together with an on/off switch. The metal shell must be in firm contact with the enclosure.

Cables

Cables often function as transmit/receive aerials. This applies equally well to screened cables. The braid of a coaxial cable must be terminated into a suitable connector such that it makes contact along the whole circumference. The braid may be used as the return path to obtain r.f. magnetic screening. For a.f. magnetic screening it is better to use twisted-pair screened cables. In a ribbon (flat) cable, each signal wire should be flanked, if at all possible, by earthed wires. The cable should be screened along one surface or, preferably, all around. Cables that carry signals ≥ 10 kHz that are not filtered in the enclosure, must be provided with a ferrite bead functioning as a common-mode inductance.

Printed-circuit boards

Elektor Electronics printed-circuit boards are provided with coppered fixing holes that are connected to the earth of the circuit. This arrangement, in conjunction with metal spacers, ensures good contact between the board and the circuit earth. Where this is important, boards have a special earth plane that can be connected, where feasible, to the earthing strip via a flatcable. These boards normally have no other earthing points and their fixing holes are, therefore, not coppered.

(960006)

T-filters and π-filters ensure that interference cannot em te from, or enter, the equipment via signal lines. They are available in various current ratings and for various frequency ranges.

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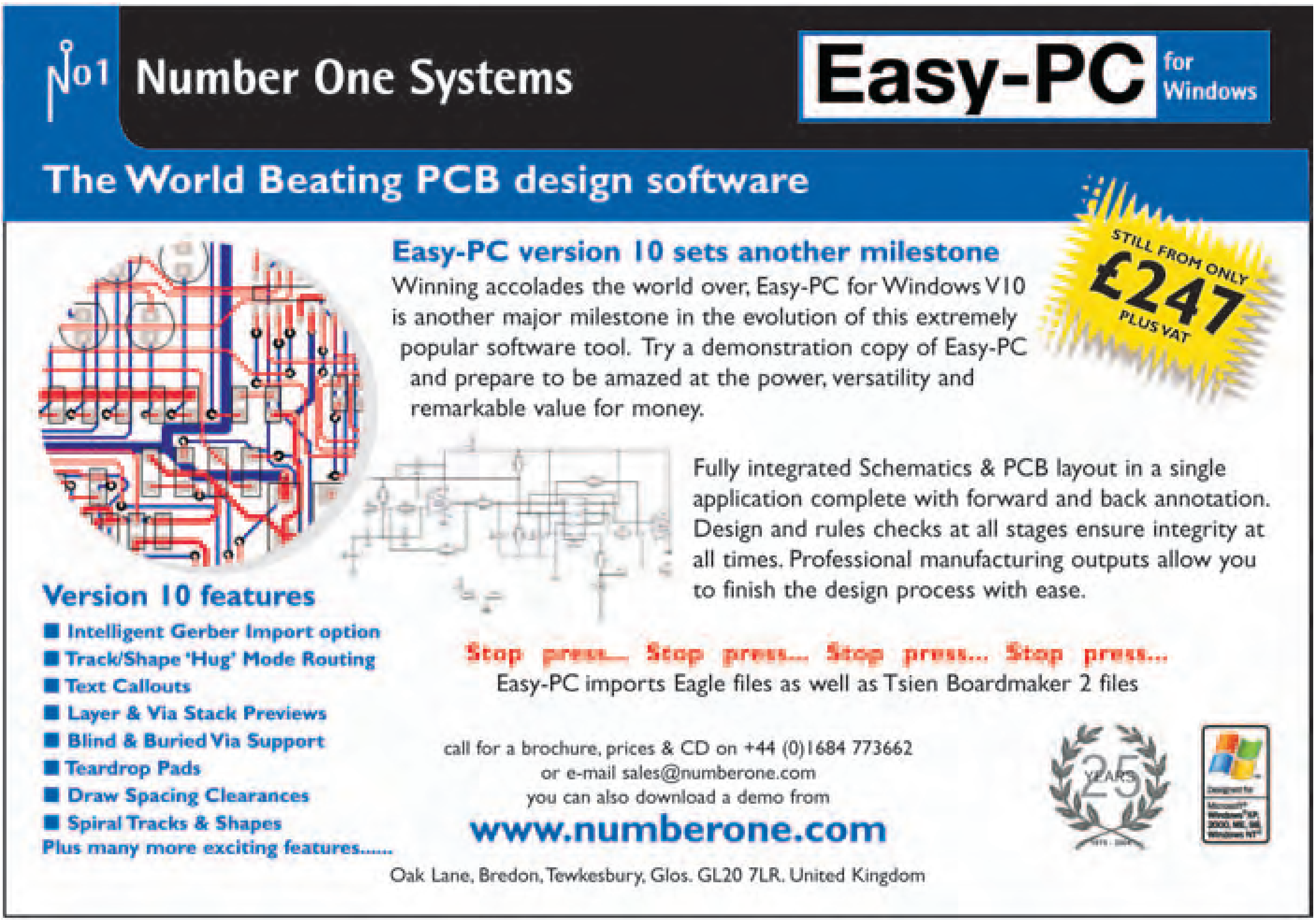

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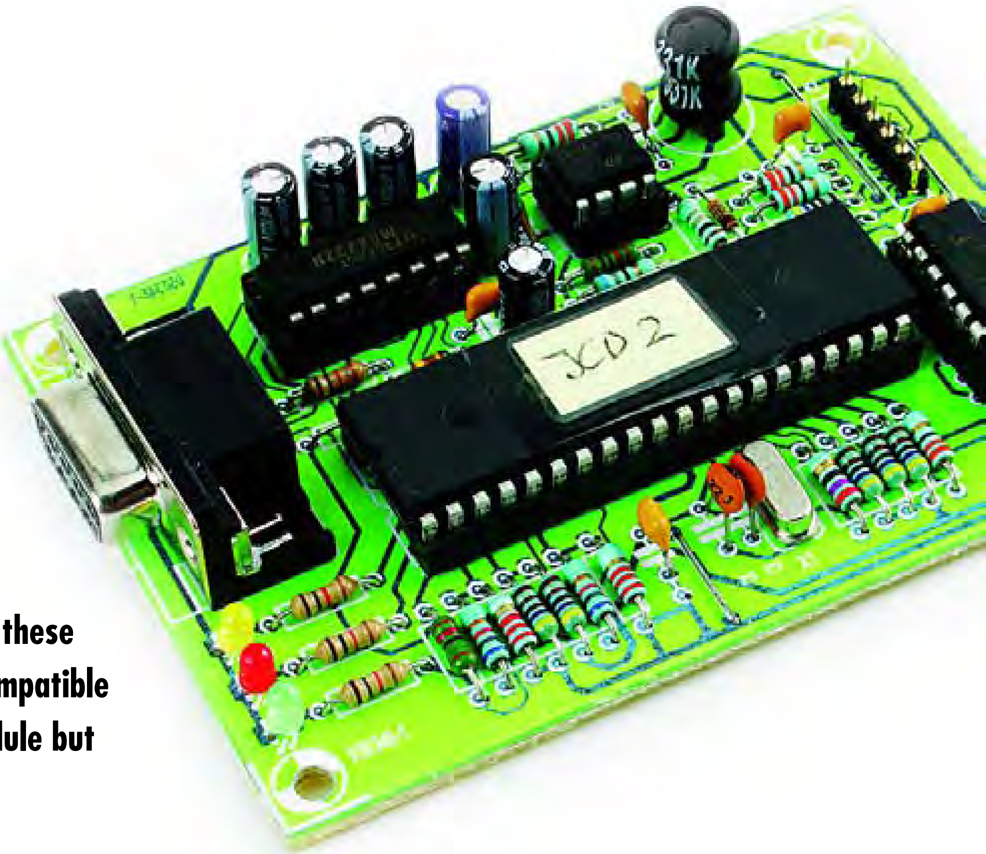

PIC microcontrollers of the 8-bit 16F and 18F family can be found in many devices. They are also a favourite of many *Elektor Electronics* readers. A must for users is a means of loading programs and an In-Circuit Debugger (ICD) for tracking down programming errors. This project addresses both of these needs and is not only substantially compatible with Microchip technology's ICD2 module but also significantly cheaper.

Designing interesting and useful applications with 16F and 18F 8-bit PICs is a straightforward task. The development environment, including the Assembler and Simulator are freely available from the manufacturer [1]. For programming in high-level languages a number of suppliers provide C Compilers.

Since most projects are fairly compact in practice, programming in Assembler is also perfectly feasible and by no means difficult either. The command set (35 commands for the PIC16 ranging to 75 commands for the PIC18) is easily mastered. For this reason it is hardly surprising that PIC controllers figure in foundation level courses at many higher education establishments [2].
Numerous circuit designs and freeware programs can be found on the Internet for porting programs into the Controller [3]. The simplest variants of these comprise a capacitor, a switch and three resistors, using a parallel port as communications channel. In many cases a so-called Bootloader is employed, enabling the target processor to write the program transferred over the serial interface into memory.

It's at this stage that it would be very handy to be able to 'look inside' the processor contained in this circuitry for any unwanted features in the program code. For example you might wish to examine and modify the register contents or else halt the program at a particular step in order to track down some error. Conveniently these functions are available in so-called In-Circuit Debuggers (ICDs) or In-Circuit Emulators (ICEs).

ICD, ICE, ICP

ICEs and ICDs are not the same thing of course. Unlike the In-Circuit Emulator, the In-Circuit Debugger uses processor-specific resources. A disadvantage of this approach is that Controller resources needed for debugging must be kept available for program development (see **Table**). The ICD's debugging functionality is also more restricted than an ICE can offer, for example in regard to the number of locations where a program under examination can be stopped automatically (the breakpoints). The system

16F877 Resources needed for debugging	
I/O-Pins	2
Stack	1 level
Program memory	NOP at address 0000h Final memory locations 100h
Data memory	70h,1EBh to1EFh

gger/Programmer

does have the advantage that the additional hardware required for debugging is generally no more than a communications module between the host processor and the development system, making it simple and cost-effective to achieve.

To enable the code alterations resulting from this program development to be transferred directly into the host hardware, an In-Circuit Debugger is generally combined with a programming module known as an In-Circuit Programmer (ICP). Enhancing the program development environment with a test and programming setup of the kind described in this article provides a single integrated user interface for program generation, transfer, translation and testing in the host hardware.

ICD2

Starting point for this exercise was Microchip's ICD2 module, the circuit of which is given in [4]. The aim was to reduce this design to its basic functionality so as to achieve a device that was reproducible and cost-effective but still widely compatible with the original. This was achieved by specifying:

- 5 V power for the module derived from the host device
- Dispensing with interface drivers between ICD module and host hardware
- Fixed programming voltage
- Confining the communications interface to RS-232 protocol

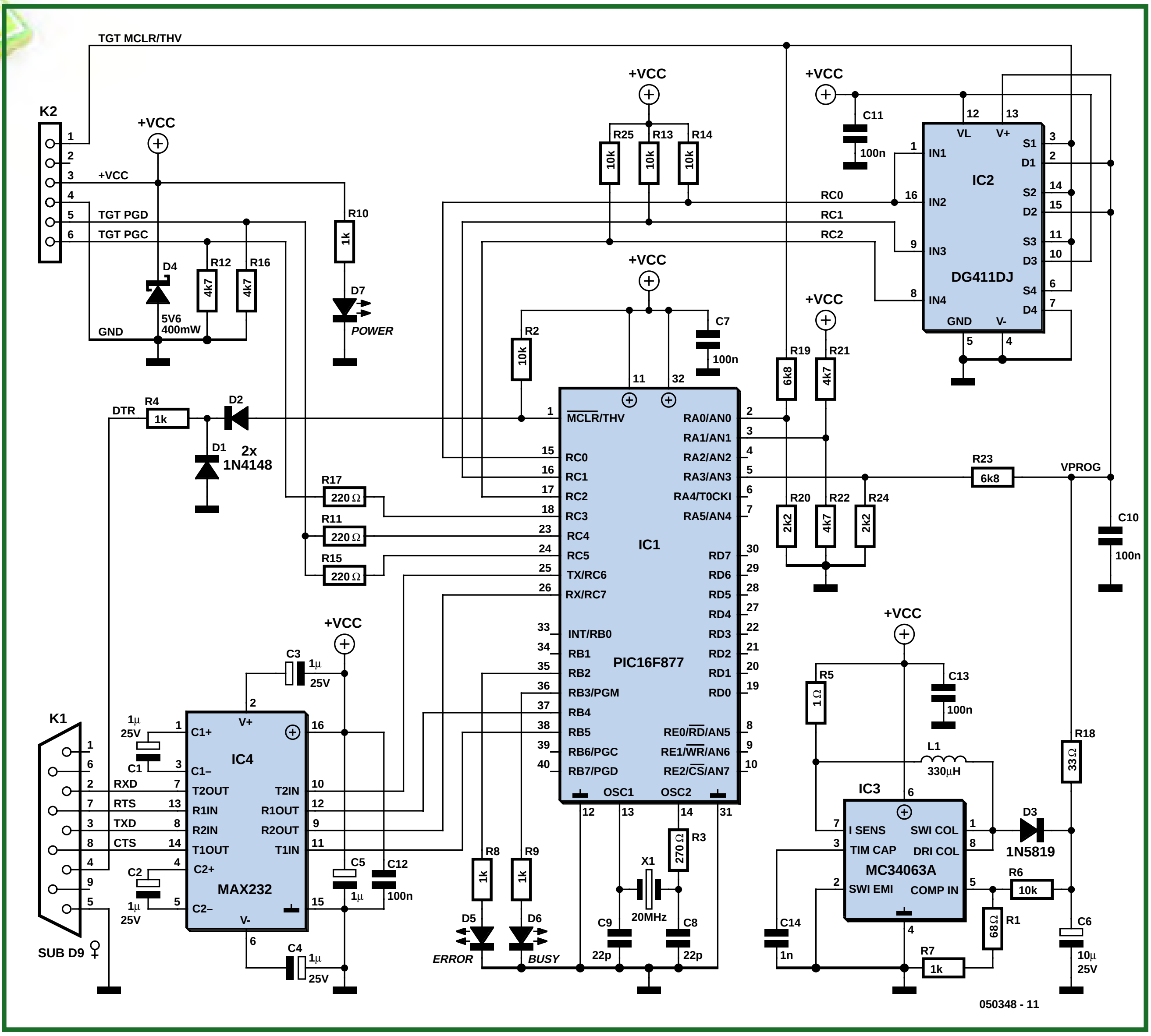

Figure 1. At the heart of the circuit is a 16F877 Controller, which communicates with the PC through its serial interface.

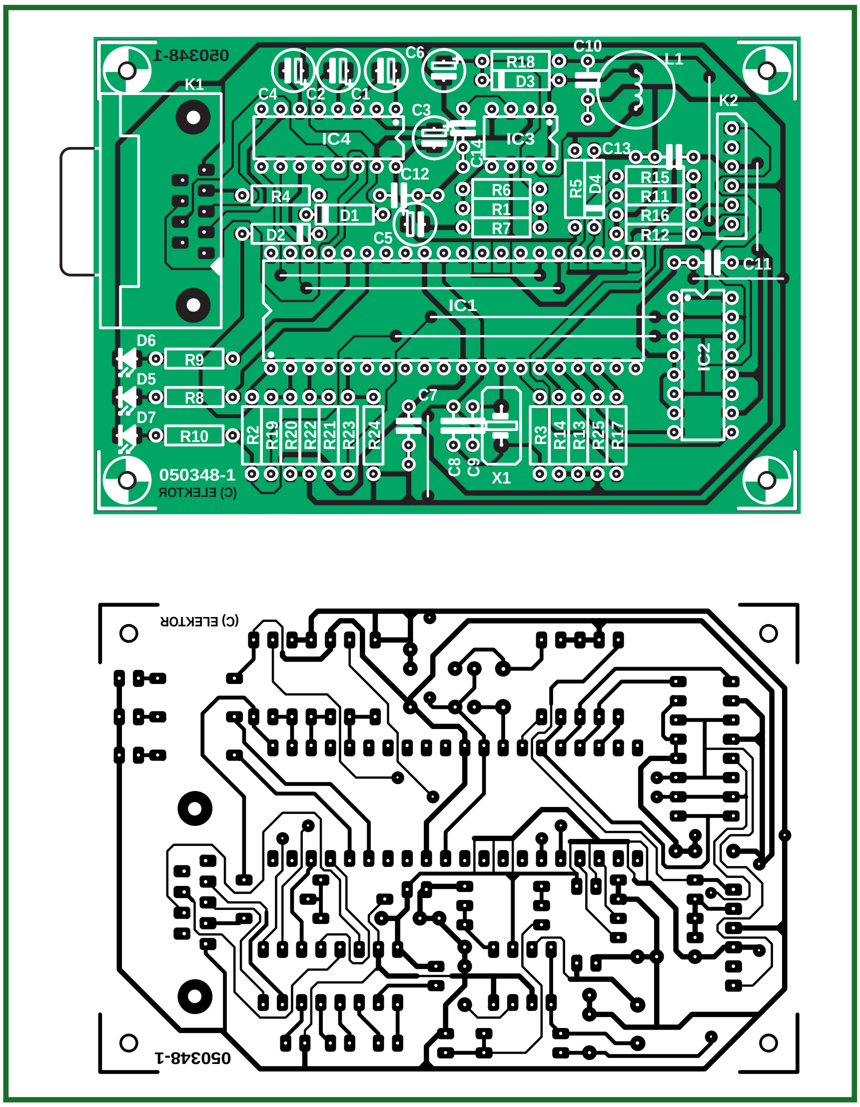

Figure 2. To make component placement easy the layout of the single-sided circuit board is not cramped.

COMPONENTS LIST

Resistors
R1 = 68Ω
R2,R6,R13, R14, R25 = 10kΩ
R3 = 270Ω
R4,R7,R8,R9.R10 = 1kΩ
R5 = 1Ω
R11,R15,R17 = 220Ω
R12,R16,R21,R22 = 4kΩ7
R18 = 33Ω
R19,R23 = 6kΩ8
R20,R24 = 2kΩ2

Capacitors
C1-C5 = 1µF 25V radial
C6 = 10µF 25V radial
C7,C10-C13 = 100nF
C8,C9 = 22pF
C14 = 1nF

Inductor
L1 = 330µH radial

Semiconductors
D1,D2 = 1N4148
D3 = 1N5819
D4 = zener diode 5V6 400mW
D5 = LED, low-current, 3mm, red
D6 = LED, low-current, 3mm, yellow
D7 = LED, low-current, 3mm, green
IC1 = PIC16F877, programmed, order code **050348-41**
IC2 = DG411DJZ (Digikey # DG411DJZ-ND)
IC3 = MC34063ECN (Digikey # 497-4280-5-ND)
IC4 = MAX232

Miscellaneous
K1 = 9-way sub-D socket, angled, PCB mount
K2 = 6-way SIL pinheader
X1 = 20MHz quartz crystal
PCB, order code **050348-1**
Kit of parts including PCB and microcontroller, order code **050348-71**

The majority of PIC Controller circuits operate from 5 V power supplies and the ICD module draws just 30 mA, so the first two specifications laid down should pose no problems in many applications. Dispensing with the firmware-determined programming voltage is not an issue either, as current PIC Controllers use 13 V for this.
Replicating the USB interface of the original device is less easy, as the IC employed is hard to obtain. Proprietary USB drivers can lead to problems from time to time as well. On the other hand there are no difficulties using an RS-232 interface; the only issue is making sure that the FIFO buffers of the COM port used are disabled. This can be set up using the Device Manager in Windows.
Users who have only a “legacy-free” computer without serial interfaces will require a USB to RS-232 adapter, specifically one with supplied drivers that allow it to operate without using FIFO buffers. If the FIFO buffers cannot be switched off, permanent communication errors arise during debugging, making it impossible to use this circuit.

Circuit

At the heart of the circuit in **Figure 1** is a 16F877 Controller (IC1), which communicates with the PC using a standard RS-232 interface driver MAX232 (IC4). Flow control is achieved using a hardware handshake, although the PC can also reset PIC Controller IC1 using the DTR signal.
The programming voltage of nominally 13 V is produced by the switch regulator module MC34063A (IC3), which is configured as a step-up converter. The value of the programming voltage is set by voltage divider R6, R7 and R1 as follows:

$$V_{PROG} = 1.25\ [1 + R6 / (R1+R7)]$$

Precise adjustment of the 13 V voltage is made possible by adjusting the value of R1.
Chip IC2 is a quad analogue CMOS switch. This has the task, in conjunction with the signals RC0, RC1 and RC2, of applying either the programming voltage, the operating voltage or else ground to the Reset pin of the host processor.
Communication between the Debugger and the host processor is achieved across the lines TGT PGD (data) and TGT PGC (timing). The values of the

pull-down resistors R12 and R16 are copied from the original ICD module. The series resistors R11, R15 and R17 limit the output current of the host hardware under short circuit conditions to a value that is not going to cause trouble for IC1. D4 protects the circuit against excessive supply voltage or reverse polarity. In view of the intentionally restricted functionality of this unit some care is necessary, as D4 may not be able to compete with an laboratory power adjusted to 30 V and 5 A.

Analogue inputs RA0, RA1 and RA3 measure the level of the programming voltage and the supply voltage at the Reset pin of the host hardware. The test values are monitored in the development environment and are displayed in the "Debugger/Settings/Power" window. For absolute precision the voltage divider can be built using 1% (close tolerance) resistors.

The LEDs D5 to D7 indicate the presence of the operating voltage, an operation in process in IC1 or a fault condition. As in the Microchip ICD2, the Power LED (D7) is green, the Busy LED (D6) yellow and the Error LED (D5) red.

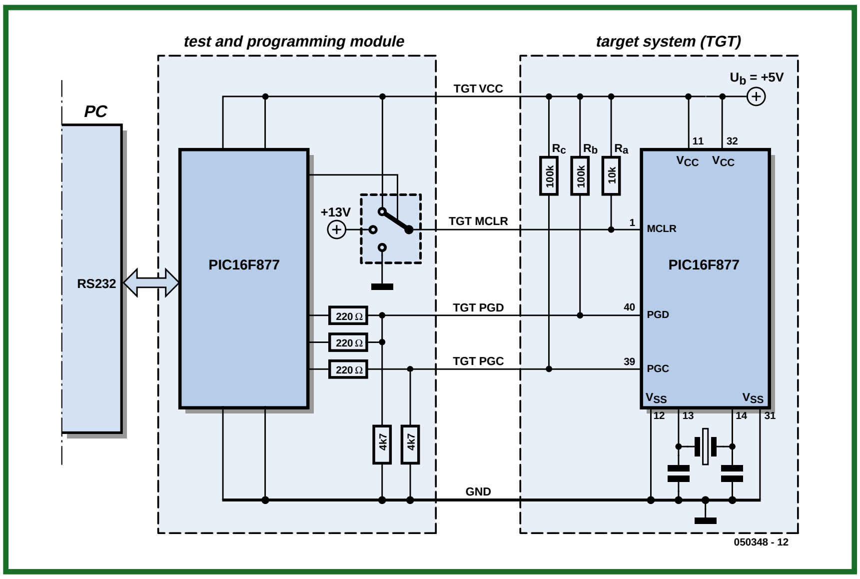

Figure 3. Five wires provide the connection from the ICD/ICP module to the target system.

Printed circuitboard and Bootloader

Since the single-sided PCB (**Figure 2**) is populated using conventional-size components with normal wire leads and is not cramped, construction is possible inside an hour, even for those less skilled at soldering. After fitting the components and making connection to the host hardware as shown in **Figure 3** the programming voltage on pin 2 of IC2 should measure in the region of 12.75 to 13.25 V. Precise adjustment of the programming voltage can be made by altering R1 if necessary. In most cases this should not be required, since many PICs can tolerate levels between 12 V and 14 V.

If not already obtained, the current version of the development environment MPLAB IDE (version 7.40 at time of writing) should be downloaded from the Microchip homepage [1] and installed. Reply 'no' to the question about installing custom USB drivers, as the circuit presented in this article uses the serial interface.

To enable the development environment to load the PIC Controller IC1 with firmware appropriate to the particular host processor being used, IC1 must be programmed with a Bootloader. This has been taken care of already in the pre-programmed microcontroller (order code **050348-41**) shown in the component list.

It is also possible to program the Bootloader into a PIC16F877 oneself. The Bootloader program BL010101.hex is part of the development environment MPLAB and can be found in the file '\Programme\Microchip\MPLAB IDE\ICD2'. People with no access to a programming device will find in [3] a simple circuit for the parallel port; this can be made up on vero board or hand-wired.

The MPLAB Bootloader is written for the 16F877. The more recent 16F877A employs a modified programming algorithm and therefore requires a modified Bootloader, available on the Internet at [5] (scroll down the page until you see the word Bootloader) and elsewhere. Using the 16F877A runs a risk, however, that the Debugger will stop working if Microchip replaces the Bootloader in the MPLAB development environment with a new version in a future firmware update.

Ready

With the circuit and programmed IC1 chip connected to the PC, the development environment can be started up. First off the 'Debugger/Select Tool/MPLAB ICD2' of Debugger type ICD2 is selected. In the menu 'Debugger/Settings/Communication' that follows the next task is to nominate the serial interface to which the device is connected. In the same menu the Baud rate is set to 57600. A warning 'ICD-Warn0034: Please ensure that your system's serial FIFO buffers are disabled' appears when the FIFO buffers have been deactivated correctly — this can be ignored.

With the command 'Debugger/Connect' the development environment opens communication with the Debugger, carries out a self-test and displays the result in the 'Output/MPLAB ICD 2' window. Curiously the message 'MPLAB ICD 2 Ready' appears even if the Debugger is not connected.

If no firmware corresponding to the host processor is present in IC1, the development environment will suggest downloading this. If the option 'Automatically download firmware if needed' has been selected in the 'Debugger/Settings/Status' menu, this download takes place automatically. During the download time of about a minute the Busy-LED D6 is lit.

After a renewed 'Connect' the development environment displays the result seen in **Figure 4** with 'MPLAB ICD 2 Ready' on the last line. The device is now ready for use and can now be used either as a Debugger (menu choice 'Debugger/Select Tool/MPLAB ICD2' or as a programming device (menu option 'Programmer/Select Programmer/MPLAB ICD 2').

Practical tips

The sample interface between host hardware and Debugging Module shown in **Figure 3** using a host processor of type 16F877 can be applied to all PIC computers that support the ICD2

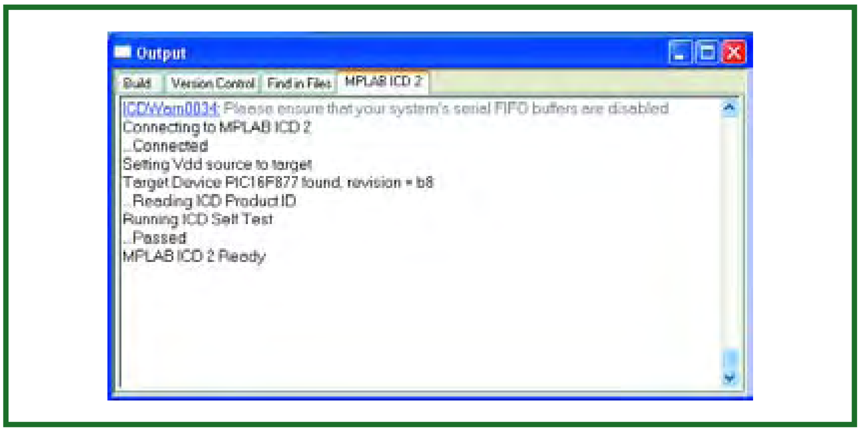

Figure 4. This message indicates the Debugger/Programmer is ready for action.

Debugger and use 5 V power rails. In Debug mode the host processor requires timing signals but these are not necessary in programming device mode.

The 'View/File Registers' option should be used only exceptionally during debugging, since otherwise the entire RAM contents are transferred across the serial interface every time the program is halted. In single step operation this leads to long waiting times between individual commands.

Programs loaded into the host processor in Debug mode cannot be run without the Debug module connected. Once bug search operations are complete the program should be transferred into the host processor in programming mode.

Lastly we must point out that Microchip understandably does not offer any support for people who make their own copies of their circuitry. Instead you can consult the *Elektor Electronics* project page for this article, the Forum or the author's own Homepage [7, in German only].

(050348-I)

References

[1] www.microchip.com

[2] www.elektronik.htw-aalen.de/sge/labor/ICD2/ICD2-Clone.html

[4] www.mcu.cz

[3] www.sprut.de

[5] http://icd2clone.narod.ru/

[6] www.elektor.com

[7]: www.elektronik.htw-aalen.de/sge/schuele

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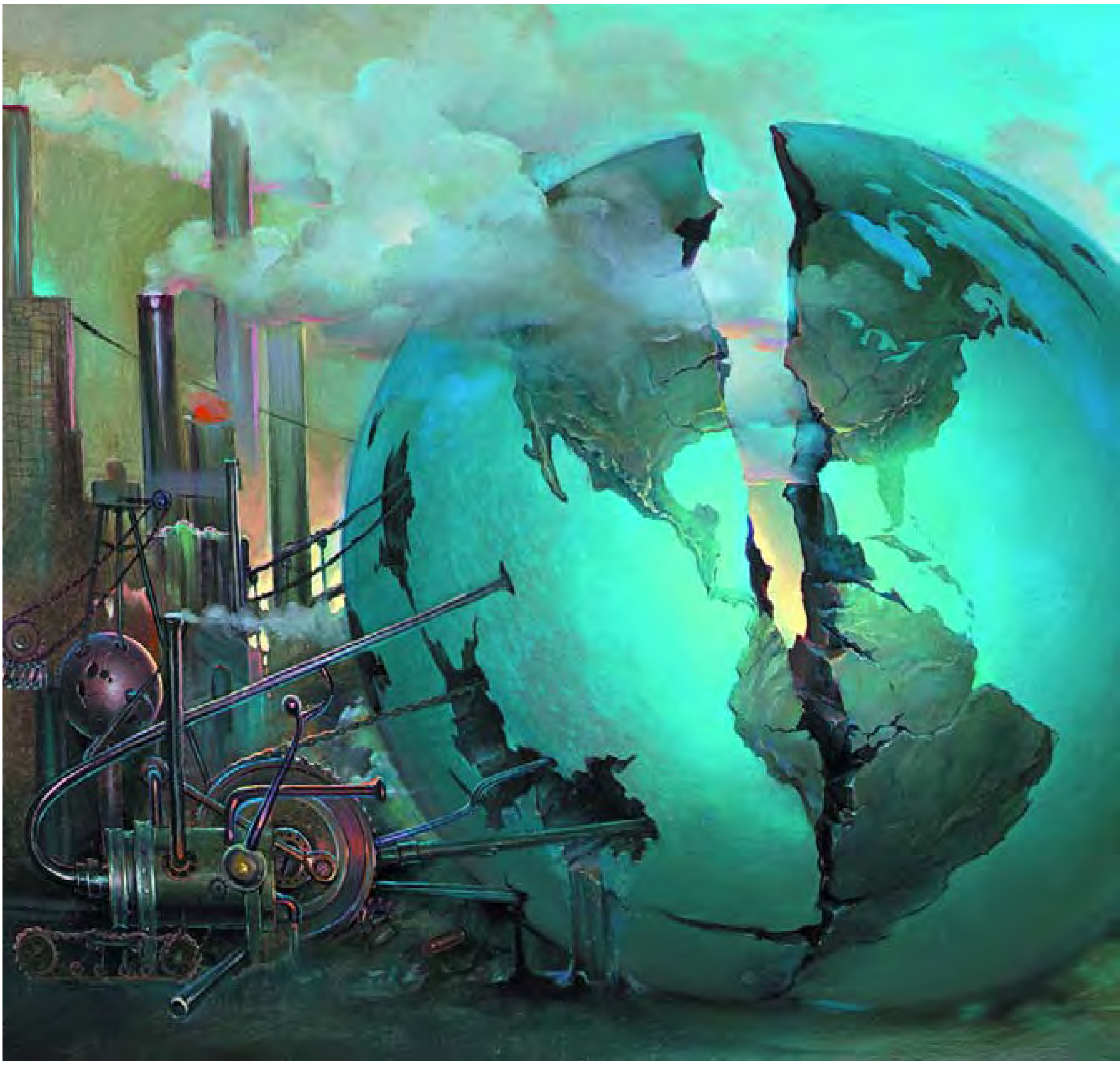
Star-point Grou



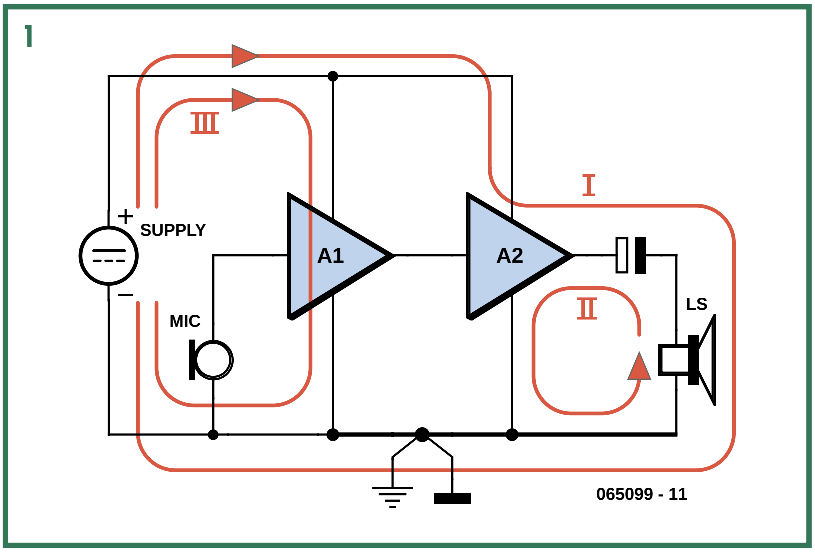
Karel Walraven

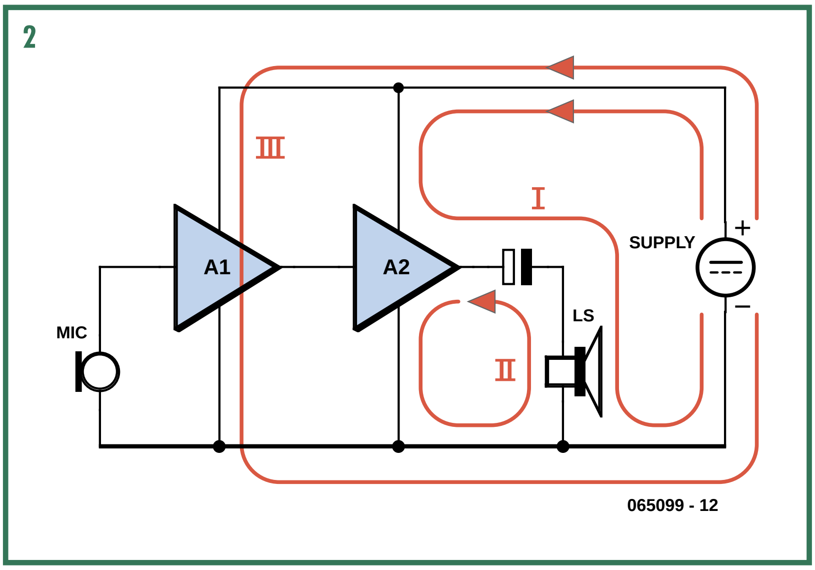
It is assumed that every electronics engineer knows what is meant by ground, earth and safety earth. Nevertheless, these terms still belong to the great mysteries in the land of electronics. Here is an attempt to lift the veil a little...

unds

Forcing current in the right direction


'Split World' illustration reproduced courtesy of John Pitre (www.johnpitre.com)





It will not have escaped you that the human race, normally speaking, stands firmly with both feet on the ground. Even those who tend to be on an esoteric plane speak constantly about 'earthing'. The worst thing that could happen to you is that you're not earthed, because then the brakes are gone and you're unprotected and subject to the whims of the surrounding elements.

Fortunately it is not quite that bad in practice. You tend to survive a visit to the Eiffel Tower and even flying high above the earth to distant places appears to lead to very few problems. We can conclude from this that it is not that important where you are, as long as your environment is stable. The same is true in the world of electronics when we're talking about the term ground. With the term ground we usually mean some more or less arbitrary point in a circuit. To keep this a little workable, we usually take this point as the negative supply voltage or a point halfway between the positive and negative supply voltage. In our thinking we assume for simplicity that this

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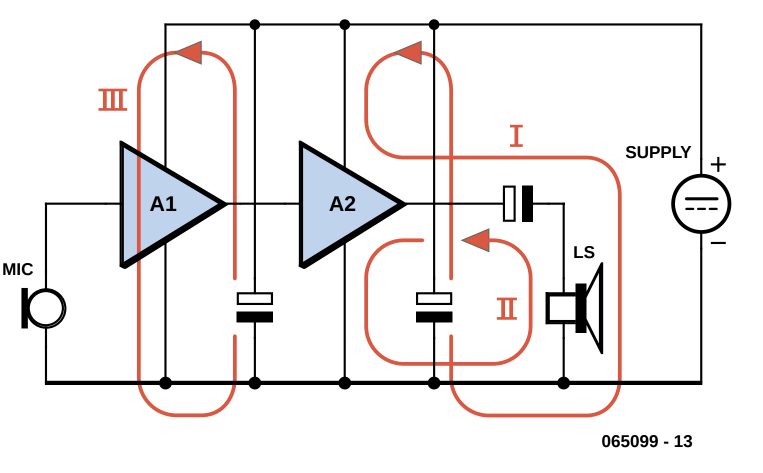

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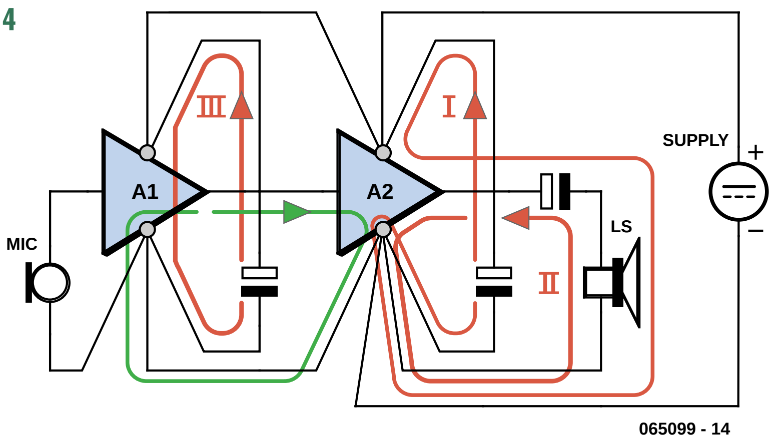

ground point provides us with certainty, is stable and is the same everywhere. If only it were true…
In **Figure 1** is drawn a very simple example that can help us to understand the phenomena that occur. There is a signal source (micr), a pre-amplifier A1, a power amplifier A2 with a loudspeaker and finally a power supply. A ground symbol is drawn is well, the short, thick, horizontal bar. Advertently or inadvertently we assume that, *solely by drawing this symbol*, all the parts connected to it are suddenly and in a mysterious way at the same potential, irrespective of changes in the surrounding universe. The reality is different. In the first instance it is not meaningful to talk about potentials, there are only continuously changing voltages and currents. They are dynamic events. So even in the ground conductor there are differences and the only thing we can do is to make these differences as small as possible by cleverly designing both the circuit itself and the printed circuit board. It gets even worse when we add another symbol: earth. Now the circuit has got to be stable! We have now, after all, connected it to everything around us! That's done by using a conducting rod that we stick in the 'earth'. Too bad, but this doesn't help us much either. Flowers do quite well in this earth, but our electronics is really not going to be more stable because of this.
We have to be convinced that placing the ground symbol doesn't really change anything and that it is there only to clarify and make it easier to think about the circuit. Noise sources can (read: will) develop across signal conductors; the ground conductor is made from exactly the same copper trace and the same noise will also occur in it. Let go of the idea that a circuit needs an 'earth' or a 'ground'. There are many battery powered devices that are completely 'floating' and nevertheless work quite well.
We are now complete free from 'earth', we float. All interconnections in **Figure 1** are cursed with a little resistance, a certain amount of self-inductance and also have some mutual capacitance. To put it briefly, they are not ideal connections, but connections as they are in the real world.
The variable current (music) that runs through the loudspeaker will generate variable voltages across the connections through which this current also flows. So the power supply voltage to A1 and A2 is influenced and because the current also runs through ground, the ground at the minus terminal of the power supply will not be equal to the ground at the loudspeaker terminal. The resulting problems are obvious at the microphone input. Current flows through the ground connection, which results in voltage changes and these are added to the microphone signal and amplified.

It is the *current* that causes the problem.

Make a copy of the schematic and draw the significant currents on it. We will now draw the schematic again, but now we will try to isolate the currents as much as is possible. Just by moving the position of the connections to the power supply we already make a significant improvement, the microphone is now no longer influenced by the loudspeaker current (**Figure 2**). You can now also appreciate why the decoupling capacitor is important. This causes the variable currents to remain local and do not wander all over the circuit (**Figure 3**).
We ultimately end up with a schematic in which the power supplies have star-shaped connections, because with this topology the mutual influence is minimised (**Figure 4**). For example, there is no longer an interfering power supply current in the signal path between the two opamps (drawn in green). Once you've gone through this exercise, you're actually done. The layout of the PCB is easy based on the re-drawn schematic. Moreover, make all loops in the layout as small as is possible (**Figure 5**).

As we have already made clear in the 'PCB design basics' in the February 2005 issue, every PCB is a com-

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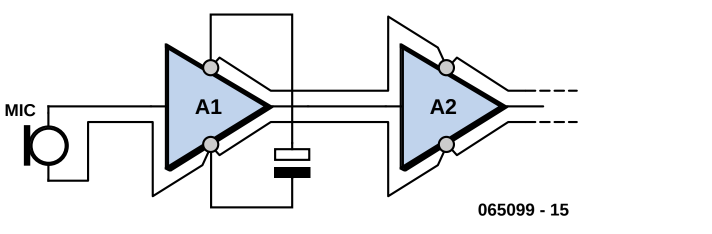
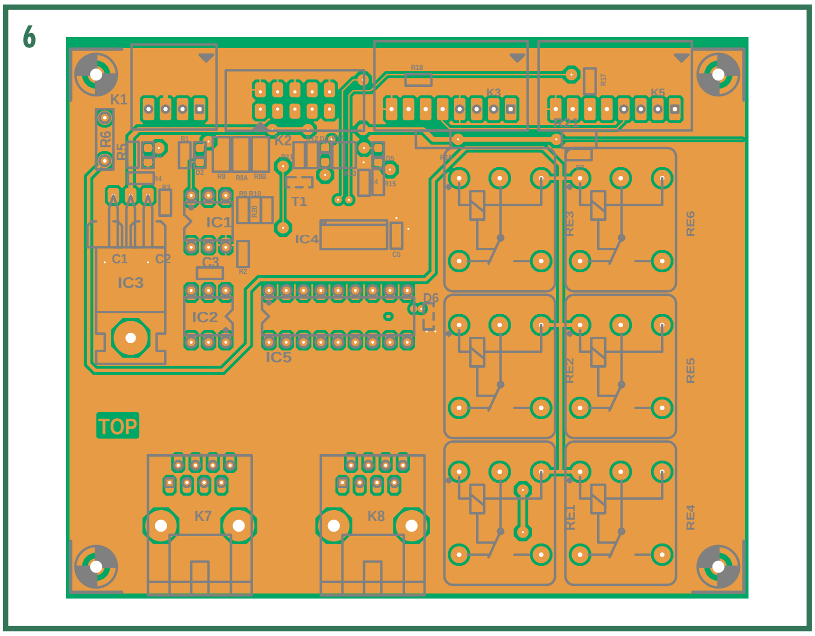


promise. When you have to choose, for example, whether to favour a signal conductor or another conductor then it is obvious that the trace that carries the signal has priority. Maybe this is labouring the point a bit: the return path is also a signal path, always look for signal current loops. In our example the signal return path is 'coincidentally' ground. Many designers deliberately design it this way because it is easy to think about and straightforward to make measurements. It is always a good idea for a double-sided PCB to make one side completely ground. But even then you cannot let go of the idea of a star-point ground and if necessary use separated ground planes (**Figure 6**). However, don't exaggerate these things, separated ground planes can also act as antennas and the cure is then worse than the illness.

Safety earth and screening

With Class I devices, the circuit is connected to safety earth. This ensures that no dangerously high voltages can appear on parts of the circuit that can be touched. Always be very careful with this, because sizeable currents can flow. This also applies to the screens of cables. Design your PCB in such a way that these types of current that you rather not have around, do not wander all over the PCB. Therefore: a separated earth plane for connections to safety earth and screens and another ground plane for the circuit. Obviously these two planes have to be electrically connected, but do this at only one point so that there is no loop for current to flow. Figure 6 shows an example. All the connectors are together on an earth plane, the star-point is at the regulator IC and from there one plane for the µP and one plane for the power stage (the relay).

6



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Base-Emitter V V_{BE}=0.71V
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Leakage current I_C=0.00mA

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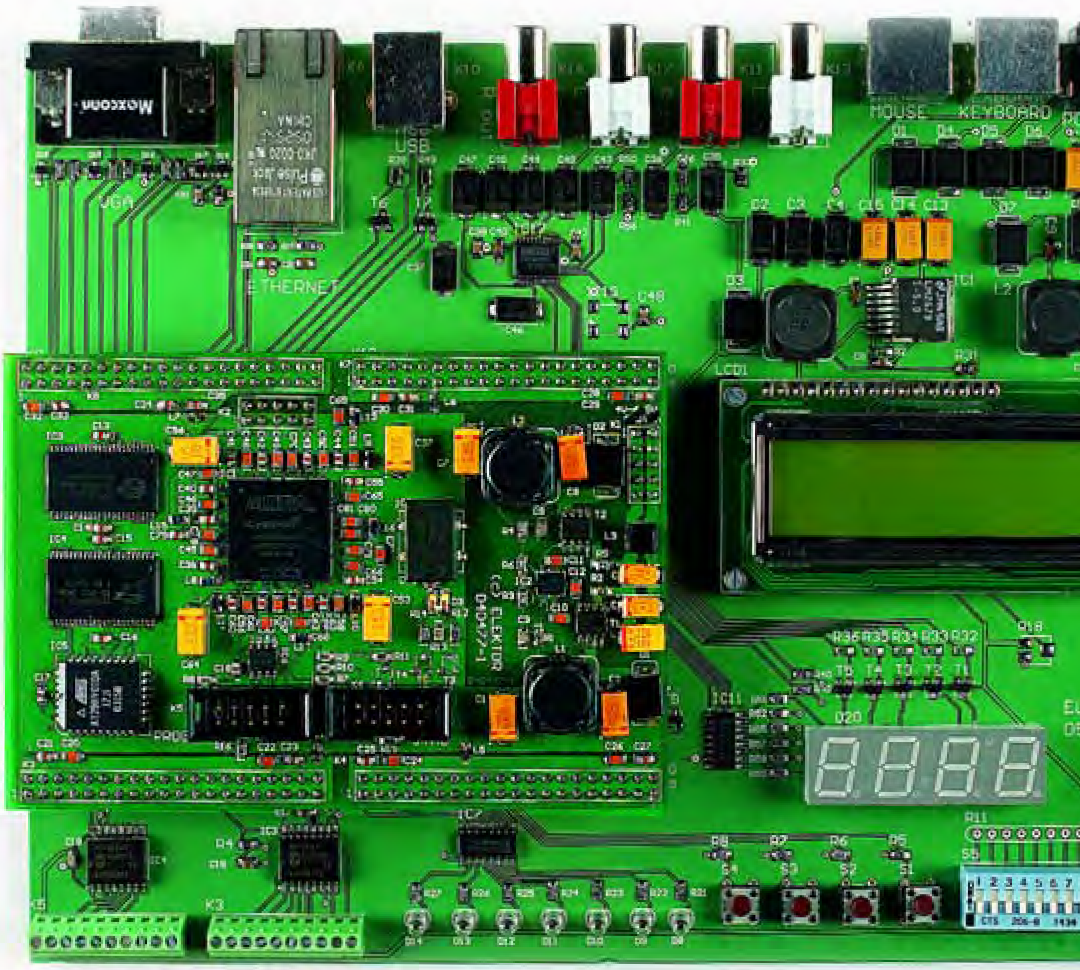
FPGA Course (5)

Paul Goossens

Every embedded system uses a system bus to transport data between the various components. This also applies to systems implemented in an FPGA. However, a different sort of bus system is commonly used in FPGAs. This month's article introduces a bus system that is often used in FPGAs.



A typical bus system in a 'normal' microprocessor circuit consists of a data bus, an address bus and several control signals, such as RD/$\overline{WR}$. The peripheral ICs put their data on the bus when requested to do so. During the rest of the time, their inputs are in a high-impedance state to give other ICs a chance to put data on the bus. These data ports are tristate ports, which means they can be set to a high-impedance state.

Different

In many FPGAs, it is not possible to put internal signals in a high-impedance state. In addition, a mistake in the design can cause short-circuits or data corruption on the bus. Tristate ports are thus not used for the system bus in such systems. Another factor is that the peripheral electronics often runs at a different clock speed than the processor. This makes handshaking necessary to ensure correct data transport.

Several standard system busses have been developed to avoid problems of this sort in FPGA designs. This instalment focuses on a system bus called the 'Wishbone bus', which is used quite often. It is used a lot at *www.opencores.com*, a handy site where you can download free designs and subdesigns.

Minimum system

A minimum Wishbone bus with a single master and a single slave is shown in **Figure 1.** The dual data bus is clearly visible. Each bus is unidirectional – one bus carries data from the master to the slave, while the other bus carries data in the opposite direction.

The STB (strobe), CYC (cycle) and ACK (acknowledge) signals provide handshaking for each data transmission. The slave can only respond to the Wishbone signals if the STB_I and CYC_I signals are both high. The master sets WE (write enable) high to indicate that it wants to write data to the slave. If this signal is low, it means that the master wants to read data from the slave.

When the slave has finished processing the data, it signals this by setting the ACK signal high. The master pulls the STB signal low in response. The slave must then return its ACK output to the low state.

This handshake protocol makes it possible to connect a slow slave device to

Part 5: bus systems and interconnections

a much faster master, since the slave can set its ACK signal high sometime later. This gives a relatively slow slave enough time to process the data. **Figure 2** shows a read operation of this sort, in which the slave needs two extra clock cycles to complete the transaction.

Example

We have prepared a simple example in *ex13*. Here the 8051 microcontroller has a master interface for the Wishbone bus. The bus is connected to a simple slave device that enables the master to drive eight outputs. The slave interface causes the ACK signal to appear with a delay of 10 clock pulses. This makes it possible to display the handshake process using the logic analyser built into Quartus.

The processor used here (T8052) uses the Wishbone bus for all transactions with XRAM memory in the region starting at address 0x1000. The only extension unit on this Wishbone bus is an 8-bit output named *wish_output*. This extension also has an internal address decoder. This is normally placed in a separate bit of hardware, but for this simple example we placed it in the core instead.
Seven of the eight outputs are connected to the LEDs on the extension board. The software causes the LEDs to light up sequentially for a 'running-light' effect.

Internal

Processing the Wishbone signals is fairly simple. The *sel* signal detects whether the address on the system bus matches the address of the extension (0x8000).
The code starting on line 63 causes the outputs to go high after a reset. When a valid address appears (*sel* = '1') while a valid write cycle is in progress (STB = '1', CYC = '1' and WE = '1'), the data present at the DAT_I input is stored in the output register by the rising edge of the clock signal.
Generating the ACK signal is somewhat more complicated in this case because it has to be delayed. The COUNT signal keeps track of how many clock pulses have occurred since the last write operation to this core. When the value of this counter reaches 10, ACK_OK goes high. This signal indicates that an ACK signal can be generated now.
The ACK output signal is finally defined in line 101. This core also generates an ACK if an invalid address is placed on the bus (*sel* = '0'). This is designed to prevent the processor from hanging if the software accidentally uses an incorrect address.
Note that the ACK signal is an asynchronous signal. In other words, it is not generated using a flip-flop. This is one of the requirements of the Wish-

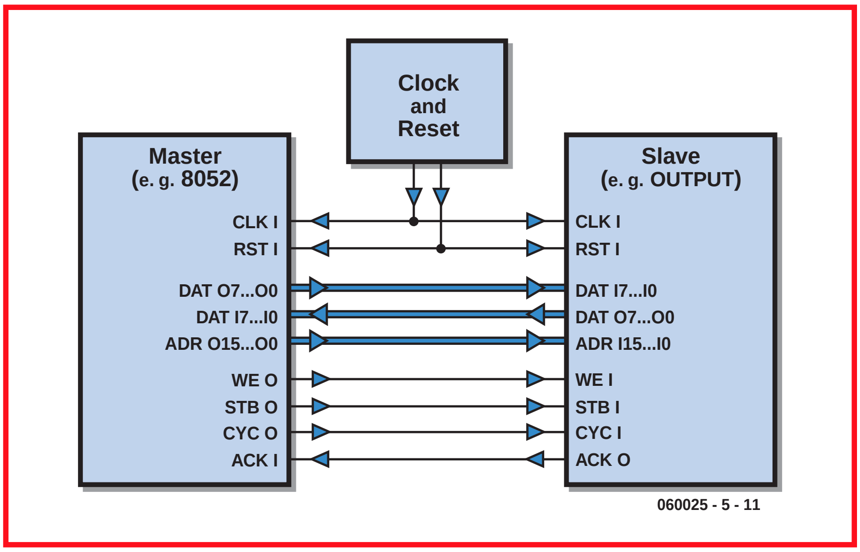


Figure 1. A minimum Wishbone bus with a single master and a single slave.

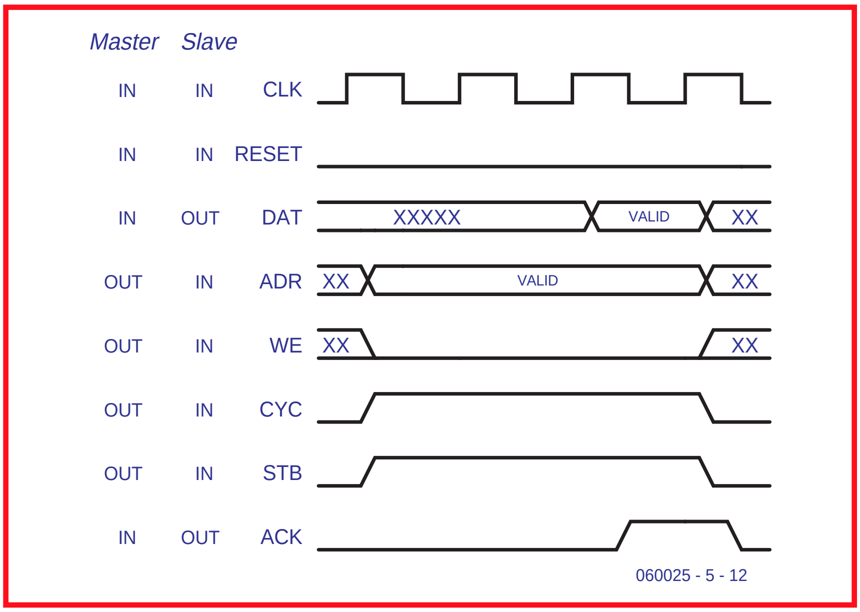


Figure 2. Here you can see that slave needs two extra clock cycles to complete the transaction.

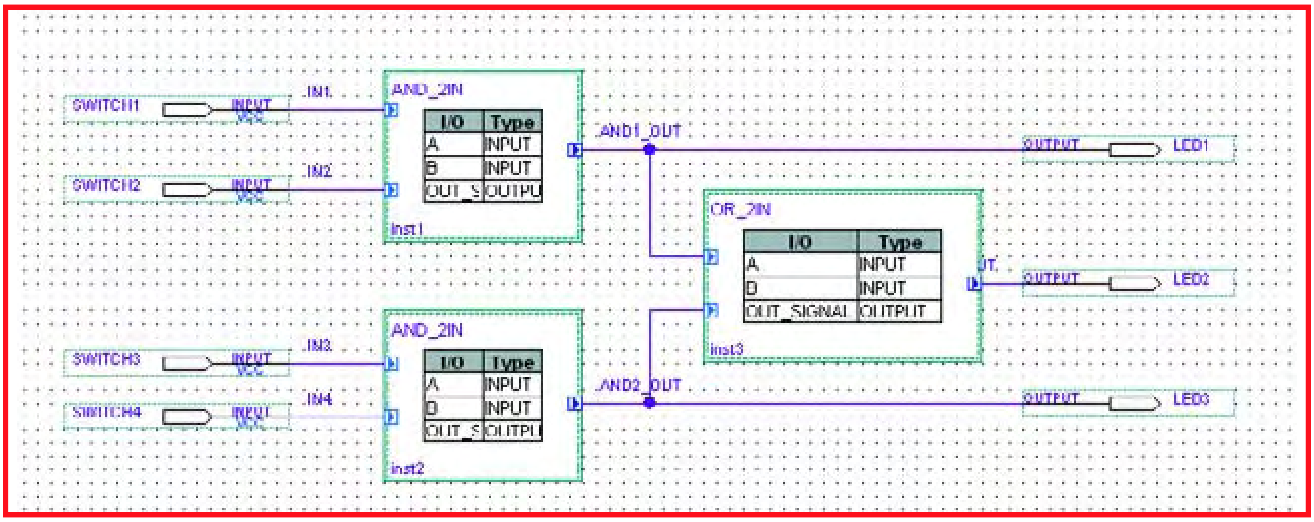


Figure 3. A simple design consisting of two VHDL files and a graphic file.

bone specification. ACK must go low in response to setting STB or CYC low.

Experiment

In the software, we send the same value to the output 20,000 times. This slows the running light down to the point that you can observe the effect visually.
ACK is delayed by 10 clock cycles in *wish_output*. If you increase this delay, the running light will also slow down. You can easily make this experiment yourself. Simply change line 87 of *wish_output.vhdl* to the following line:

IF (COUNT=200) THEN

Recompile the project and load it into the FPGA. Now the running light will run quite a bit slower than before. This proves that a slow slave on the Wishbone bus causes the master to run slower. This slowdown only occurs during read and write operations with the slave. All other instructions in the microcontroller are executed at full speed.

Multiple slaves

In practice, microcontroller circuits usually have more slaves than just a single I/O slave. All these slaves must communicate with the microcontroller via the same bus. This makes it necessary to add another piece of hardware that uses the address to determine which slave is being addressed.
In *ex14* the microcontroller is connected to two slaves. They are nearly the same as the slave used in the previous example. The address input has been omitted because there is only one write register and one read register. The slave also has eight inputs.

The job of the address decoder (*wishbone_decoder*) is to pass the signals to one of the two slaves depending on the address. We use two signals for this purpose (S1_SEL and S2_SEL), which go high when the right address appears on the Wishbone bus. The corresponding code for S1_SEL is:

```
S1_SEL<='1' WHEN ADR_I=x"8000"
ELSE '0';
```

In this case address 0x8000 was selected for slave 1.
A master–slave transaction can only occur when the CYC and STB signals are both high. It's easy to generate these signals now for slave 1:

```
S1_STB_O <= STB_I AND S1_SEL;
S1_CYC_O <= CYC_I AND S1_SEL;
```

The above lines of code ensure that the STB and CYC signals for slave 1 do not go high unless the slave is addressed. Finally, the data bus from the master to the slave has to be modified. If slave 1 is addressed, data must be sent from slave 1 to the master, and of course the same applies to slave 2. This is provided by the following line of code:

```
DAT_O_MASTER <= S1_DAT_I WHEN
(S1_SEL='1') ELSE
S2_DAT_I WHEN (S2_SEL='1')
ELSE x"00";
```

The same considerations apply to the ACK signal. It is passed on to the master in a similar manner.

Versatile

The handshake protocol makes the Wishbone bus very versatile. Besides the features already described, the bus can be extended with other signals such as an error signal, it can be configured so several masters can drive a single bus, and so on. If you want to know more about this, you can download the bus specification from the Opencores website.
There are also several other SoC busses. Most of them also use a handshake protocol, which makes it easy to implement a bridge between different bus systems.

Hierarchic VHDL

Up to now we have used graphic representations in our course to interconnect various blocks. However, you can also describe a complete design in Quartus using only VHDL.
We have prepared two examples to show how this can be done in VHDL. The first example (*ex15*) is a simple circuit consisting of two VHDL files and a graphic file. The graphic file is the 'top-level entity', which means it is the highest level in the hierarchy. The purpose of this file is to couple the subdesigns to each other and link the signals to the outside world (in other words, the FPGA pins). This is the method we have used up to now in all the examples. **Figure 3** shows this in schematic form.

The second example (*ex16*) contains the same design, but here the top-level document has been replaced by a VHDL file. The first statement in the *ex16.vhdl* file (see inset) is a standard ENTITY declaration. The inputs and outputs of this entity are ultimately connected to the pins of the FPGA, since this is our top-level document.
The input and output signals of the AND_2IN subdesign are described in lines 13-19. The signal names in this description must be the same as the names used in the AND_2IN.VHDL file. The same information must be provided for the OR_2IN subdesign.
Next we declare the signals used in this design. The signal names are the same as the names already used in example 15. In that example, these signals were drawn and labelled. In VHDL, this corresponds to signals of type STD_LOGIC.
A component with the name *inst1* is instanced in line 38. This reference is comparable to the designation 'IC1' or the like in a normal schematic diagram. The type of component to be placed here is described after the colon (:). In this case it is the component AND_2IN.
Finally, the inputs and outputs of this component are connected to signals starting with line 41.
If you compare the two examples, the principle involved will quickly become apparent.

Compatible

The advantage of describing a design entirely in VHDL is that the resulting source code is compatible with other CAD programs. Such a design can thus be used with the software of a different FPGA manufacturer without too much trouble. It's even possible to produce a real ASIC using exactly the same source code.

Another advantage is that it is often faster to modify a VHDL file than to make the corresponding changes in a graphic design, especially if there are a lot of signals between the various subdesigns.

(060025-5)

Web links

Opencores homepage:
www.opencores.org

Wishbone specification:
www.opencores.org/projects.cgi/web/wishbone/wbspec_b3.pdf

Listing ex16.vhdl

```
LIBRARY ieee;
USE ieee.std_logic_1164.all;

ENTITY ex16 IS
PORT
  (
    SWITCH1, SWITCH2, SWITCH3, SWITCH4 : IN STD_LOGIC;
    LED1, LED2, LED3 : OUT STD_LOGIC
  );
END ex16;

ARCHITECTURE arch OF ex16 IS
  COMPONENT AND_2IN
  PORT
    (
      A,B : IN STD_LOGIC;
      OUT_SIGNAL : OUT STD_LOGIC
    );
  END COMPONENT;

  COMPONENT OR_2IN
  PORT
    (
      A,B : IN STD_LOGIC;
      OUT_SIGNAL : OUT STD_LOGIC
    );
  END COMPONENT;

  SIGNAL IN1,IN2,IN3,IN4 : STD_LOGIC;
  SIGNAL AND1_OUT,AND2_OUT, OR_OUT : STD_LOGIC;

BEGIN
  IN1 <= SWITCH1;
  IN2 <= SWITCH2;
  IN3 <= SWITCH3;
  IN4 <= SWITCH4;

  inst1 : AND_2IN
  PORT MAP
  (
    A => IN1,
    B => IN2,
    OUT_SIGNAL => AND1_OUT
  );

  inst2 : AND_2IN
  PORT MAP
  (
    A => IN3,
    B => IN4,
    OUT_SIGNAL => AND2_OUT
  );

  inst3 : OR_2IN
  PORT MAP
  (
    A => AND1_OUT,
    B => AND2_OUT,
    OUT_SIGNAL => OR_OUT
  );

  LED1 <= AND1_OUT;
  LED2 <= OR_OUT;
  LED3 <= AND2_OUT;

END;
```

Software Updat

Enhanced features in Version 2.0

Steffen van de Vries

Main photo: RailEurope

EEDTS Pro is undoubtedly a highly successful DIY model railway control system. Thousands of enthusiasts have used this to control their model railway. The EEDTS Pro designer hasn't been resting on his laurels though. Here we introduce you to the latest version of his control software: EP 2.0.

The versatile EEDTS Pro has been with us for several years now, but it still works well with current model railways because of its regular hardware and software updates.
The PC control software is definitely the part of EEDTS Pro that has the shortest life cycle.

In the computer world developments follow each other in quick succession, so a new version is essential every three or four years just to keep up to date. And this is the reason for the release of version 2.0.
A modern program does have bigger system requirements. In order to run version 2.0 you need a PC with

e for EEDTS Pro

Windows 98SE/ME or XP, a minimum of 256 MB RAM and at least a 1 GHz processor. Users with larger displays (e.g. 1600 x 1200 pixels) will now be able to clearly view very large track layouts.

Improvements

Apart from several interesting additions, many sections of the program have been enhanced. The result should satisfy the needs of most digital railway modellers.
Existing designs made with EP (an abbreviation of EEDTS Pro) 1.2 can be loaded using EP 2.0, although the program lines need to be removed.
The capabilities of the faster controller with version 1.2 of the firmware really come to the fore when used with EP 2.0. As yet there is no need for an updated controller. It makes sense to wait with adapting the controller until the new Märklin System has been released and all of its features are known.
The EEDTS Pro control software can be used to 'draw' a track layout onto the screen using a range of symbols. This set of symbols is sufficient to create even the most complex track layouts on the screen.
This control screen looks very similar to the control panels that are in use in the railways. Even so, this program lets you design, correct and maintain layouts with ease.
Apart from the on-screen control of turnouts and signals, it is also possible to control up to 240 trains, define block sections and program the running of the trains (**Figure 1**).

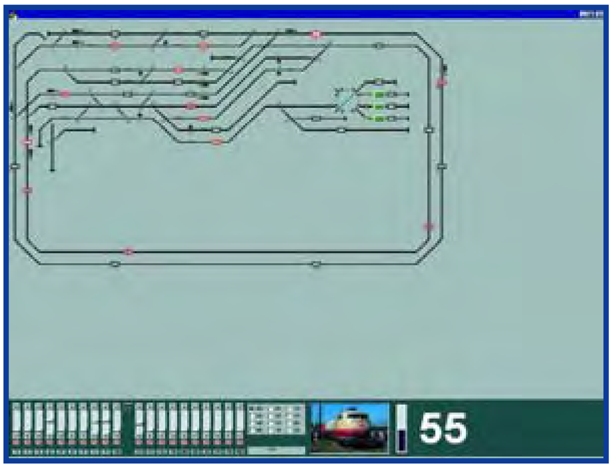


Figure 1. **The new version of EEDTS Pro offers plenty of room for large track layouts.**

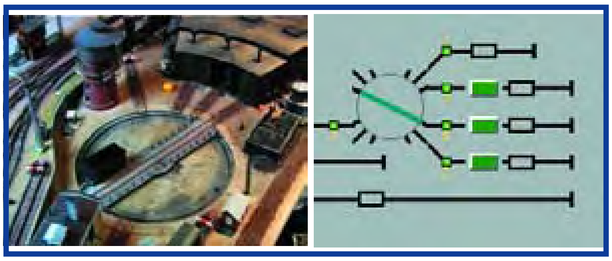


Figure 2. **Three types of turntable are supported.**

Main menu

There are six options on the main menu of the program:

1. Build control panel

The first step is to create the track layout by dragging a range of building block symbols onto the screen.
There are building blocks for straight and curved tracks, turnouts and signals and for detector buttons.
Detector buttons are rectangular symbols that are included in the track layout and which show the train address, but they can also act as the start or end point of a block section.

A new feature in version 2.0 is the support for 3 types of turntable, with 8, 12 or 16 track connections (**Figure 2**). These turntables are usually controlled in one of 3 ways:

- Time related control.
- Control via an EP decoder with feedback.
- Märklin turntable decoder.

2. Decoder addresses

In this step the (decoder) addresses for the active components (turnouts, signals) and the (decoder) addresses for the train (address) detector modules are defined.
Version 2.0 also has the facility to read the status of reed switches. This will be particularly useful to those of you who have an outdoor track in the garden. A block segment can then be defined by reed switches at the beginning and end, which are activated by a permanent magnet.

3. Block sections

From this menu option you can define block sections. You have to choose two detector buttons, which are at the ends of the block section and click on them with the mouse. When you click on everything between these two buttons, you've made your block section. The status of the turnouts and signals that are in this section block can be changed by clicking on them.
In version 2.0 it is possible to get the software to generate a block section automatically. After clicking on a start and end point the software will attempt to find a route between these two points. When you are adding block sections this can save a lot of time.
The maximum length of block sections has been increased from 25 to 35 elements in version 2.0.

4. Soft controllers

From this menu option the train decoders can be programmed and a matching symbol can be chosen for the direction dependent function.
From here you can choose between the new and old Motorola format. If you select the new format then you can control 4 extra functions, as well as the direction dependent function.
The software can program up to 240 controllers. Since it would take up a lot of screen space to show 240 con-

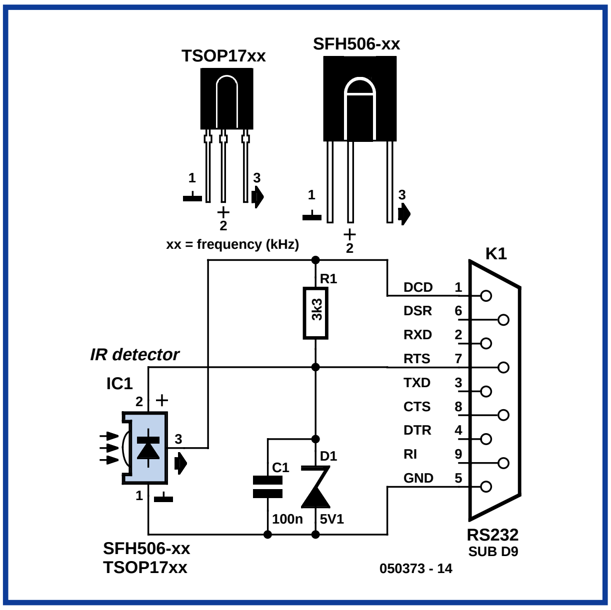


Figure 3. This is how an IR receiver can be connected to an RS232 port.

trollers (and not many people have 240 trains), we've added radio buttons that can select blocks of 20 controllers at a time.

5. Programming

A module has been added that lets you automate the running of trains with the help of a few mouse clicks. With this it is fairly easy to create shadow stations, train timetables and automatic control of block sections. There is a built-in protection against train crashes. The programming has been implemented such that the trains determine when events occur. The program lines are therefore linked to the return or detection buttons that are activated by the train.

Before version 2.0 the program lines were linked to a detector button. This program acted on all trains with the result that only relatively few program lines were needed to control many trains. The disadvantage was that this setup was fairly complex and abstract.

In version 2.0 the trusty method is used whereby each train has a complete program for itself. This does mean that many more program lines are needed, but since version 2.0 has improved editing facilities (you can copy&paste the program lines), this isn't really a problem. An additional advantage of this setup is that the trains are closely tracked, making it unlikely that a train gets lost.

Since each train has its own program, it's possible to enable or disable these programs individually (in version 1.2 you could only enable or disable all programs at the same time).

Version 2.0 also lets you enable or disable a train program wherever a train is on the track (as long as it's in a position that occurs in the program).

In version 2.0 you can now see how the train runs: when you click on a program line you'll see on the screen where the action takes place. You'll also see the start and end points of the block section that is opened by the program line.

When several program lines are selected all the affected areas will be shown.

Figure 4. Remote controlled functions are show extra-large on the screen.

6. Run

From here the user can operate the model railway.

From the screen you can operate turnouts and signals, start trains or change their direction of travel, and turn their auxiliary functions on and off. The manual control of block sections is also possible.

Track occupancy is reported and the train detector shows which trains pass through. Each train can have its individual program enabled or disabled.

Each track layout and its properties can be stored onto the hard drive. The current state of the system is also stored at the moment you stop controlling it.

If the program is used with a display that has a higher resolution than 640x480, a picture of the train can be shown on the screen when a controller is selected. This visual aid is not only pleasing to the eye, but it also makes the system easier to operate (see Figure 1). These images can be either your own photos or photos found on the Internet (jpg format).

A very fascinating new feature of EP V2.0 is the infrared remote control. Virtually any TV or video remote control can be used in conjunction with a small IR receiver that is connected to a spare RS232 port (**Figure 3**).

To add this facility to the system we've used a program called Winlirc, because it returned very good results.

The functions provided by such a remote control are1:

- Controlling up to 240 trains and their auxiliary functions
- Controlling 4x100 electromagnetic functions.

Because the screen is at a greater distance when the system is controlled remotely the remote functions are shown prominently on the screen, providing clear confirmation of the received commands (see **Figure 4**).

The programming menu for the loco decoder has been expanded in version 2.0, so that every speed step of the loco decoder can be set individually.

We had to remove the programming options for Lenz and Uhlenbrock decoders because it became almost impossible to keep supporting these.

The EEDTS Pro software 2.0 is available on CD-ROM under number **050373-81** (refer to the Magazine and SHOP pages on www.elektor-electronics.co.uk). The CD also contains a PDF file with a full description of the software.

The future

We decided to release version 2.0 of the software first and consider an upgrade to the controller later, because version 1.2 of the controller works perfectly well in conjunction with version 2.0 of the software.

As we mentioned at the beginning of the article, the MFX decoder and Märklin Systems have only just been released and we don't yet know enough about the protocols used. However, we'll keep an eye out for further developments.

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In Control with Eclipse

A modern development environment with many options

Thijs Schoonbrood

So you would like to start a new programming project — the whole idea is clear in your mind and you already have an eye on a programming language. But then things get harder, because which development environment will you use this time? One is too complicated to allow a small program to be written quickly, and another is too limited for large projects. Eclipse is a modern development environment, which is not only easy to learn but also easily expanded and suitable for the most diverse programming languages. Furthermore, the package is free and open-source!

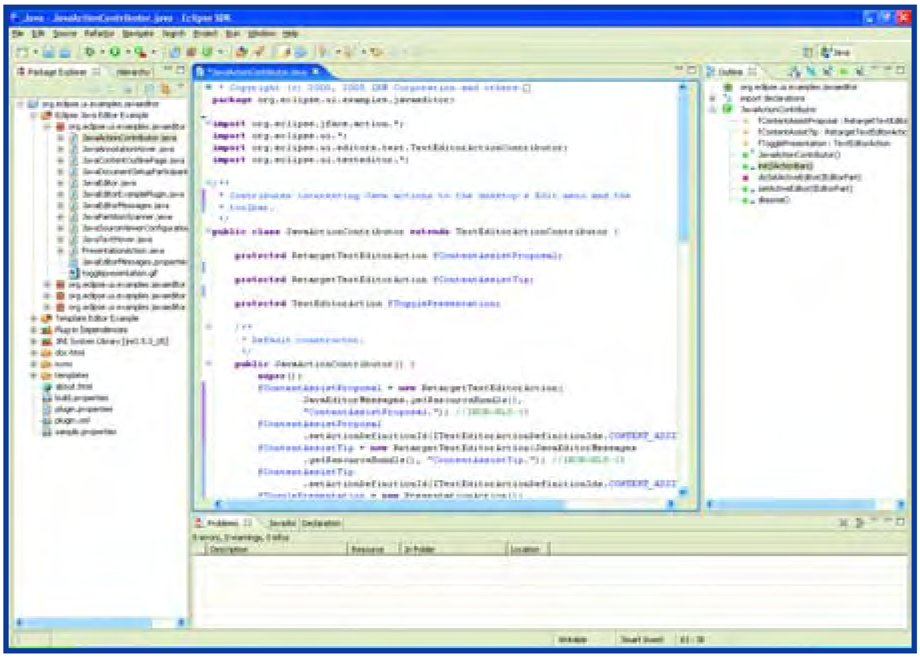

Figure 1. This is what Eclipse looks like most of the time.

Eclipse is an open-source and platform independent software-framework for the development of rich-client applications. The software is used frequently as a Java IDE (Integrated Development Environment) and is viewed by many as the best of its type. Eclipse is nevertheless also eminently suitable for other programming languages. Although IBM initiated the development, for several years now the non-profit Eclipse Foundation has continued to maintain Eclipse, with support from, among others, IBM and Borland.
The current (stable) version of Eclipse is 3.1. This one, as well as all previous versions, can be found at www.eclipse.org. The size of this package compared to other IDEs can be considered modest: a little more than 100 MB. This is caused, in part, by the fact that much of the functionality of Eclipse resides in separate plug-ins, which we will describe a little further on.
After completing the download, we can get started immediately, since Eclipse does not need to be installed. Simply unzip the file and Bob's your uncle! After starting the program, you choose the so-called workspace, the folder that will contain all our projects. After that we arrive at the welcome screen, where we can choose from several tutorials or examples, or go straight to work.

Different perspectives

We now end up at the so-called workbench. This workbench consists of several perspectives. The idea behind perspectives is that when developing a program several different tasks can be distinguished, such as among other things, programming (creating source code), debugging

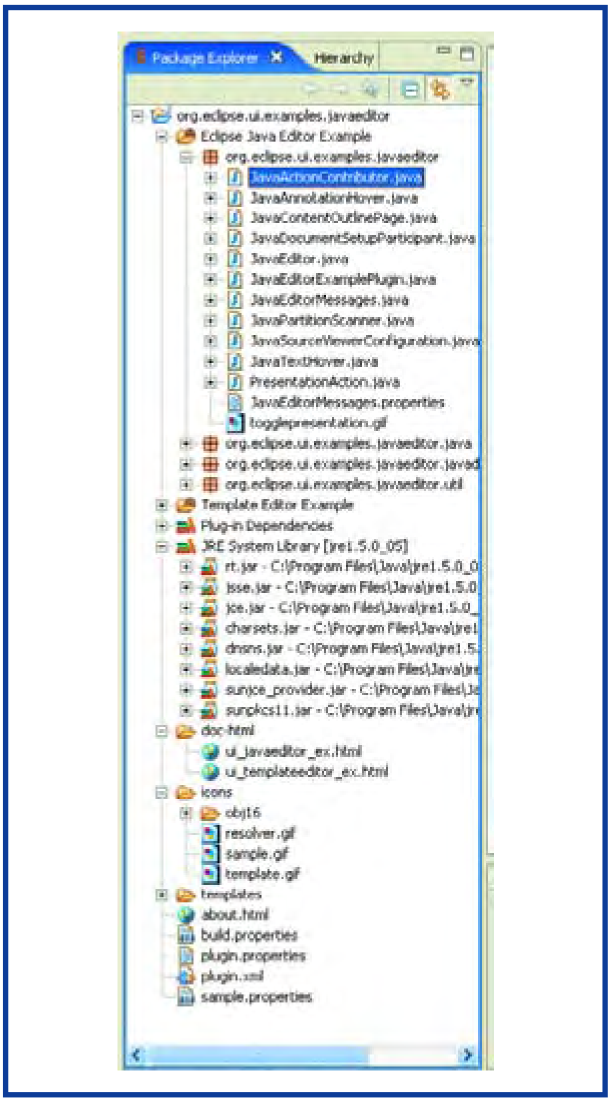

Figure 2. The package explorer offers an overview of all the elements in a project.

(fixing errors) and adding or maintaining code from others. Because much information relating to a particular task is not pertinent to another task, it is only presented when carrying out the relevant activity (read: in the relevant perspective). This way the screen remains uncluttered and

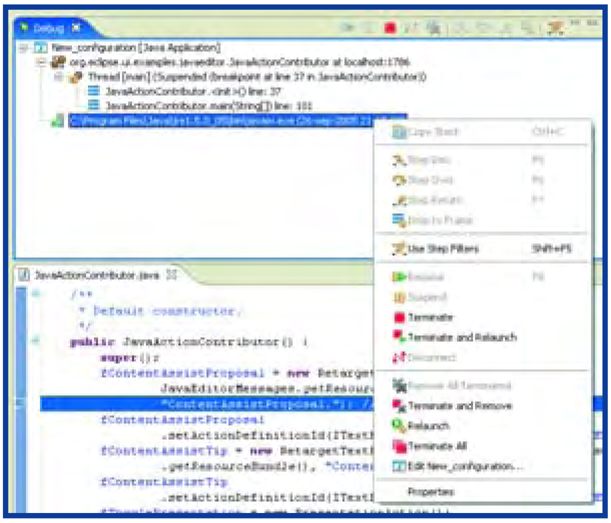

Figure 3. You are kept informed of everything while debugging.

only the relevant information is presented. Each perspective, in turn, is itself built up from different views and editors. An editor is usually in the middle of the screen and is used to change the code. A view gives additional information over (or the properties of) a particular part in a graphical way. Although the concept of perspectives can look rather abstract at first glance, you will get used to it quickly once you start to work with it. Within each perspective just about everything can be configured as desired, such as the selection, position, arrangement of the different views and editors. In this way you always have the appropriate information at your fingertips that is the most relevant to you at that time.

Getting started with Java

Eclipse is eminently suitable as a development environment for Java-applications. With this there is a central role for the Java-perspective. At the far left we find the so-called Package Explorer. This is a kind of explorer, which shows the contents of all the projects in the workspace selected earlier. Think for example about source code, graphics and configuration files, but also imported libraries and information regarding the Java Runtime Environment being used. From the Package Explorer we select which files we want to view or edit.

For more information regarding the open file in the editor, we can use the outline-view. Three separate parts can be distinguished in here: at the top we can see the package that contains the class. Underneath that is a list with import declarations, which can be collapsed to make room for the rest. The last part is the most interesting of these three. It provides a detailed overview of the construction of the relevant class. This includes all variables and methods together with all accompanying information.

A helping hand

Eclipse has a feature with the name ‘auto completion’, which will show all relevant options within a class. It suffices to type the letters ‘get’ and hit the Ctrl key and space bar to list all the methods that begin with ‘get’. And if this is not enough, a separate pop-up screen also displays the accompanying java-documentation.
The handy auto-completion window is also used in a different context, where the feature is called ‘quick assist’. This is mainly useful to quickly change the code when the compiler has found an error or has issued a warning. All errors and warnings are, incidentally, also clearly presented in the ‘Problems’-view. With the key combination ‘Ctrl+1’, Eclipse immediately proposes a number of possibilities for solving the problem.

Tracking down errors

No matter how clever a development environment is, a sizable amount of code will always contain a few errors. Once we’ve established that there is an error it becomes the objective to determine the cause and that is where the debug-environment comes in. Debugging is so important that a separate perspective is dedicated to this activity. By doing so, space is made available for information that is indispensable while debugging. Naturally we find here everything with connection to actual values of variables, breakpoints that have been set, etc. It also presents all running threads and their states. We can terminate, continue or restart threads as we please.

But it gets really interesting when we start to use conditional breakpoints. Want a breakpoint in a loop that activates on the seventh iteration? Not a Problem! Or only when a variable has a predetermined value? That is also possible.

Cooperation with version control

Programmers who work on projects with other developers generally make use of some form of version control system. The option of storing the different source code versions at a central location is then essential. The system that is used most frequently for this is the so-called Concurrent Versions System, better known as CVS. This is supported natively by Eclipse; there is a special perspective for the management of CVS-repositories. In addition to the usual checking out and synchronising of projects, this perspective is also used to manage tags and branches. Using an external diff-application is redundant, because this functionality is also built into Eclipse, just as there is also a view to display the resource history of a file. The management of tags and branches is child's play.

Plug-ins for additional functionality

As was already mentioned earlier, the functionality of Eclipse can be enhanced with plug-ins. There is a large selection of plug-ins available and these can be roughly divided into two categories. The first category comprises a relatively small number of plug-ins developed under the banner of the Eclipse organisation. In this category belong, among others, the C/C++ and Visual Editor plug-ins, which will be discussed a little further on. These can be found at www.eclipe.org/tools. The second category is much larger and contains all the third-party plug-ins. Many of these plug-ins are able to keep themselves up-to-date with the aid of the built-in update-manager of Eclipse.

C for yourself

An IDE only becomes really interesting to developers when it is able to handle multiple programming languages without loosing much of the functionality. That is why within the Eclipse Foundation the CDT project (C/C++ Development Tools) has sprung into life (you can find details at www.eclipse.org/cdt). As the name implies, this plug-in changes Eclipse into a development environment that knows how to deal with C and C++ code. This means that once again we can make use of the functionality of CVS, the debugger, auto completion, etc. In contrast to developing in Java, this plug-in does not provide a built-in compiler. This is of course a little bit more complicated with C and C++ considering the strong platform dependency. If you work in Linux, then there will almost never be a problem. Just about every distribution contains a version of GCC (GNU C compiler), which can be used by Eclipse without any trouble. Via CygWin (http://cygwin.com), GCC together with a selection of other Linux-features can be used in Windows. If you're not that keen on all that Linux-functionality, then MinGW (www.mingw.org) may be a good alternative.

User-interface illustrated with the Visual Editor

If you build many applications in Java, you will then also regularly have to design and implement a GUI (Graphical

Figure 4.
Just on the plug-in website of Eclipse alone we can find nearly 1000 plug-ins.

User Interface). Of course, you could do this in the same way as any other programming task: enter all the code yourself and frequently check the result by running the application. But particularly when implementing graphical elements the so-called 'What you see is what you get'-method (or: WYSIWYG) is quickly becoming popular. This approach makes it possible to assemble the GUI in a graphical interface, while at the same time the corresponding source code is generated in the background. In Eclipse this functionality is contained in the plug-in called Visual Editor (VE) (see www.eclipse.org/vep).

Finally

As you have seen, it is possible to use Eclipse for a wide range of tasks and programming languages. And we didn't even mention COBOL, PHP, designing with UML/UML2 or database development. All these projects are free and are continuously being developed further. In this way there is practically always a configuration of Eclipse available that meets your requirements. And in the unlikely event that this is not the case, you can always just develop a plug-in yourself.

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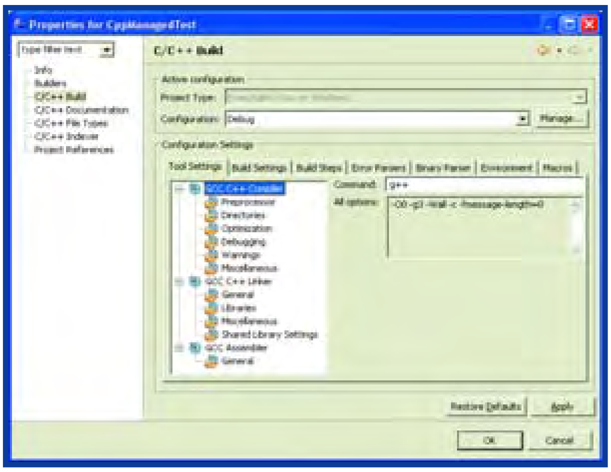


Figure 5.
The compiler settings are very extensive.

Programmable Laser Lightshow

Using a DIY projector

Jeroen Domburg & Thijs Beckers

The act of mounting an additional LCD in a computer case is now fairly commonplace among case modders. Such a display can be used as a readout for all kinds of useful information without using the PC monitor for that. This is not unusual anymore and as a case modder you will have to think of something new to be noticed. This simple laser projector is sure to draw attention.

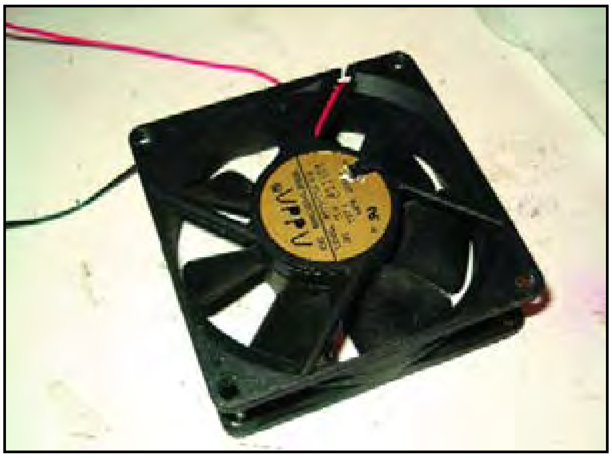
The LCD that's often built into the PC case by case modders has a few advantages (such as the direct readout of certain information) but, alas, also a few disadvantages — for example, you always have to look at the PC case to see this information. This case is generally not right next to the monitor, but often hides under the desk instead and that's mighty inconvenient. For sure, you could put the LCD in its own enclosure, connect it to the PC with a cable and then put it on your desk. Although the solution described here may not be ideal, it is a nice alternative for such a display: a do-it-yourself laser projector.
This project is certainly not only suitable for case modders. It is also a nice toy just to experiment with.

Method

In this month's Modding & Tweaking instalment we will make a laser projection display with a few household articles and fairly common components. Such a display can be made in several different ways. The starting point is always the same, however: the laser beam has to be deflected in one way or another. This is usually done with electronically controlled mirrors. By moving the mirrors in a certain way, the laser draws an image on a surface.

Hot glue is perfect to attach the little mirrors with varying angles.

With a sheet of A4 and a laser pointer we can easily set the angle.



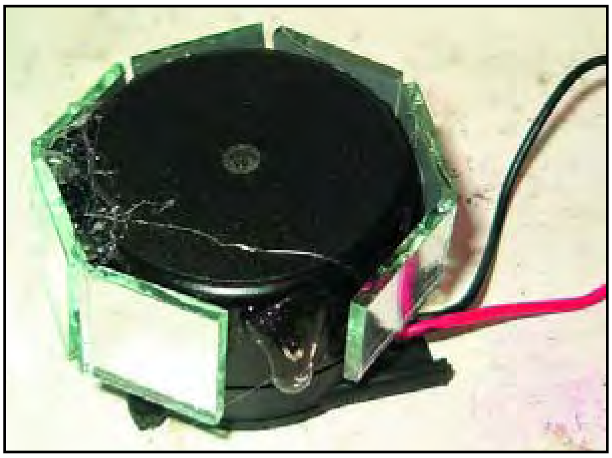
The fan that we need to mount the mirrors on.

The frame we don't need for this project…
…just like the fan blades.
In this way we are left with a nice, round 'puck'.

Just like the way an oscilloscope does this with an electron beam and horizontal and vertical deflection plates. This principle is used quite frequently in discos.
Commercial laser projectors are unfortunately rather expensive — you could easily spend a few thousand pounds on one. It is not really an option to build a cheap one yourself either. The galvanometers (the components that move the mirrors) are not easily home made and are not cheap enough to experiment with yourself.
Fortunately we can make a simple deflection mechanism with straightforward methods. If we mount a number of small mirrors on the edge of a rotating disk and point a laser pointer at it, the laser beam when reflected by the mirrors will draw a line on the projection surface. If we now also tilt the mirrors a small amount with respect to each other we will have a number of lines, one above the other. We now have the equivalent of a TV picture tube where the electron beam continuously draws horizontal lines on the front of the tube. Just as with a TV we can generate an image by turning the beam on and off.
In addition to the laser (a cheap laser pointer works well) and the rotating mirrors we also need an optical sensor for synchronisation. There's also a requirement for a drive circuit for the laser in order to project some useful information on the wall. Although it is slightly more complicated in practice, the final circuit did turn out to be relatively simple.

The schematic

The heart of the circuit consists of a microcontroller, an ATTiny2313 (see **Figure 1**). This controls the laser module (LM1) via T2. Using T1 it also regulates the speed of the motor that turns the little mirrors. For the motor we used an old computer fan (see photos). Not every fan is suitable — it has to turn relatively slowly and silently with a 12 V power supply voltage applied. Because the microcontroller drives T1 with a digital signal (PWM) there is no need for a big transistor or heatsink. So we can use an ordinary BC547 for this. In addition, the controller detects the position of the laser and deals with communicating with the PC.
IC1 provides the power supply for both the laser pointer as well as the microcontroller. P1 determines the output voltage of IC1. T4, T5 and the parts around it convert the inverted TTL levels of the serial port signal from the microcontroller into RS232-compatible 0-V and 12-V levels. Although this is not exactly according to the RS232-specifications (no –12 V is being generated), it tends to work well 99% of the time (the experience of the editors is that



This is what it looks like. Note the space between the mirrors.

A rotating motor generates lines instead of one concentrated laser dot.

something like this doesn't tend to work with laptops; these often do need the negative voltage of –12 V). The reason we didn't use the standard solution with a MAX232 is that there is no 5 V available in the circuit to power the MAX232.
Phototransistor T3 needs to be positioned in such a way that the start of the 'laser line' drawn by the mirrors falls on the sensor. In this way the microcontroller remains synchronised with the motor.

µC

The microcontroller in this circuit does the lion's share of the work, that is clear. The program that runs in the controller consists of a few parts: the synchronisation routine, the routine for controlling the laser and the menu system.
The synchronisation system measures the times between the pulses detected by the phototransistor. When the system is synchronised there is a longer time between the pulse from the seventh line and the pulse from the first line. If this is not the case the synchronisation system will try to correct it via a fixed routine.

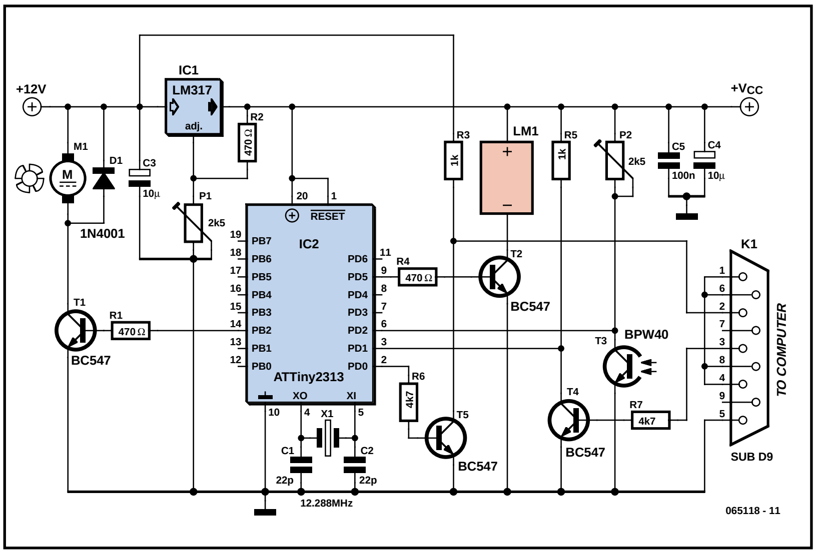


Figure 1. The schematic is a little bit more complicated this time. However for the controller of a (little) projection system it is actually very compact.

In addition for the synchronisation, the times are also used for the display system. This system controls the laser when it 'writes' a line. By making the length of a 'pixel' exactly 1/128 of the longest measured line time, we can in practice display 96 pixels. The duration that is necessary to display one pixel depends on the motor speed. Consequently, the displayed image does not change. At a low speed the image will flicker noticeably.
The microcontroller contains a menu system that allows the user to test and calibrate the system to a large extend without needing complicated test equipment or even leave his comfy chair. The microcontroller code is open source. The code can be downloaded from the *Elektor Electronics* website [1] or from the Jeroen's own website [2].

Tweaking and tinkering

The mechanical construction is not that involved. The whole thing can be assembled with a hot glue gun in a few spare hours.
The motor is an 80-mm fan, as often used in PCs and power supplies. Remove both the fan blades and the outside frame, so that just a rotating 'puck' on a stationary base remains. Attach this base to a supporting base, a piece of wood, for example.
On the outside of the puck we glue a total of seven small mirrors (for seven lines). This has to be done reasonably accurately. Every mirror has to deflect the laser beam a little higher. For this purpose place a sheet of paper about 50 cm away from the puck. Let the mirror deflect the laser beam onto the sheet of paper. Glue the mirror in place and mark the spot where the deflected beam hits the paper. Rotate the puck in the normal direction of rotation for the motor. The next mirror has to be glued in such a way that the reflected laser beam is about two centimetres above the previously marked spot. Mark this spot again and repeat until all seven mirrors are attached.
The laser pointer can now be positioned in a fixed location. When the laser pointer and the motor are both turned on, and all is well, there should be seven lines on the surface where the whole assembly is pointed at. The phototransistor has to be positioned at the location where the lines begin. Mount it as close as possible to the puck, so that the changing vertical position of the lines has the least effect. It is best to just guess the optimal initial position of the sensor. Later on, the software has a few helpful routines to fine-tune the position. It is also useful to mount the phototransistor in a tube so that ambient light has less of an effect.
A brief comment about the laser pointer. Because the laser pointer has to be switched on and off rapidly, it can be useful to open it and check for the possibility of decoupling capacitors. These need to be removed to prevent an afterglow from the laser when it is switched off. Some laser modules even have an enable-input which ensures rapid on and off switching. If this input is available then it is obviously best to make use of it.

Adjustment

Now that the mechanical part has been assembled the construction and adjustment of the electronic part can commence. The first thing is to adjust the power supply voltage for the laser pointer. Make sure that the laser pointer is not connected during this procedure! Apply a power supply voltage of up to 6 V to the PCB and adjust P1 so that the voltage between pin 1 and pin 10 of IC2 is equal to the voltage that is normally supplied by the batteries in the laser pointer. For two penlight (AA) batteries the voltage must be 3 V, for example. Note that the voltage has to be between 2.7 and 6 V, otherwise the microcontroller doesn't work.
The system needs to be completely built and connected before doing the remainder of the adjustments. Make a serial connection to the PC and start a terminal emulator (for example (HyperTerminal or Minicom). Use the following settings for this: 9600 baud, no parity, 1 stop bit, no handshaking.
It is now time to turn the laser display on. First the motor will get up to speed. NOTE: because it is possible that the motor is not balanced well and may vibrate it is wise to check that all the mirrors are well attached. If in doubt, start by placing something over the whole assembly.
After a couple of seconds the laser will be turned on and the motor will spin at its final speed. After this there is a significant chance that there is a motor error because the

whole system has not been calibrated yet. Press 'i' in the terminal program to ignore the error. Now use the escape key to enter the main menu of the microcontroller. First we have to adjust the speed of the motor to an acceptable level. For this select menu-option 'm'. Adjust the speed of the motor so that it goes around but the whole assembly does not vibrate or resonate. Do not make the speed too slow, otherwise the image that the laser writes on the wall will flicker noticeably. Once the motor rotates at a good speed, we store the setting with the escape key and return to the main menu.
Now we have to calibrate the phototransistor. This is done with the 'show timings' option in the menu. Type '9' for this. This option shows the amount of time as measured by the microcontroller between the instances that the laser beam hits the phototransistor. In the ideal case the numbers in each column change very little or not at all. The largest number needs to be in the first column. If the phototransistor is mechanically in a good position, is suffices to turn P2 until this time pattern appears. If this doesn't work, then the phototransistor will have to be positioned in a better location (closer or inside a tube).
It is a little easier to make these adjustments using an oscilloscope. Measure at the node of P2/T3. There should be a signal of 3 V (depending on the adjustment of P1) that shows 7 'spikes' to 0 V. The spacing between the spikes is more once in seven times (refer also to the scope picture in the strip). If need be, use menu option 8 to turn the laser on continuously.
Once the phototransistor has been calibrated the only thing that remains is calibrating the horizontal offset of the mirrors. This is quite easy. Use menu options 1 through 7 to nicely align the lines one above the other.
Once the calibration has been completed successfully and the microcontroller is not in menu mode, we can project the text by typing 12 characters. After starting, the display will go directly to this mode. Any program that can transmit its message via the serial port can therefore drive this circuit.

Finally a few notes. Should the whole assembly resonate badly then this can be solved with a drop of hot-glue in the correct position on the puck. In addition, we are dealing here with a set of glass squares rotating at high speed. If there is even the slightest doubt that any of these could come lose, it is better to build the whole assembly in a transparent enclosure.

The laser pointers that are normally available are generally 'class 1'. This means that they will normally not cause any harm to eyes. Just to improve the safety, the laser is turned off if it appears that the motor is stationary. Nevertheless it is not a good idea to look directly at the laser.

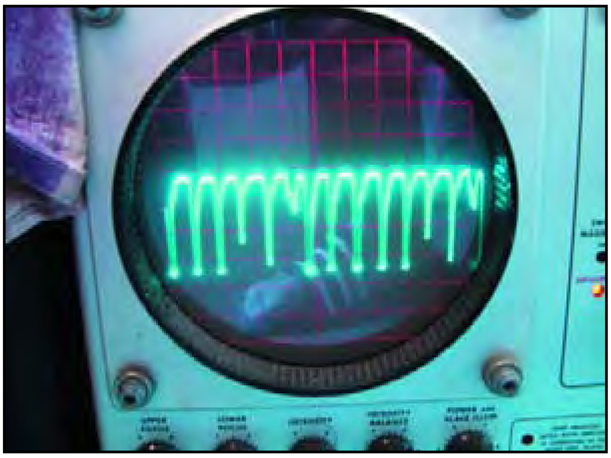
In addition you may ask yourself why the menu options are so brief and to the point. The reason for this is that the program space for the microcontroller is filled to the brim: of the 2 kBytes of available space there are, all told, two spare bytes.

(065118-1)

Internet links

[1] www.elektor-electronics.co.uk, articles for October 2006.

[2] http://sprite.student.utwente.nl/~jeroen/projects/laserdisp



The scope picture shows the signal from the phototransistor.

About the author

Jeroen Domburg studies Electro Technology at the Saxion University in Enschede. He is an enthusiastic hobbyist who is very interested in microcontrollers, electronics and computers.

In this column he showcases is personal handiwork, modifications and other interesting circuits, which do not necessarily have to be useful. They are unlikely to win a beauty contest in most cases and safety is generally taken with a grain of salt. But that doesn't concern the author at all. As long as the circuit does what was intended then all is well. You are therefore warned!

The end result. Now if this doesn't draw attention…

CDP1802 –

Jan Buiting

Way back in 1975 a brilliant designer at RCA in the US of A, Dr Joseph Weisbecker, got inspired by the architecture of the Intel 4004 microprocessor. Joe developed two chips, the CDP1801R and CDP1801U to create his own microprocessor. By early 1976, as IC fabrication processes at RCA improved, the two ICs could be combined in a single package dubbed CDP1802 and still later, 'Cosmac'. The clock frequency also went up from 2 MHz to 6.4 MHz at a supply voltage of 10 V. Striking, as most other TTL or NMOS based micros available at the time ran from 5 volts, consuming hundreds of milliamps and running hot to the touch. The CDP1802 was the world's first CMOS-only CPU which offered a number of advantages: low current consumption, wide temperature ranges, better noise margins, wide supply voltage range and the ability to interface directly to 4000 series CMOS ICs as well as good old 7400 TTL. The 1802 featured a single-phase clock, static operation (meaning the CPU can work at any clock frequency and simply freezes its state at 0 Hz) and a fairly unusual architecture often described as 'bright', 'totally clean' and 'efficient'. It was an 8-bit micro with an array of sixteen 16-bit wide registers, any of which could be assigned the function of program counter (P) or stack pointer (X). It also had DMA, four logic inputs that could be directly tested by instructions, and seven rudimentary byte-wide output channels.

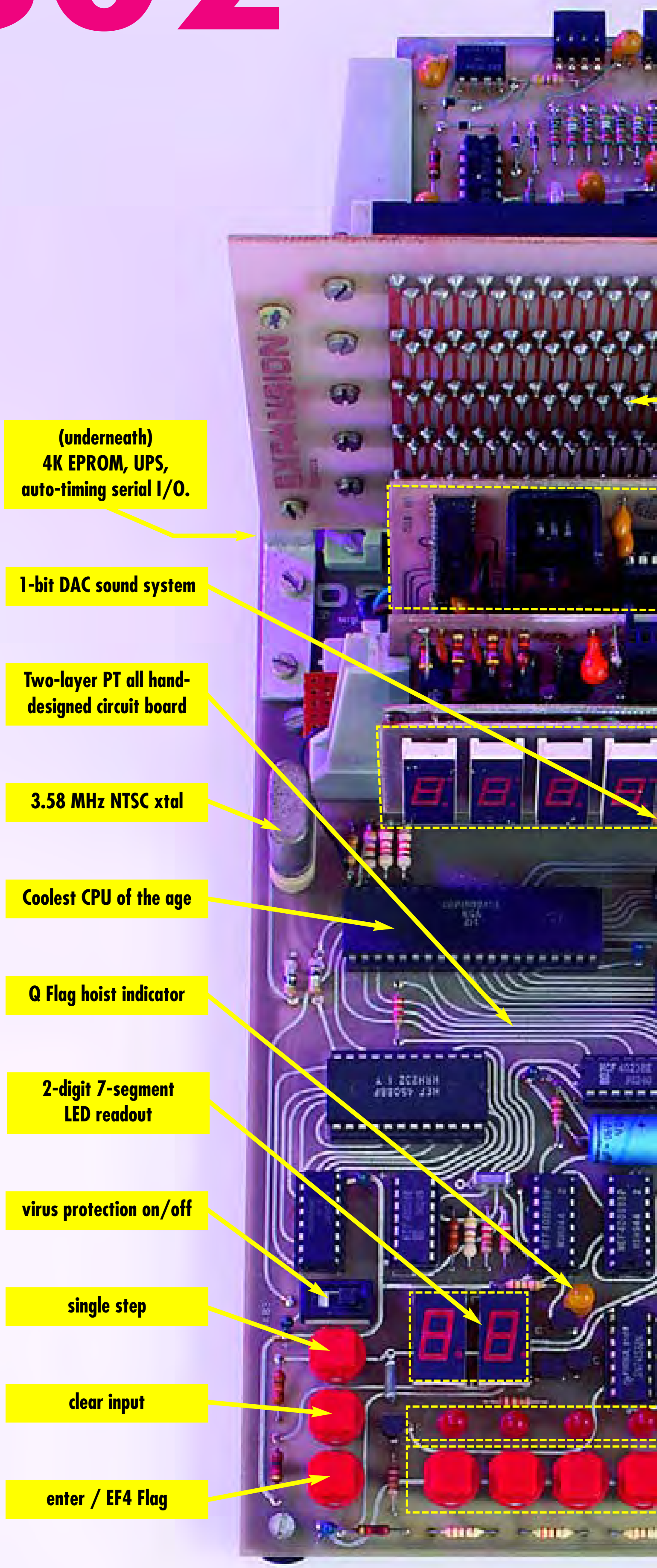
The publication in 1976 by Joe Weisbecker of his Cosmac 'ELF' DIY computer in *Popular Electronics* gave a tremendous boost to the popularity of the 1802 as thousands of hobbyists jumped the CMOS microprocessor bandwagon, leaving 8080, 8085 and 6502 users to worry about the heat developed in their power supplies. Like so many other homebrew microcomputers systems of the age (like the KIM), The ELF was graced by lots of follow-up projects, hardware extensions and application software, right up to FORTH, Tiny Basic, floppy disk interfacing and colour video output.

Promotion through the hobby channels worked. On the professional front, the CDP1802 was spotted as the first micro suitable for fabrication enhancements using silicon on sapphire (SOS) techniques that made the device resistant to cosmic radiation. And up into space it went — the CMOS/SOS versions of the CDP1802 fabricated with the help of Sandia National Labs were used in spacecraft including UoSAT-1, UoSAT-2, Viking, Voyager and Galileo in which they functioned for decades without fail under pretty harsh conditions.

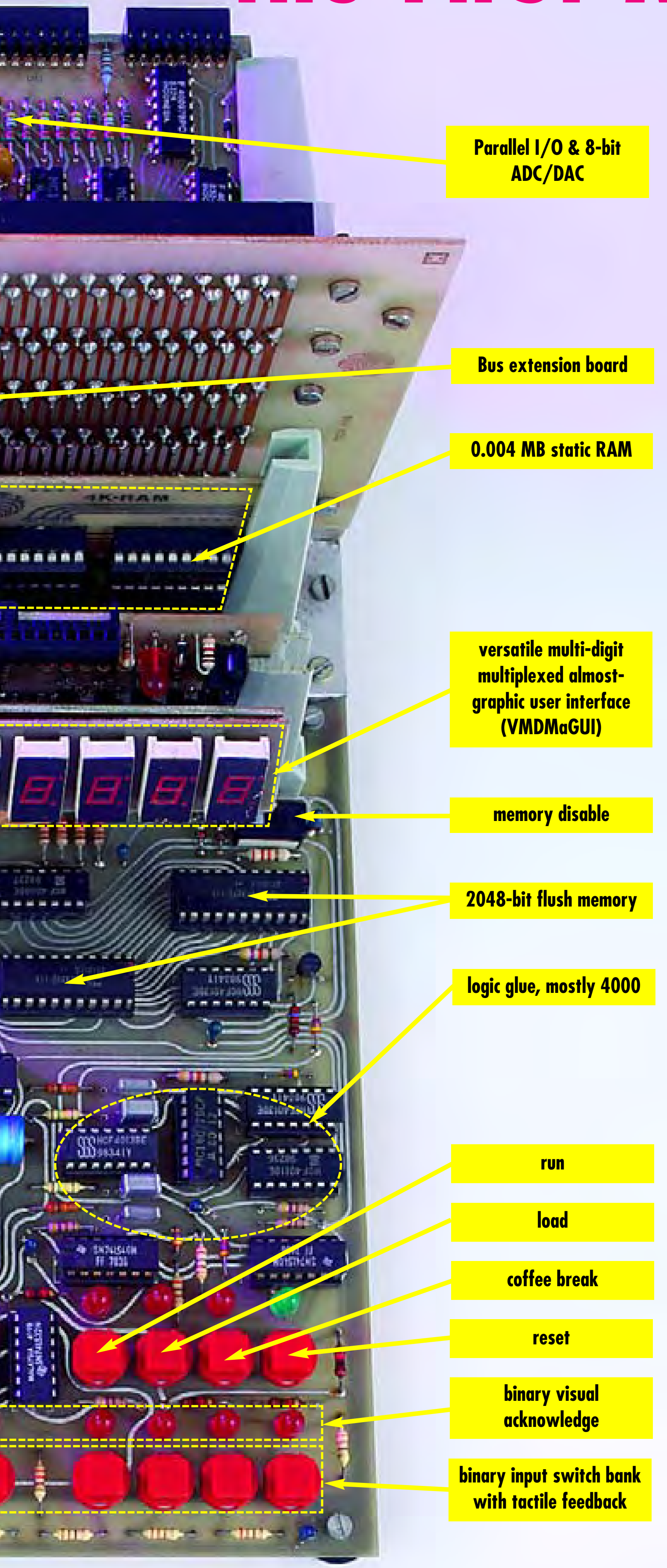
My personal experience with the 1802 goes back to 1981 when I bought a book describing what I now consider a much improved, Europeanised, version of the ELF computer. I had already seen a friend struggling with his 8085 kit and decided to give all things Intel a miss. Within weeks of opening the book (written by Bob Stuurman, now a contributing author to Elektor magazine) I had built my own CDP1802-based single-board microcomputer and was able to switch an LED on and off under control of a pushbutton. I also made the board play a Christmas tune through an earpiece connected to an output line. No one marvelled except me.

The improvements of my 'Cosmicos' system over the ELF, on which it was clearly based, were mainly an ingenious use of dead standard CMOS ICs around the 1802 and a very high quality circuit board designed with system expansion in mind. Moreover, I could buy everything I needed locally instead of ordering from the USA. Quality-wise, if the ELF was NTSC TV, then my Cosmicos was PAL — cleverer and technically more sophisticated.

Over the years the Cosmicos CDP1802 system shown in the main picture has acted as a simple



the First Micro in Space



alarm system, a printer buffer (using 48 K dynamic RAM), a video game and a test chart and titles generator for my amateur TV station. Until quite recently it was used as a greenhouse temperature/humidity controller. The system was initially programmed directly using the 1802's easy to learn 90 or so opcodes, then in assembly code, and finally in a slightly modified version of 'Chip-8', a wonderful little interpreter available for a number of microcontrollers at the time.

If I remember correctly, my Cosmicos system in its largest configuration comprised a CDP1806 CPU running at 8.86 MHz, 128 K dynamic RAM, a floppy disk drive with a bootstrap loader, a modem, a simple colour video card and sound output. It ran assembler/disassembler, FORTH, Chip-8, Tiny Basic, a few games and a plethora of nifty utilities, all from 5.25-inch floppy disk or cassette tape. The lot was built into a tabletop 19-inch case that took a bashing in my car boot as it was hauled up and down the country to friends and club meetings. It was also confiscated once by German customs. Remarkably, the system could be dismantled literally within minutes to get back to the nitty-gritty of the bare mainboard with just its binary input keys and 7-segment LED display.

Mind you, this was in the pre-Internet age so books and other documentation had to be obtained the hard way while literacy and membership of a club were essential if you were serious about the hobby. Fortunately, lots of friendly Americans also hooked on the 1802 and cheerfully programming their ELF-2 systems sent me books, magazines and what must have been hundreds of photocopies by mail—all against a few IRCs to cover the postage (anyone remember IRCs). Downloads there were none — the 1802 just made it into late 1980s BBS craze using 75/1200 baud modems — say no more!

I'm confident in saying that without the construction and programming skills developed using my 1802 system I would not have been appointed Technical Editor of this magazine in 1985 — the then editors at Elektor were bowled over there was a microcomputer system not unlike their own Junior Computer but far less cluttered and power hungry.

Today, the CDP1802 and its derivates the 1805 and 1806 are vintage micros although a surprising number are still in use in lots of systems and equipment including traffic lights, data loggers and vending machines. In the early 1990s a Dutch company sold a home computer based on the CDP1802 micro. Called the COMX-35, it had to compete with Sinclair and Commodore computers hence it never became a success.

(065062-1)

No way you could do without your books and datasheets. All publications supplied by RCA for their Cosmac microprocessor series were renowned for clarity and accuracy.

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

Metal film resistor trimming

K. Bertholdt

Suppose you need an oddball resistor value like 2.8 kΩ but you only have 2.2 kΩ available. Of course you can create the desired value from two or more standard resistors (if available!) or employ a preset as a makeshift solution (space allowing). There is, however, an alternative, cheekier method that seems to be little known, hence this Design Tip.

Connect your 2.2 kΩ resistor to an ohmmeter (or a multimeter set to the Ω range). Next, use a sharp hobby knife to scratch a tiny amount of lacquer off the resistor body. You'll find that careful scratching increases the value of the resistor as effectively the metal film layer is reduced. You'll be surprised how easily a metal film resistor can be trimmed to a slightly higher value!

(050295-1)

Editor's note

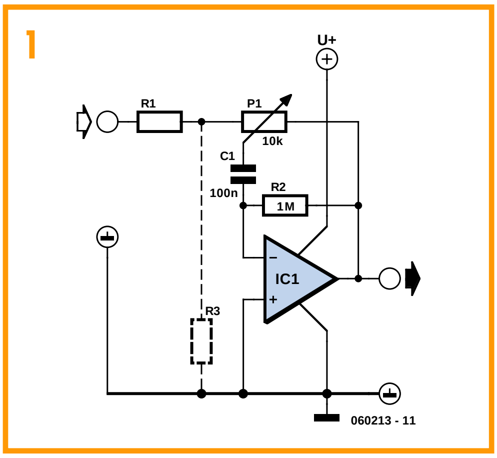
As already intimated by the author, the method is fairly brutal, hence should only be used in experimental situations or when no alternative is available. The damaged resistor loses its rated wattage and mechanical stability, while the bared metal film is not a permanent solution.
In circuits designed for regular use resistors with the proper value should be used, or failing that, a combination of standard undamaged resistors approaching the desired value.

Logarithmic volume control

Bart Boerman

This volume control makes use of an operational amplifier and a few passive components to mimic the operation of a logarithmic control while using a linear potentiometer. The circuit does better in terms of reliability when compared to other designs employing double linear pots to create the logarithmic transfer function.
The circuit is also handy when digital potentiometers are used, the majority of these being linear-law. The circuit shown here allows such a digital pot to be easily changed into its logarithmic counterpart.

1



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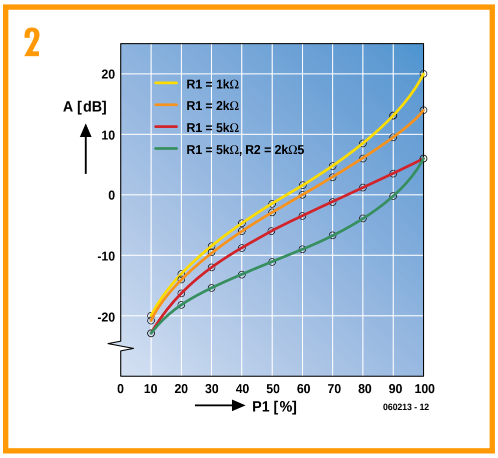

The graph shows the transfer function of the circuit for alternating voltages. The horizontal axis shows the spindle position, the vertical axis, the gain of the circuit for three different values of R1.
With R1 at 1 kΩ the range of the circuit extends from –20 dB to +20 dB (potentiometer span 10% to 100%), i.e., an effective range of 40 dB. In the same control area, a linear pot would have a range of just 20 dB (from –20 dB to 0 dB). In linear terms, the difference between the two ranges equals a factor of 10!
Thanks to components C and R2, the offset voltage at the opamp output remains small even at relatively high gain. The values of these components are uncritical and can be chosen from a wide range, for example, C = 100 nF and R2 = 1 MΩ. This will result in roll-off frequency of about 10 Hz.
In practice, both extremely low and extremely high gain settings should not be used. Simply make sure R1 is always larger than one tenth, and smaller than the maximum, value of the potentiometer.
If you need to set attenuation levels higher than 20 dB, then an extra resistor (R3) is an option. Do note however that the replacement value (R1 | | R3) then equals the initial value of R1.

(060213-I)

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The instructions for the puzzle are straightforward. In the diagram composed of 16x16 boxes, enter numbers in such a way that **all** hexadecimal numbers 0 through F (that's 0-9 and A-F) occur once in every row, once in every column, and in every one of the 4x4 boxes (marked by the thicker black lines). A number of clues are given in the puzzle and these determine the start situation.

Your solution may win a prize and requires only the numbers in the grey boxes to be sent to us (see below). The puzzle is also available as a **free download** from our website (Magazine → 2006 → October).

(065070-1)

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Please send the numbers in the grey boxes by email, fax or post to

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Bob Martin (Birmingham).

Well done everybody!

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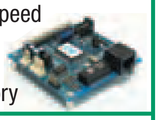

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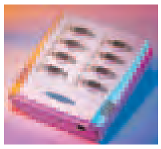

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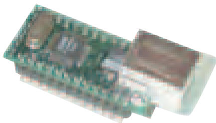

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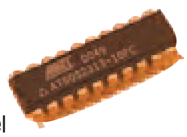

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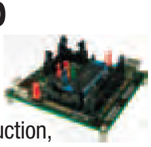

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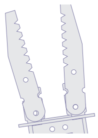
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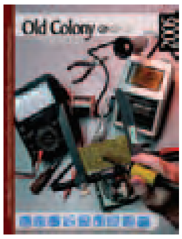

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E-blocks Internet board	£	71.95
PIC16F877	£	10.50
Ethernet 'crossover' cable	£	5.30
Total value:	**£**	**331.65**
Special Offer:	**£**	**232.50**

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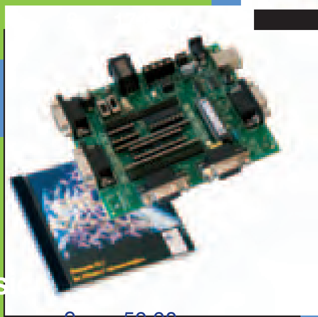

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Flowcode student/home:	£	59.90
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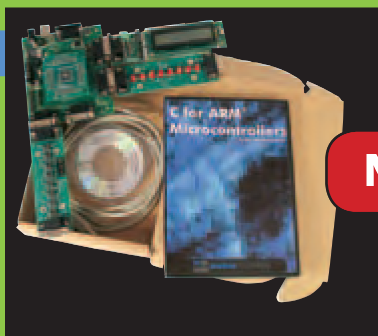

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kit

C for ARM microcontrollers single user	£	118.00
E-blocks ARM programmer	£	89.20
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CD-ROM BESTSELLERS

1 USB TOOLBOX

This CD-ROM contains technical data about the USB interface. It also includes a large collection of data sheets for specific USB components from a wide range of manufacturers. There are two ways to incorporate a USB interface in a microcontroller circuit: add a USB controller to an existing circuit, or use a microcontroller with an integrated USB interface. Included on this CD-ROM are USB Basic Facts, several useful design tools for hardware and software, and all Elektor Electronics articles on the subject of USB. **£18.95 (US$ 34.95)**

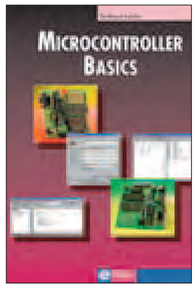
2 Home Automation

This CD-ROM provides an overview of what manufacturers offer today in the field of Home Networking, both wired and wireless. The CD-ROM contains specifications, standards and protocols of commercially available bus and network systems. For developers, there are datasheets of specific components and various items with application data. End-users and hobbyists will find ready-made applications that can be used immediately. **£12.95 (US$ 22.90)**

3 ECD Edition 3

Elektor's Components Database gives you easy access to design data for over 5,000 ICs, more than 35,000 transistors, FETs, thyristors and triacs, just under 25,000 diodes and 1,800 optocouplers.
All databank applications are fully interactive, allowing the user to add, edit and complete component data. **£14.95 (US$ 26.50)**

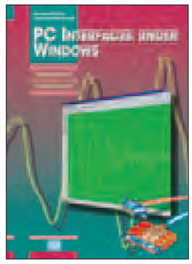
Microcontroller Basics



Microcontrollers have become an indispensable part of modern electronics. They make things possible that vastly exceed what could be done previously. Innumerable applications show that almost nothing is impossible. There's thus every reason to learn more about them. This book offers more than just a basic introduction.
It clearly explains the technology using various microcontroller circuits and programs written in several different programming languages. In the course of the book, the reader gradually develops increased competence in converting his or her ideas into microcontroller circuitry.

ISBN 0-905705-67-X
230 Pages
£18.70 (US$ 33.70)

PC-Interfaces under Windows



PC Interfaces can be used for more than just the printer, mouse, modem and joy-stick!
While it was relatively easy to directly access PC interfaces using a DOS computer, under Windows things are not all that simple.
This book (CD-ROM incl.) shows you how it can be done. The authors describe the DIY construction and programming of a number of highly interesting circuits.

ISBN 0-905705-65-3
265 Pages
£25.95 (US$ 22.90)

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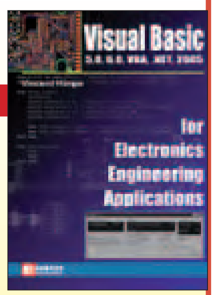

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(September 2006)

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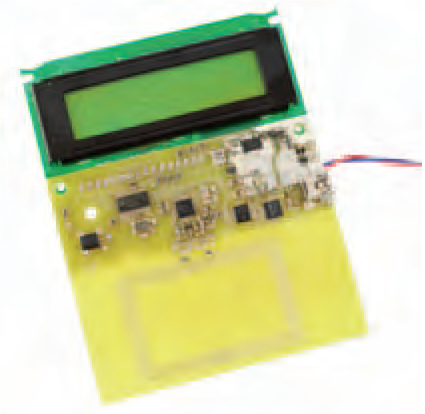
- MIFARE and ISO 14443-A compatible
- Programmable



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030451-72
£ 7.25 / $ 13.65

Matching enclosure

060132-71
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CD-ROM (all project software)

060132-81
£ 5.20 / $ 9.75

GameBoy Programmable Logic Controller

(July/August 2006)

GameBoy Programmable Logic Controller

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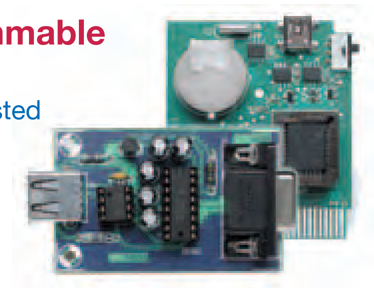

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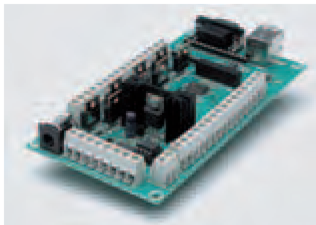

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030060-91	Microprocessor Board, ready-assembled	75.90	142.95
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044026-92	Combined package (030060-91 & 044026-91 & related articles)	117.50	220.95
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050348-71	Kit, incl. PCB, controller, all parts	34.50	64.95
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050280-91	PCB, ready built and tested	55.20	103.95
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Kits & Modules

Onboard OBD-2 Analyser
(May 2006)

Kit of parts including ATMega board, programming adapter board, preprogrammed ATMega microcontroller and all components, but excluding LC display and Case.

050176-72
£ 24.80 / $ 46.70

LC-display
4 x 20 characters, 60 x 98 mm, with background lighting

050176-73
£ 28.80 / $ 54.50

Case, Bopla Unimas 160
with Perspex cover and mounting plate

050176-74
£ 15.80 / $ 29.90

OBD-2 Analyser
(July/August 2005)

Kit of parts including PCB, programmed controller, components (including IC7 ; IC3 = PCA82C250, 12 V), enclosure and RS232 cable. OBD cable not included.

050092-71
£ 52.50 / $ 96.95

OBD cable
050092-72
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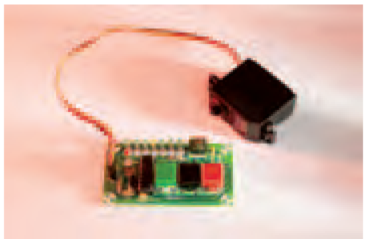
RC Servo Tester / Exerciser
(July/August 2006)

Kit of parts including PCB, programmed controller and all components.



040259-71
£ 22.70 / $ 42.85

No. 355 JUNE 2006

FM Stereo Test Transmitter

050268-1	PCB	11.70	22.00

Network Cable Analyser

050302-1	PCB	8.20	15.55
050302-11	Disk, PIC source code	5.20	9.75
050302-41	PIC16F874-20/P	16.90	31.85

NO. 354 MAY 2006

Onboard OBD-2 Analyser

050176-72	Kit of parts, incl. 050176-1, 050176-2, 050176-42, all components, excl. LCD and Case	24.80	46.70
050176-73	LCD, 4x20 characters with backlight	28.80	54.50
050176-74	Case, Bopla Unimas 160 with Perspex cover and mounting plate	15.80	29.90
050176-42	ATmega16, programmed	10.30	19.45
050092-71	OBD-2 Analyser: Kit of parts without cable	52.50	96.95
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Mini ATMega Board

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NO. 353 APRIL 2006

Simple recharable A Cell Analyser

050394-1	PCB, bare	4.80	9.04
050394-11	Disk, PC Software	5.18	9.75

Universal SPI Box

050198-41	AT89C2051-24PC, Programmed	7.25	13.65

No. 352 MARCH 2006

Application Board for R8C/13

050179-92	Ready-assembled board	48.27	90.94
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FPGA-Prototyping board

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	For non-subscribers	216.30	398.50

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NO. 351 FEBRUARY 2006

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050157-41	ST7MC1, programmed	3.80	7.15

A 16-bit Tom Thumb

050179-91	R8C Starter Kit	8.30	15.60
050179-C5	Set of 5 pcs. R8C13 microcontroller only	20.70	39.00

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95-watt Laptop PSU Adaptor

050029-1	PCB	4.80	9.05

Automatic Attic Window Controller

050139-11	Disk, PIC source & hex code	5.20	9.75
050139-41	PIC16F84A-20I/P, programmed	13.10	24.65
030451-72	LCD Module 2x16 characters	7.25	13.65
030451-73	PLED Module 2x16 characters	25.50	48.05

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050319-11	Disk, source and hex code	5.20	9.75
050319-41	AT89C52/24JI, programmed	7.60	14.25
030451-72	LCD Module 2x16 characters	7.25	13.65
030451-73	PLED Module 2x16 characters	25.50	48.05

Timer Switch for Washing Machine

050058-1	PCB	8.90	16.70
050058-11	Disk, PIC source & hex code	5·20	9.75
050058-41	PIC16F84, programmed	13.10	24.65

NO. 349 DECEMBER 2005

From A to D via USB

050222-1	PCB	7.95	14.95
050222-41	IOW24-P, programmed	9.40	17.75

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January	Recycling / Reverse Engineering
February	Motors / Propulsion
March	Development / Microcontrollers
April	Power Supplies / Safety
May	Soldering / Etching
June	Test & Measurement
July/August	Summer Circuits
September	RFID / Satellites
October	E-Simulation
November	**Chipcards / Security**
December	Electromechanical / Enclosures

Chipcard Readers

A suitable card reader is required whenever you want to develop or analyse circuits whose operation depends on chip cards. Some applications require a blank chip card, others, a card with an operating system on the chip. In this article we present two chip card readers capable of reading the vast majority of today's 'flexible friends'. The first design reads FUN and Jupiter cards, the other, Phoenix, SmartMouse and JDM. In good Elektor tradition we not only discuss the DIY aspects of these readers but also the principles of operation of various types of chip card.

Market Overview: Solder Stations

If you're an Elektor reader (and you are), you'll need one: a solder station, preferably one suitable for soldering tiny parts like SMDs which find ever wider use in electronics.For our market overview we asked relevant suppliers to send us solder stations in the 25 to 300 pound price range. Some 15 stations eventually arrived and were subjected to a couple of basic tests. You can read the results in the November issue.

USB Stick with ARM and RS232

This may well be the 'missing link' between your PC and a microcontroller circuit. Thanks to an ARM controller and smart software, this little card is RS232 compatible at the 'micro' side, and USB compatible at the PC side. The board has a slot for MMC and SD memory cards, allowing you to determine the best memory capacity for a given application.

R8C competition results

Also...

Zigbee with Xbee*; RTOS for the R8C, Marten Deterrent, FPGA Course (6); Hexadoku.

** due to lack of space these articles could not be accommodated in the current issue.*

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