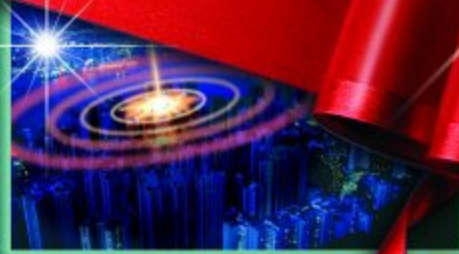


## WHAT GIFT for the spoilt electronics fan

gadgets, gizmos and wannahaves



• Electronic Warfare dangerous fields!

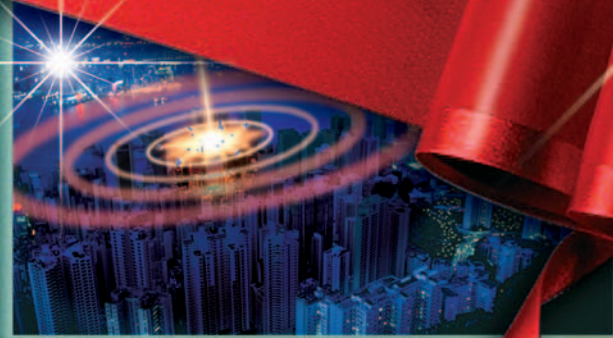
### Build it!

- Reverse Engineering toy R/C car as router control
- From A to D... via USB!
- Telephone Supervisor
- Christmas Light String



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## From the Editor's desk

Early reports show that our November 2005 issue with its free Kaleidoscope e-CAD DVD achieved not only good sales figures but also a number of sell-out reports from several major newsagents including WHS shops. As our distributors do not restock sales points, the best way now to get your copy of the issue with the free DVD inside is to contact our Customer Services department, see page 6 for the contact information. Feedback on the free DVD is starting to come in, too. We had a good laugh when someone reported that the Kaleidoscope DVD would not run on the CD-ROM player in his PC nor on the family's DVD player connected to the TV set ("no music or menu on me screen"). We've launched an on-line Survey to help us find out which of the programs on the Kaleidoscope DVD our readers think is the best of the lot. The Survey is accessible via our homepage.

E-blocks have rocketed into popularity, proving that the concept of 'connectivity for the future' holds true. Designs using E-blocks are starting to come in and we sure hope to publish some in the near future. Meanwhile, this December issue has an article on Flow-code, the magic software behind E-blocks. This issue marks the end of two article series: *Delphi for Electronic Engineers* and *Quizz'Away*. As a cautious estimate, the Delphi course has attracted about 3,000 followers so we can confidently say it's been a resounding success. *Quizz'Away* will be followed up by a different kind of puzzle to stimulate the grey matter — in hexadecimal fashion.

Finally, hot news from the Elektor lab! The resident pizza oven is temporarily out of order while Paul Goossens is converting the thing into an SMD bakery — look and smell in the January 2006 issue. Meanwhile our drinks fridge is back to normal — see page 8.

**Happy reading and enjoy the Christmas holidays.**  
**Jan Buiting, Editor**

## 18 Jumbos and Minis



Displays are probably the most important man-machine interface. Everywhere you look — televisions, monitors, and industrial applications — the old-faithful CRT display technology is losing ground and being superseded by more up-to-date technologies, which are also conquering new application areas. In this article we look at the current situation and examine possible future trends.



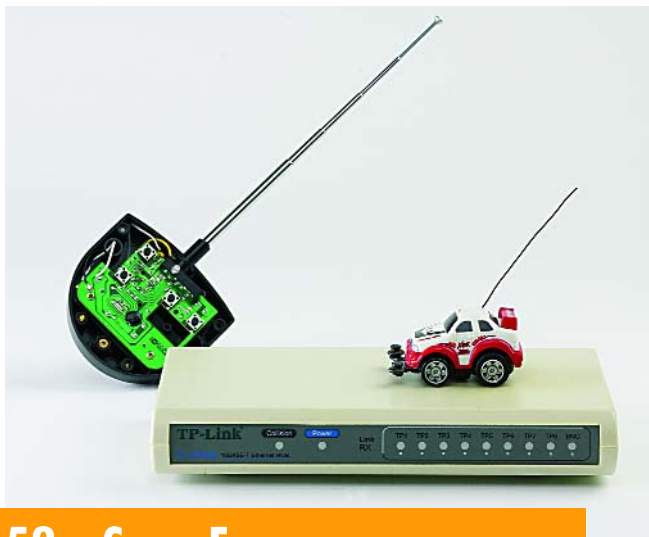
People have been busy experimenting with electricity ever since it was 'discovered'. Many good things have come out of these experiments, and the world would look completely different without all our electronic aids. But there's also another, darker, side to the picture.



## 36 Telephone Supervisor

If you have a fit looking at your monthly phone bill you might want to know who's on the phone all the time. Also, you may want to start exercising control over which extension in your home is disabled or enabled. Our Telephone Supervisor comes with smart Windows software that puts you (back) in control of things.

**We thank all our readers, contributors and advertisers for their support during the past year and wish you all a happy and peaceful 2006.**



## 52 Save Energy by Reverse Engineering

This design shows a toy R/C car can be adapted to act as a (W)LAN Router 'watch-dog' to switch the Router on or off depending whether any networked PCs are present.

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## Towards the Zero-Oil Noise Cancelling PC Cooler

Dear Jan — I have come to the conclusion Elektor Electronics should include a Public Health Warning on its

front cover. I had a pink fit when I read in the October 2005 issue — a PC had been immersed in oil to eliminate

noise and heat. There are far simpler solutions to the problem of PC heat and noise, and far more enjoyable than having to explain to one's wife why oil is dripping onto the carpet!

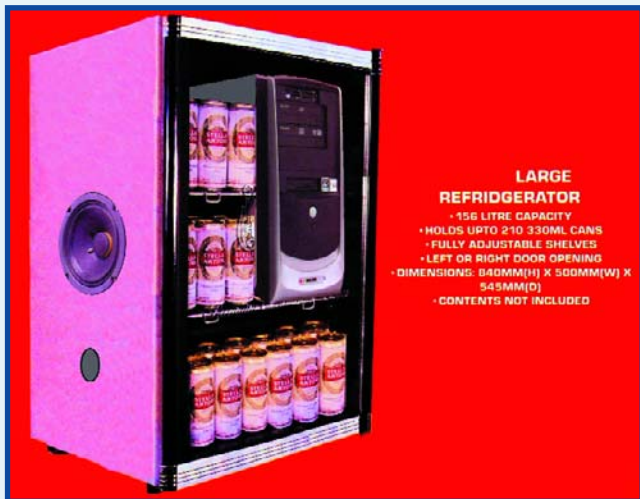
Firstly, buy a small domestic fridge. Bore a 50-mm hole in the side, remove the shelves then carefully install the PC inside. Feed all the cables through the hole, then fill the remaining fridge space with cans of beer or lager. Software and hardware crashes take on a whole new dimension as one downs several cans of lager. Secondly, for those troubled with PC fan noise — could I suggest your buy a microphone and large speaker, and con-

struct a noise cancelling circuit. Not only will it eliminate fan noise, but will deaden the noise of your raucous singing while you are attempting to repair the crashed PC!

**David Jack (UK)**

*Excellent idea David but what to do about the heat and noise generated by the fridge, and the objections of the Missus against a fridge installed for the sake of a PC?*

Good morning Jan — you must own a very old fridge? From my experience modern fridges are ultra quiet. Repositioning the microphone over the compressor would resolve that problem.



## Rejektor

Under this heading we will occasionally publish circuits, ideas and suggestions that did not make it to full publication in this magazine for various reasons (like lack of space).

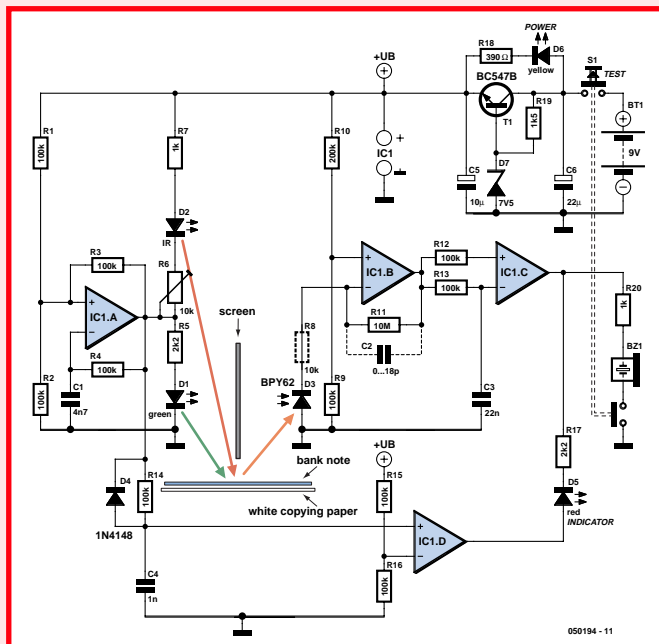
### Euro forgery detector

The detector for forged Euro banknotes as proposed by Mr. Karl Prodingler is marked by an interesting measurement principle and a well thought out concept complete with some remarkable technical tweaks. Initially we wanted to post-engineer this project into a full-blown Elektor Electronics DIY project but arguably the mechanical construction so essential in this design is hard to make repeatable in an electronics magazine like ours. However, the approach to the problem is innovative enough to warrant publication in this month's Rejektor section. Possibly readers in the UK and USA are able to modify the design for use with pound sterling or US dollar banknotes respectively.

The measurement principle is based on a lesser known characteristic of Euro and other banknotes: sections of the banknote surface are printed using infra-red blocking ink, while other sections have ink on them that's transparent to IR light. The difference is not visible until the banknote is held under an IR light source, as evidenced by the photo showing a 10 and a 50 Euro note being tested. The banknotes are placed on a white background. Under IR light exposure, only the right-hand side of both banknotes is visible, the wider, left-hand part remains white. The author used a simple monochrome video camera without a built-in IR filter to view the results. A piece of black film carrier material in front of the camera objective was used as a filter against visible light and so boost the camera's IR sensitivity. A couple of IR LEDs may be used for the light source, but off the shelf halogen lights are also quite suitable as they emit quite a lot of IR light.

The circuit shown here is based on an approach filed under no. AT6392U with the German Patents Office. On the DEPATISnet website you can view patents applied for free of charge (<http://depatisnet.dpma.de>).

The circuit is built around a quad opamp type TL084 and is remarkable for having just one adjustment point. The measurement setup for the detection light reflection against the surface of a banknote consists of two LEDs and a photodiode. LEDs D1 (green) and D2 (IR) are driven by an oscillator built around IC1.a. It supplies a frequency between 1 and 3 kHz. By means of an array of series resistors, the intensity of the LEDs is controlled. Preset R6 is required to compensate product tolerances on the BPY62 photodiode as well as response deviations



My main concern is the noise generated from the fridge door being constantly opened and closed to check the beer is cold enough!  
The image on the left shows the proposed 'Zero-Oil Noise Can-

selling PC Cooler'.

*Excellent comment again David and the right-hand photograph shows our editorial fridge on a typical Friday afternoon around 2 pm.*



### Formant synth goes online

Readers may like to know that some 25 years after publication, the world-famous Elektor Formant synthesizer still enjoys great popularity and is graced by a group of staunch supporters. Formant users may be found in a Yahoo discussion group at <http://launch.groups.yahoo.com/group/ElektorFormant/>



### Battery backup for bike — help please

Dear Editor — I believed I had thought up a simple battery backup using capacitors to isolate the 'dynamo' from DC and an optoisolator driving a transistor (with series diode) to switch the backup.  
I was quite hopeful about my design but in practice puzzlingly it seems not to work —

it won't switch over to the dynamo!

I had hoped to send it as a circuit idea — perhaps you could use it for your puzzle page.

**Alan Bradley (UK)**

*Thanks Alan, your hand drawn circuit is reproduced here for*



between the LEDs, ensuring stable operation of the detector over longer periods. Opamp IC1b is configured to act as a transimpedance amplifier typically used with photodiodes (here, D3). Sensor D3 has to be fitted with a piece of black heat shrink tubing to prevent ambient light corrupting the measurement results. The circuit around the third opamp, IC1c, is fairly unusual. Both inputs receive the same signal, but only the inverting input has a capacitor to ground (C3). This capacitor allows the signal supplied by the BPY62 to be averaged (remember, the LEDs are controlled by a rectangular signal, hence produce light pulses). The function of this stage is the crux to the operation of the entire circuit. While the inverting input of the opamp determines the average value of the signal, the non-inverting input receives the brightness values resulting from the light reflections on the banknote. When the banknote paper has IR blocking print on it, D3 will receive a small amount of light from the two LEDs. If, on the other hand, the ink is transparent to IR light, D3 will receive a weak signal from the green LED (D1), but a strong signal from IR LED D2. The stronger signal is converted by IC1c into a nearly rectangular-shaped signal.

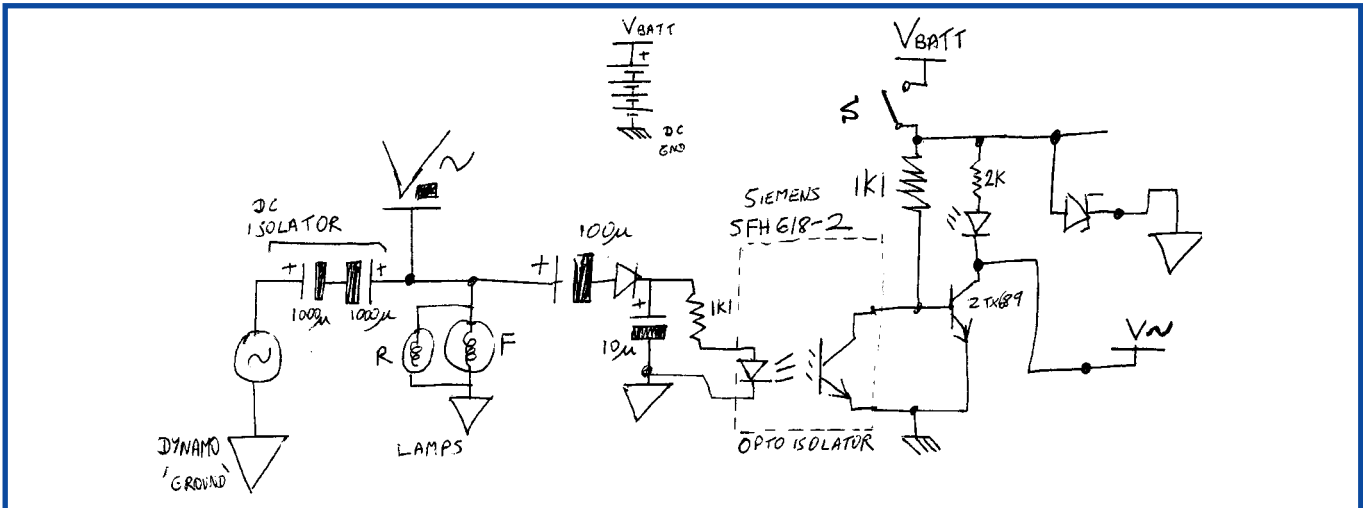
The fourth opamp in the circuit, IC1d, serves to compensate the difference in propagation time between the oscillator output and the output of IC1c. The output of IC1d supplies signals synchronously with IC1c output signal. Although the

rest of the circuit looks fairly simple, we are in fact looking at a complete synchronous demodulator. The pulses at the outputs of IC1c and IC1d are compared using LEDs D5 and series resistor R17. If a clear signal appears at the output of IC1c as a result of IR-transparent ink, this signal will be in anti-phase with that at the output of IC1d. Diode D5 then lights to indicate the presence of the IR transparent ink. Via R20, this point is also connected to a piezo buzzer providing an audible indication.

The power supply section built around T1 ensures good stabilisation of the supply voltage. A power-ok indicator has been added in the form of yellow LED D6. If the battery voltage drops, so will the LED current, eventually to a level so low the LED will go out. The author's prototype was built using SMD parts because the resultant shorter PCB tracks allow the sensitivity of the opamps to strong RF fields to be kept to a minimum. In the event of RF oscillations arising, the dashed components may be added (R8, 10k; C2 approx. 10pF). To adjust the circuit, the tester is held above a couple of sheets of white (copy) paper. Preset R6 is adjusted for LED D5 to just come on. This setting remains stable — due to the signal averaging (there is no fixed reference value for IC1c), any drift on part of D3 can have no effect. Provided it has been built correctly, the circuit will then respond reliably to IR-transparent and IR-blocking types of ink.

In practice we still need to look at the problem of finding the right areas on banknotes to be subjected to the false/good test. In the relevant range the transition from IR-transparent and IR-blocking has to be recognisable as clearly and reliably as possible to ensure that really good forgeries are also detected. With the 10- and 50-Euro banknotes in the photograph, the relevant transition area is near the figures in the top right hand and bottom right hand corners. In this test area, the banknote has to show a clearly visible decolouration effect. With a larger white component (lighter print) it is however possible that the brightness difference detected by the IR test is too small.

The rear (verso) side of Euro banknotes (showing the bridge motif) is entirely transparent in the IR range, only the serial numbers will show up black. Information on commercially available banknote testers may be found at, among others, [www.wekaverif.com](http://www.wekaverif.com)

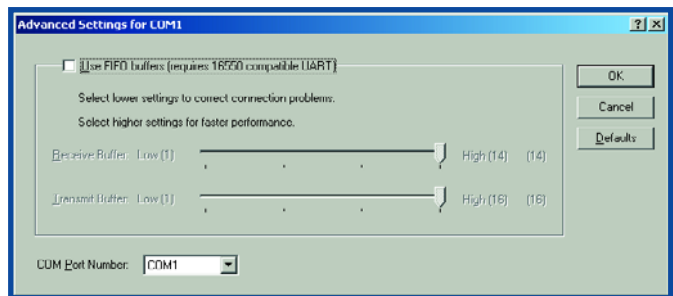


other readers to examine and hopefully help you discover where the fault is! Please send feedback to the Editor so this subject may be continued in a truly constructive way!

This month's issue has the last instalment of Professor Ohsmann's 'Quizz'Away' series of electronics brainteasers. As of January next year we will be printing a contemporary puzzle for the electronics-minded to pit their wits against.

**Windows FIFO buffer**

Dear Editor — I refer to the inset on page 35 of the October 2005 issue ('Colossus Jr.', Ed.) where you show that disabling the FIFO buffer in Windows XP can help to solve problems with RS232 serial communication. While experimenting with a DCF77 time signal receiver module, I discovered that switching the FIFO buffer does not take effect until the PC is restarted. This may be confus-



ing as the operating system does not produce a matching message. Without a restart of the system it would seem that changing the FIFO settings has no effect.

**Peter Simoons (Netherlands)**

*Thanks for that Peter, the word is being passed on.*

**SMD soldering aid**

Dear Elektor staff — I applaud the attention you give in your articles to the problems of SMD soldering.



Being an electronics designer myself, I recently had my own share of problems with these tiny bits and decided to build a special tool to help me get them properly soldered onto a board. To my surprise, inexpensive tools that help you get an SMD properly soldered are few and far between. My design for an SMD locker may be found on [www.midibutton.nl](http://www.midibutton.nl).

**G. Bouland (Netherlands)**

*That looks like a very useful little tool indeed, and we print a photograph of the device here. It may be ordered through Mr Bouland's website. This month's Design Tips pages also show an SMD soldering aid.*

**Marketplace**

We're pleased to say that the Forum and E-News pages of our website attract a lot of visitors every day. Not so, as it turned out, with the Marketplace section we set up earlier this year, and that is why we

**Corrections & Updates**

**ESR/C Meter**

September 2005, p. 30, 040259-1.

The parts list states a wrong enclosure; this should be a Hammond type 1593YBK.

FAQs on this popular project may be found on our website Forum.

**1-MHz Frequency Counter**

July/August 2005, p. 100, 030045-1.

The original software contained a few errors and a new version may be obtained from our website (ref. 030045-11.zip).

The software has been written for a 4.194304-MHz quartz

crystal. To enable the microcontroller to be used with an 8.388608-MHz crystal, the program has to be modified as explained in the source code file, and then compiled again.

**Precision Barometer/Altimeter**

September 2005, p. 54, 040313-1.

New software that solves the problems with the real-time clock is now available from our website (ref. 040313-11.zip).

A 56 pF capacitor between pin 12 of IC2 and ground will improve the accuracy of the internal clock.



decided to remove it effectively as of 1 October 2005. However, registered users of our website at [www.elektor-electronics.co.uk](http://www.elektor-electronics.co.uk) can still offer components, equipment, tools, books, magazines etc. for sale, or post a *Wanted* message, in the relevant sections of the Forum. Everyone's invited!



### ESR/C Meter — capacitor equivalent diagram

Dear Editor — as a long-time subscriber to your magazine I enjoyed reading the 'ESR/C Meter' article in the September 2005 issue. I was a little surprised however to see a capacitor electrically represented as a capacity with resistor in series with it. I would have expected a capacitance with a shunt (parallel) resistor (actually, the leakage resistor). How else to explain:

1. A charged capacitor in storage will gradually lose its charge. This can only be due to a parallel resistor across the capacitance.
2. If you connect a capacitor with a series resistor to a voltage source  $U_b$  and select ever higher values for the resistor, you will notice that the voltage on the capacitor will eventually become lower than  $U_b$ . This is explained by the voltage drop across the series resistor due to the virtual resistance in parallel

with the capacitance. Will you share your views on this with me?

**A. Wilcox (UK)**

*The Elektor ESR/C Meter has been a resounding success and also gave rise to some hot debates in Internet newsgroups on electronics.*

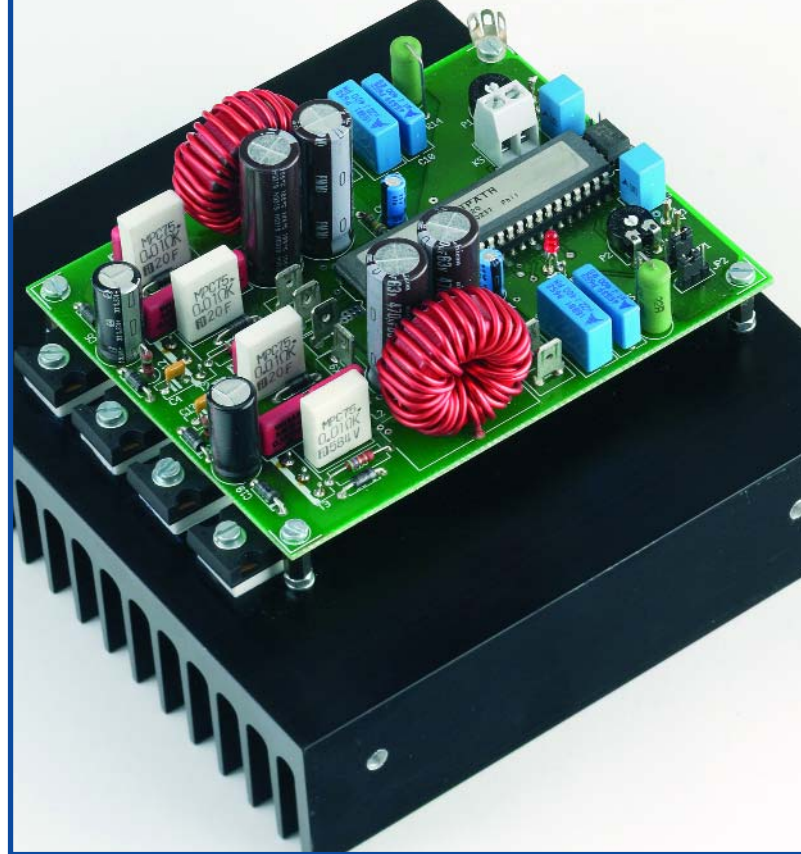
*The capacitor equivalent diagram shown in the article was purposely kept as simple as possible, showing only the main virtual components — in this case, the capacitance and the series resistor, both of which being accurately measured by the instrument. The complete equivalent circuit would also comprise a series inductance (formed mainly by the wire terminals and rolled up electrodes), a shunt (leakage) resistor as you correctly describe (being responsible for all listed effects) and an RC network again in parallel with the capacitance and responsible for the so-called dielectrical absorption of the capacitor.*

*The phenomena you list can indeed be explained on the basis of the comprehensive equivalent diagram.*

### Identifying SMD components

Dear Editor — thanks for a great program called Resistor Colour Band Identifier in 040203-11.zip. However I was wondering if there was a similar program, pdf sheets collection or website for identifying SMD components. I currently use the Farnell/RS cata-

1st character of code		G4PMK's SMD Codebook			
0123456789		Codes beginning with 'A'			
A	BA82	Sie	J	SCD80	35V 100mA pm
A	1SS355	Roh	J	USM	100V 50mA sw
A	MR947	Mot	N	SOT323	npn RF 8 GHz
A0	HMS-2800	HP	C	SOT23	HP2800 schottky
A0	HMS-280B	HP	C	SOT323	HP2800 schottky
A03	VAM-03	MC	AG		modamp MAR 3 Similar
A06	VAM-06	MC	AG		modamp MAR 6 Similar
A07	VAM-07	MC	AG		modamp MAR 7 Similar
A1	HMS-2801	HP	K		HP2800 schottky
A1	BAW56W	Phi	A	SOT323	dual ca BAW62 (1N4148)
A1	BAW56	Phi	A	SOT23	dual ca BAW62 (1N4148)
A1p	BAW56	Phi	A	SOT23	dual ca BAW62 (1N4148)
A1t	BAW56T	Phi	A	SOT416	dual ca BAW62 (1N4148)
A1t	BAW56S	Phi	A	SOT363	dual ca BAW62 (1N4148)
A1s	BAW56W	Sie	A	SOT323	dual ca BAW62 (1N4148)
A1s	BAW56	Sie	A	SOT23	dual ca BAW62 (1N4148)
A1s	BAW56U	Sie	A	SC74	dual ca BAW62 (1N4148)
A1X	MBAW56	Mot	A		ditto
A2	HMS-2802	HP	D	SOT23	dual HP2800
A2	HMS-280C	HP	D	SOT323	dual HP2800
A2	1N4148W	CSC	J	SOD123	1N4148
A2	BAT18	Phi	C	SOT23	BA482
A2s	BAT18	Sie	C	SOT23	BA482



logues which can be time consuming. I think it would be useful to have an article on SMD repair and component identifying. Again, thanks for a great magazine.

**Keith Harris (Australia)**

*SMD identification can be very tricky and time consuming. However, have a look at Mr R.P. Blackwell's excellent overview at [www.marsport.demon.co.uk/smd/mainframe.htm](http://www.marsport.demon.co.uk/smd/mainframe.htm)*

### Clarity on electrostatic speakers?

Dear Jan — can you tell me if the Clarity amplifier (June, September, October 2004, Ed.) is suitable for use with electro-

static loudspeakers? I have built my own ES loudspeakers with depth-adjustable membranes.

*We do not recommend connecting ES drive units to the Clarity amplifier because the transformer with the capacitive load of the electrostatic loudspeaker forms a complex impedance that's sure to affect the output filter response to some degree.*

*To this we should add that the final impedance of a typical ES speaker is likely to drop below 3 W at higher frequencies, which is too much of a load for this amp.*

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## 2.4-GHz WirelessUSB™ Radio-on-a-Chip



Cypress Semiconductor Corp. recently introduced its next-generation 2.4-GHz WirelessUSB™ Radio-on-a-Chip. The new WirelessUSB LP offers the most robust solution with the lowest power consumption for keyboards, mice, and other Human Interface Devices (HIDs), while providing an unparalleled feature set enabling low BOM costs, higher data rate applications, and faster time to market.

WirelessUSB LP operates between 1.8 and 3.6 volts, using many advanced techniques to extend battery life in devices such as wireless mice. The new device uses Cypress's patented Direct Sequence Spread Spectrum (DSSS) and frequency-agile technology to offer best-in-class interference immunity for a 2.4GHz radio system. This combination of low power consumption, interference immunity and low cost make it ideal for wireless HID applications such as keyboards, mice, remote controls, presentation tools and game controllers. WirelessUSB LP brings these benefits to the Voice over Internet Protocol (VoIP) market for products like wireless headsets by transferring data at a maximum speed of up to 1 Mbps.

WirelessUSB LP uses Cypress's patent pending AutoRate Receiver™ technology enabling the device to receive data at any

data rate without the need to negotiate speed changes. In addition, the device includes integrated features such as an automatic transaction sequencer, deep packet buffers (16 byte) for TX and RX, and a boost converter (generating up to 2.7V). These features simplify firmware design, offload processing requirements, allow for the use of lower cost microcontrollers, and power external devices such as optical sensors. The device also has highly optimized timing, including quick startup, fast channel changes, and immediate link turnaround capabilities. All of these enhanced features combine to significantly extend battery life, save design time and reduce overall system costs. WirelessUSB LP lowers support call costs with the user-friendly KISSBind™ feature, which enables a user to intuitively link a wireless peripheral to the desired host by simply bringing them in very close proximity with one another. The device also supports the recently announced TouchWake™ capability to save additional battery power by allowing a WirelessUSB peripheral to instantly wake from an ultra-low-power sleep mode when the user touches it.

More information about the product is available online at [www.cypress.com](http://www.cypress.com).

(057175-2)

## Zigbee-ready wireless network

Cratlon, the wireless sensor semiconductor company, and Betatherm, a leading provider of high precision NTC thermistors and temperature probe assemblies, announced the successful deployment of Cratlon's wireless sensor network at Betatherm's manufacturing plant in Galway. This is believed to be the first successful European deployment of the emergent IEEE 802.15.4 ZigBee wireless protocol in a monitoring system. The results of the deployment were outlined in a paper at the Radio Solutions Conference in Sophia Antipolis, France, on October 12.

The wireless sensor network measures temperature, light and humidity at several locations around the manufacturing plant and performs wireless data transmission at regular intervals to a PC server in Betatherm's administrative office block over one hundred metres away. The measurement modules are powered by long-life batteries with a projected operational life of up to ten years.

The modules use Betatherm's interchangeable Series II range of NTC thermistors, which are suited to high precision temperature sensing in plant monitoring applications because of their

accuracy, sensitivity and robust construction. The wireless network operates in an environment that is particularly harsh for RF signals with the presence of electrical manufacturing equipment, a neighbouring three-storey metal-clad building and a nearby telecommunications tower transmitting at microwave frequencies. Even under these conditions the modules are capable of transmitting over several hundred metres at the ZigBee ISM frequency of 2.4 GHz. The modules can additionally use Cratlon's patent-pending 'Lo-Hop' frequency hopping algorithm to avoid RF blocking in the event of interference from Wi-Fi access points or microwave ovens.

A live-demo link to the wireless network in real-time operation is available at: <http://www.cratlon.com/cratlon/app.html>

Evaluation kits of the modules are now available, and the module design, software stack, sensor interface circuits, and RF deployment guidelines are available for license to OEMs in the energy conservation, building management and related sectors.

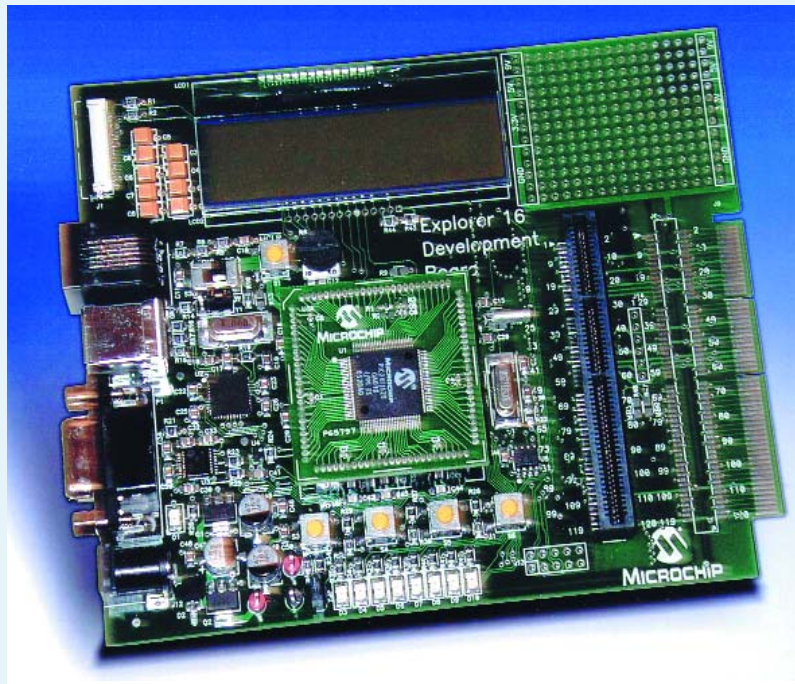
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[www.cratlon.com](http://www.cratlon.com)  
[www.betatherm.com](http://www.betatherm.com)



# Microchip: 49 new 16-bit microcontrollers in one launch

Microchip announces the PIC24 family, its first family of 16-bit PIC microcontrollers. The family debuts with 22 general-purpose devices and offers up to 40 MIPS performance, 16 kBytes of RAM and 256 kBytes of Flash program memory, in packages up to 100 pins. Besides the PIC24 family, Microchip also launched the dsPIC33 family. Both families maintain compatibility with Microchip's MPLAB® Integrated Development Environment (IDE) platform and upward compatibility with all dsPIC® digital signal controllers.



There are two series of devices within the PIC24 family. The PIC24F offers a cost-effective step up in performance, memory and peripherals for many demanding 8-bit microcontroller applications. For even more demanding applications, the PIC24H offers 40 MIPS performance, more memory and additional peripherals, such as CAN communication modules. Overall, the PIC24 delivers increased performance without sacrificing interrupt flexibility and responsiveness, code execution predictability, easy I/O manipulation, C code efficiency and system integrity.

As with all Microchip microcontroller families, the PIC24 is designed to meet a wide range of needs across a broad spectrum of applications. Specific examples include consumer items such as handheld remote controls; communications applications such as optical network components; instrumentation and measurement applications such as hand-held and remote terminals, POS terminals and medical instruments; and industrial applications

such as factory automation systems, building monitor-and-control systems and security/access systems.

Additional key features include: 16 MIPS performance with cost-effective PIC24F family; 40 MIPS operation with high-performance PIC24H family; 64–256 kBytes of Flash program memory; 8–16 kBytes of RAM; 64–100 pin package options with JTAG; 2 x UART; 2 x SPI™ and 2 x I2C™; up to 2 CAN ports; Real

Time Clock Calendar (RTCC); Direct Memory Access (DMA) on PIC24H family; 10-bit, 500 kps A-to-D converter with 16 input channels (PIC24F); 2 x 12-bit, 500 kps A-to-D converters with 16 input channels (PIC24H).

The new dsPIC33 family is highly compatible with the existing dsPIC30 family – it has the same instruction set, has compatible pinouts, and offers an attractive price and feature-set for applications requiring larger

Flash and RAM. The two initial dsPIC33 product families share the following key features: 40 MIPS deterministic performance; 3.3V operation; 64 to 256 Kbytes Flash; 8 to 30 Kbytes RAM; 64- to 100-Pin TQFP packages; serial I/O subsystems, including up to two each: SPI™, I2C™, UART and CAN; Direct Memory Access (DMA); one or two 500 kps, 12-bit A/D converters; Codec interface.

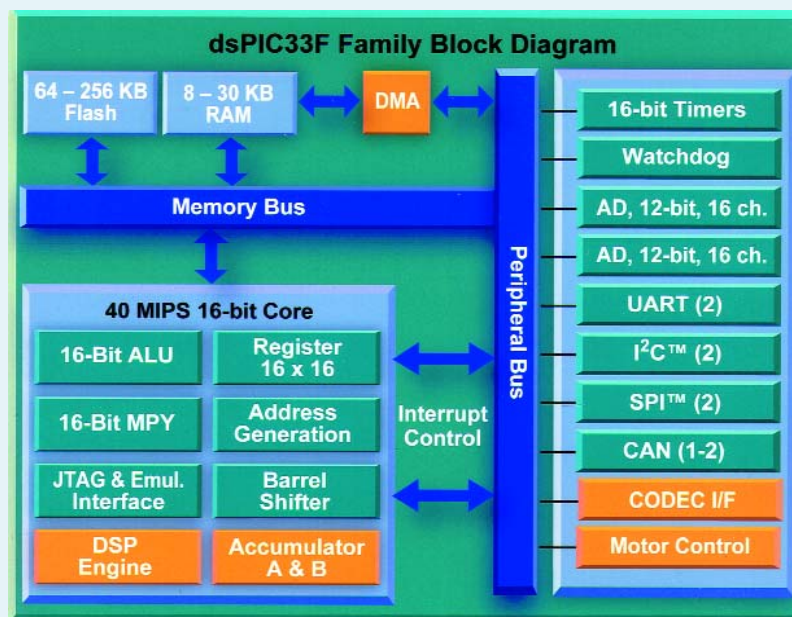
The dsPIC33 Motor-Control and Power-Conversion DSCs have one or two 1.1 Msps 10-bit A/D converters; up to 8 sample-and-holds for simultaneous sampling; specialized PWM for Motor-Control, Lighting and Power-Conversion applications; Quadrature Encoder Interface.

Both new families are marked by backwards compatibility with existing products. A similar pinout and an identical instruction set make the transition from PIC18 to the 16-bit PIC24 as easy as possible. Existing Microchip development tools such as the MPLAB C30 C compiler and the MPLAB PM3 universal device programmer can be used.

Microchip has also created the Explorer 16 Development board to support all 16-bit PIC24 microcontrollers and 16-bit dsPIC digital signal controllers.

Samples are available in the first quarter of 2006 and volume production is scheduled for the second quarter of that year. The Explorer 16 kit (p/n DM240001) will be available from November 2005.

(0577178-1)



Further information from [www.microchip.com](http://www.microchip.com)

## Fusion of anti-collision radar and video sensors for pedestrian safety

Cambridge Consultants has developed pedestrian-sensing software to support its anti-collision radar for automobiles. The technology allows radar and video sensors to work in tandem to sense pedestrians - or cyclists - enabling the introduction of advanced active safety concepts such as tilting the bonnet to mitigate an impact or deploying external airbags.

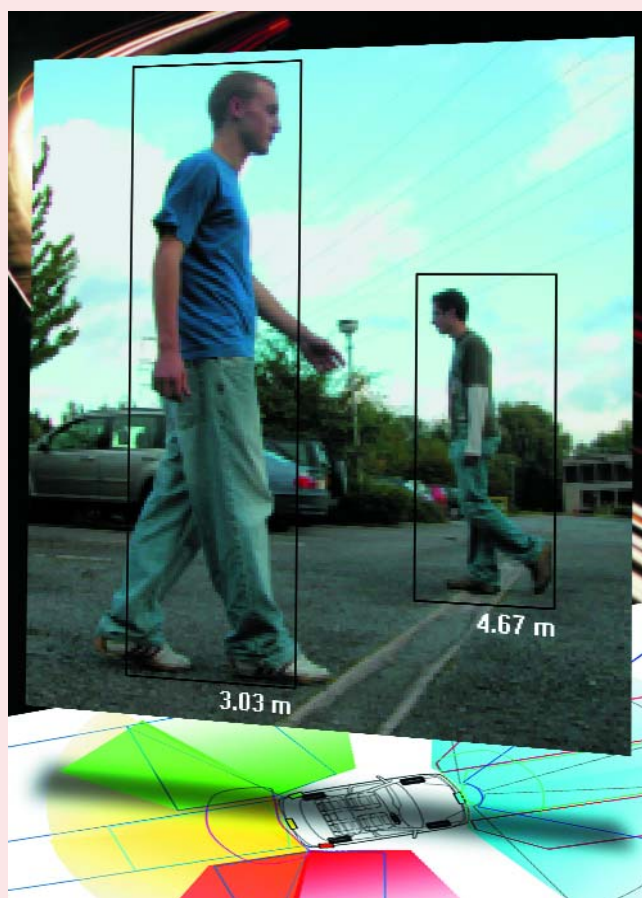
This 'sensor fusion' technology uses the forward-looking radar to cue the video, greatly reducing the amount of real-time processing required. Cambridge Consultants has exploited this to develop a system that can run on a low-cost DSP (digital signal processor) developed for mass consumer appliances - making the technology well suited to the cost demands of the automobile industry.

This low cost focus is complemented by Cambridge Consultants' innovative radar technology, CCL-Softcar, which operates at the low frequency of 5.8 GHz - greatly reducing system costs compared with conventional automobile radar technologies operating at 24 or 77 GHz.

The new software performs object classification. It uses radar scatter information, object movement information, shape and colour matching and other techniques to distinguish humans from other moving objects.

Analysis is performed in real-time. Results from the company's prototype system, which is based on a low-cost DSP, are currently generated at a typical rate of 10 to 20 Hz (or every 100 to 50 milliseconds). Combined with the radar system's 20 to 25 metre range, this provides the time margin required to initiate active safety measures. Among the impact mitigation measures under discussion by the industry are tilting the bonnet to lessen the severity of impact, firing external airbags, and assisting braking.

It's likely that the final object classification rate will be increased to around 50 Hz for commercial use — by selecting higher clock



speed versions of the DSP — to match the new generations of fast, low-cost image sensors currently being developed for automotive applications.

Cambridge Consultants' sensor fusion technology is equally applicable to improving the performance of next-generation reversing aids, by providing the driver with a full colour display where the object classification software automatically identifies objects, along with approximate distance information, to help drivers take necessary action.

This new development is a valuable enhancement of the CCL-Softcar anti-collision radar technology announced in 2003. CCL-Softcar is a pulsed radar system working in the 5.8-GHz band, rather than the 24 or 77 GHz bands used in alternative anti-collision radar approaches. The effect of this relatively low frequency is to reduce the cost of the components required to build a system, and avoid the time and

cost overhead which precision assembly of higher frequency equipment imposes. With this technology, just four radar modules and one electronic control unit (ECU) are required to provide 360 degree protection for an automobile — further reducing the bill of materials compared with alternative approaches, which can require two or more modules to be installed on every side of a vehicle.

The new video-equipped CCL-Softcar demonstration system is installed in a mid-range car, and is currently being shown to European automobile and accessory manufacturers.

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**[www.cambridgeconsultants.com](http://www.cambridgeconsultants.com)**

(057175-1)

## Class D controller chip

International Rectifier recently introduced the IRS20124S, a 200V control IC developed specifically for Class D audio applications up to 500W per channel. Integrated features such as adjustable dead-time generation and bi-directional over-current sensing protect the amplifier system. Also, these features allow audio designers to simplify circuits and minimize component count for Class D audio amplifiers in home theatre entertainment systems, audio-video receivers and automotive sound systems.

The internal, selectable dead-time generation circuit is thermally compensated for stability, and is immune to noise and supply voltage fluctuations to help improve total harmonic distortion, or THD. The IRS20124S has built-in bi-directional current sensing and combines with an integrated shutdown function to protect the output MOSFETs when an over-current condition occurs, such as a short-circuited speaker wire.

The new IRS20124S Class D audio high voltage control IC is available immediately. The device is lead-free and RoHS-compliant.

[www.irf.com](http://www.irf.com)

(057175-3)



# Jumbo and Mini

## Flat-screen displays conquer

Rainer Bücken

**Displays are probably the most important man-machine interface. Everywhere you look – televisions, monitors, and industrial applications – the old-faithful CRT display technology is losing ground and being displaced by more up-to-date technologies, which are also conquering new application areas. Here we look at the current situation and examine possible future trends.**



Photo: Toshiba

In 1897, Karl Ferdinand Braun wrote a paper about 'a method for demonstrating and studying the time progression of variable currents'. In that paper, he proposed using a cathode ray tube (CRT) as a quickly responding display and observation instrument. Braun's idea quickly led to unforeseen new uses. A patent for the 'Braun tube' was awarded in 1907, and in 1930 the German physicist Manfred von Ardenne, who was only 23 at the time, succeeded in transmitting a television image using only electronic techniques.

The basic principle hasn't changed since then: an electron beam strikes a phosphor layer inside a vacuum valve and causes it to emit light. A cathode ray tube consists of a glass envelope with a front surface that is usually convex. That is necessary to withstand the powerful pressure on the outside of the CRT, because the air is evacuated from picture tubes to create a vacuum. A filament and cathode are located in the funnel-shaped neck of the CRT. They are surrounded by a 'Wehnelt cylinder', which forces the electrons to escape through a small

hole. The cathode and Wehnelt cylinder are held at a negative potential that can be adjusted to control the brightness of the image. That assembly is complemented by a set of horizontal and vertical deflection coils and an anode, which is driven by a positive potential. Electrostatic beam deflection was used initially, but it was quickly replaced by magnetic deflection. These components collectively form an assembly that is called an 'electron gun'. The inside surface of the glass envelope has a graphite coating that is connected to a very high anode potential (as much as 17,000 V). A mask in the form of a dot mask, slot mask or aperture grill is located in front of the phosphor layer (see reference [1]).

The evolution of the CRT can be read from the steadily increasing deflection angles and screen sizes. The CRT depth can be decreased by using a larger deflection angle. The most commonly used angles until recently were 65 degrees, 90 degrees and 110 degrees. Types with a 125-degree deflection angle and a depth of around 40 cm are now available.

# er the world

The screen diagonal of CRTs was 23 cm in 1953. In 1955, the standard size was 43 cm. The 110-degree deflection technical breakthrough came in 1970 and led to the prevalence of 66-cm television sets. In 1987, several exhibitors exhibited 82-cm (32-inch) sets, and Grundig even exhibited a 95-cm (36-inch) CRT display. The set weighed in at a hefty 125 kg and had a suggested price of 8000 German marks. In 2001, Sony presented the KV-40XBR700 'Super Triniton' with a 101-cm screen diagonal. That was the high point of the trend everywhere in the world.

## HDTV stimulates innovation

The Japanese television institution NHK has been working to develop high-definition television (HDTV; also known as 'Hi-Vision' in Japan) since 1964. Instead of 525 horizontal lines as specified by the NTSC standard commonly used in Japan, the high-definition system was specified to have 1125 lines. It was first demonstrated in 1985 using CRTs and projectors. The first broadcasting tests started in 1986. Digital Hi-Vision broadcasts via satellite were initiated in 2000, and high-definition terrestrial systems were introduced in 2003. The systems are planned to provide coverage for 80% of Japanese households by the end of the coming year.

However, this all requires new displays that can handle the newly created HDTV broadcast standards designated as '1280 × 720p/60' and '1920 × 1080i/30'. The first number of the designation is the number of pixels per line, and the second is the number of lines. The letter 'p' or 'i' indicates the type of image reproduction used: 'progressive' (p) or 'interlaced' (i) (see inset). The final digit specifies the number of image frames transmitted per second. European broadcasters must choose between 1080i/25 and 750p/50. For comparison, the current PAL TV system effectively provides only 2 × 288 lines per image frame. Incidentally, Europe has also been trying since 1986 to establish its own HDTV system with 1250 lines and a 50-Hz half-frame rate. A non-interlaced technique was also on the agenda. Unfortunately, the technology was developed without any attention to the market. On British behest, in late 1992 the EU was prevented from investing any more funds in the programme. The entire affair ended up as a multi-million boondoggle that set back the development of European high-resolution television by many years.

## Large-format plasma displays

In the 1970s, NHK established a plasma laboratory in its Science and Technical Research Laboratories (STRL).

## Interlaced versus progressive

Television broadcasting using interlaced frames was first demonstrated at the German Broadcasting Exhibition in 1935. The technique involves splitting the image frames into two subframes and writing them successively – first the odd-numbered lines, and the even-numbered lines. The persistence of the phosphor and the latency of our eyes cause the two images to merge. The apparent frame rate is thus doubled, which reduces flicker and the required bandwidth. However, the interlacing technique also has drawbacks. For instance, there is a time offset between the two subframes, which causes sawtooth patterns to be generated on vertical edges in rapidly changing parts of the image. Interlacing also causes major difficulties for modern video encoding methods used to reduce data rates.

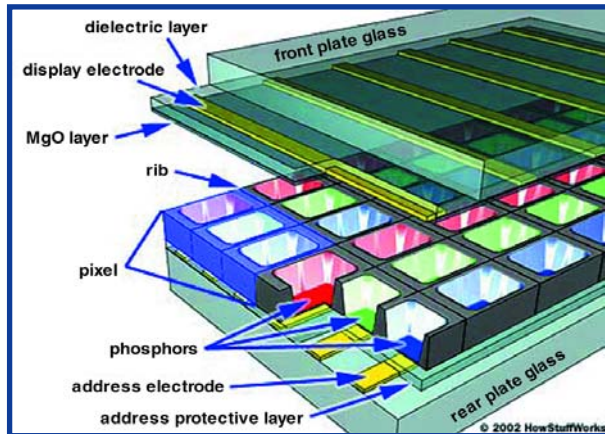
As a result, the 720p standard has become established in the course of the conversion from the European PAL television standard (which effectively provides 2 sets of 288 lines) to high-resolution television (HDTV). Here '720' designates the number of lines and 'p' stands for 'progressive display', which means full-frame display without interlacing. However, good-quality imagery can also be produced using the interlaced HDTV standard 1080i. The next stage is already being discussed with the 1080p standard. It's claimed that the new displays won't have any trouble handling that standard.



**Figure 1.** CRT televisions have been around for nearly 100 years, this one was made in 1960. (Photo: Sony)

Experts from Matsushita also worked in the plasma laboratory. STRL developed the phosphors for the three primary colours (red, green and blue) and the fill gas for the cells. Fujitsu began development of plasma-based displays in 1967 and presented the first panels in 1992, with a display diagonal of 21 inches (53 cm). The world market for plasma TVs may have been as much as 6 million units in that year, which was more than twice as many as in the previous year. Matsushita, which sells products under the Panasonic brand name, is by its own account the world's largest producer, followed by Samsung, LG Electronics and Pioneer. At this year's IFA exhibition in Germany, Panasonic presented 50- and 65-inch displays with 'true' HDTV resolution of 1920 × 1080 pixels. For the domestic market, 1366 × 768 is probably good enough for a start. Samsung also has no plans to market its newly presented 1080-line displays in Europe for the time being.

The largest plasma TV screen yet developed, with a diagonal of 259 cm (102 inches) and a resolution of 1920 × 1080 pixels, also comes from the Korean firm. Even if it only represents a feasibility study, currently available plasma display panels (PDPs) can certainly hold their own without it. With display diagonals of 165 cm or more, they transform living rooms and pubs into personal home cinemas. PDPs are primarily used in television sets and as display modules in locations such as fairs and airports.

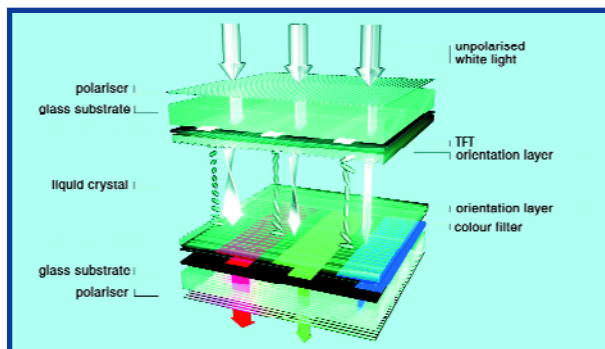


**Figure 2.** Plasma displays do not need an external light source, as they generate UV light by exciting noble gasses in individual cells. The UV light is converted into one of the three primary colours by suitable phosphor coatings in the cells. (Diagram: Clarycon, [2])

### Stimulating light emission from noble gasses

Although plasma displays have a certain external resemblance to liquid-crystal displays, their operating principle is completely different (see **Figure 2**). Two glass substrates enclose a large number of small cells that are filled a mixture of the noble gasses argon, neon and xenon and whose walls are coated with a phosphor for one of the three primary colours (red, green and blue) [2]. Ultraviolet light is generated in each cell by a high voltage (approximately 500 V) applied to an address electrode and a display electrode. The ultraviolet light is converted into visible red, green or blue light by the phosphor coating on the walls of the cell. The question of whether it is better to use a DC voltage or an AC voltage to excite light emission from the plasma was disputed for a long time. Most current PDPs use AC excitation. According to video expert Wolfgang Klinger of Panasonic, they have lower power consumption than DC types.

Relative to CRT displays, plasma displays have better brightness uniformity between the centre of the display and the edge regions. They also allow displays with



**Figure 3.** Schematic diagram of an LCD. Polarized light is 'rotated' by the helical liquid crystals and can thus exit via the second polarizing filter, which is rotated by 90 degrees relative to the first one (see text). The pixel thus appears to be bright. If an electric field is applied, the liquid crystals straighten out and no longer rotate the plane of polarization of the light. That results in a dark pixel. (Diagram: Merck)

large diagonals to be manufactured relatively economically. However, these benefits come at the cost of slightly higher power consumption. The power consumption of plasma displays is variable and reaches a maximum with large white areas, while the power consumption of LCDs is primarily determined by the background illumination source and is nearly constant. The total power consumption of some plasma displays is as much as 50% higher. However, Panasonic recently proved the opposite situation during an internal demonstration: plasma displays can perform better than LCDs with low-brightness imagery.

In any case, the time when plasma displays required enormous fans is long past. However, the useful life of the displays is still a subject of heated debate. The maximum operating time of plasma displays is often specified as 30,000 hours, but figures of 50,000 to as much as 60,000 hours can now be regarded as realistic. After that time, the luminous efficiency of the phosphor starts to gradually decrease, so accurate colour reproduction is no longer possible. On the other hand, 'burn-in' effects are quite rare with proper use.

### A liquid-crystal all-rounder

The growing significance of liquid-crystal displays (LCDs) is due to the large variety and versatility of their potential uses. Liquid crystals were first described in 1888 by the Austrian Friedrich Meinitzer, and in 1963 the American R. Williams discovered their electro-optical properties. The first LC display was created in 1968, and in 1973 Sharp introduced a pocket calculator with an LCD. In June 1983, Casio presented the first LCD pocket television set with a 2.7-inch (67-mm) display. Starting in 1985, portable computers became a reality with the Toshiba model T1000, and similar colour displays were first marketed in the early 1990s. It's estimated that around three million LCD television sets were sold worldwide in 2003, and the predicted figure for 2008 is 30 million. Turnover from flat-screen displays increased from 45 million euros in 2003 to 80 billion euros in 2006, with LCDs accounting for around 70% to 80% of that figure.

A LC display is constructed using the sandwich principle (see **Figure 3**). Light from a backlight source passes through a polarizing filter on the outer surface of the first glass plate and the first electrode layer. After that it encounters the liquid crystal layer, which is located between two orientation layers. That is followed by another electrode layer, an insulation layer, a colour filter, a glass sheet, and a second polarization filter. The orientation layers are aligned at right angles to each other, which causes the crystals to assume a helical shape along the light path in the absence of an applied electric field. The light is polarized in a specific plane by the first polarizing filter, and the plane of polarization rotates by 90 degrees as the light passes through the liquid crystal layer. That allows it to emerge through the second polarization filter, which is suitably rotated by 90 degrees relative to the first filter. This process yields a bright pixel.

If an electric field is applied to the crystals, they lose their 'twist'. As a result, the plane of polarization of the light does not change during its passage, so the light is blocked by the second polarization filter. The pixel thus appears to be dark.

## Overcoming teething troubles

LC displays and projectors are classified into two types: reflective and transmissive. With a reflective type, light from an external source is reflected by an internal mirror, while a transmissive type uses light produced by a built-in lamp. The light must also pass through the LC layer during projection. If the pixels are not driven by transistors, the display is called a 'passive' display. With an active display, which is also called a 'thin-film transistor' (TFT) display, each pixel is driven by a transistor. That results in a very fast frame rate. The response times of top-end displays are currently around 10 ms, with values as low as 4 ms now being quoted. The luminance of LCDs can be as high as 800 candela per square metre, while a realistic value for PDPs is only 500 cd/m<sup>2</sup>, although some manufacturers now claim up to 1500 cd/m<sup>2</sup>. Plasma displays have the advantage with regard to contrast, which is the ratio of the luminance of the brightest possible and darkest possible pixels. They have values of 800:1 to 5000:1, while LCDs sport figures of 400:1 to 1000:1. However, that situation could change. NEC exhibited a LCD monitor with LED background illumination that can achieve precise colour reproduction. That makes an integrated luminescent lamp unnecessary. Dynamic control of the brightness of the backlight allows the illumination to be increased for bright scenes and reduced for dark scenes. Besides reducing energy consumption, that makes dark images truly dark.

Incidentally, a restricted viewing angle is now regarded as a teething problem that has long since been overcome. Viewing angles of up to 180 degrees are not uncommon. Sharp and Philips have introduced new displays that show completely different images depending on the viewing angle (**Figure 4**).

## Big is beautiful

It is already possible to construct displays using LC technology with display diagonals of 3.5 to 208 cm (1.5 to 82 inches) and resolutions up to 1920 × 1080. Even QUXGA-W resolution (3840 × 2400 pixels) is feasible for computer monitors. The largest LC display to date, which Samsung presented a few weeks ago, still doesn't represent the end of the line. According to reports from a recent international display convention, a 102-inch unit is currently being developed.

The market leader in LCD technology is by all accounts Sharp. It has a 45-inch display with HDTV resolution (1920 × 1080) in its product line for a year already, and a similar 65-inch version was exhibited at the fair. The production figure was said to be 1000 units per month. Loewe even displayed a 65-inch set in Berlin with an integrated HDTV receiver.

However, the prices of LCDs are still quite high, particularly for true HDTV displays. For instance, the official selling price in Japan of the 65-inch display exhibited by Sharp in Berlin was said to be the equivalent of

15,560, although it was readily available in Tokyo's Akihabara electronics district for as low as 12,500. For comparison, Sharp's 45-inch display is available in Germany for less than 6000.

Production capacities are presently being sharply increased to allow large and medium-sized displays to be produced more economically. Joint ventures for this purpose have been established by Philips with LG and Sony with Samsung. Fujitsu and Hitachi also operate a joint factory.



**Figure 4.** Viewing a television programme and the Internet at the same time on a single LCD: this special Sharp display could solve space problems. (Photo: Sharp)



**Figure 5.** OLEDs have primarily conquered a market niche for small displays. (Photo: Novalod)

Sharp and other manufacturers already have production lines that mass-produce man-sized 'mother panels'. The first eighth-generation plant is currently being built in the Japanese city of Kameyama. It will produce panels with dimensions of 2.40 × 3.16 metres starting October 2006.

At the same time that screen sizes are increasing, pixel sizes are shrinking. A pixel density of 100 to 200 pixels per inch (ppi) is currently possible, which for example would allow 5-cm displays to be produced in QVGA format (320 × 240) or 9.4-cm LCDs with VGA resolution (640 × 480).

## Organic LEDs

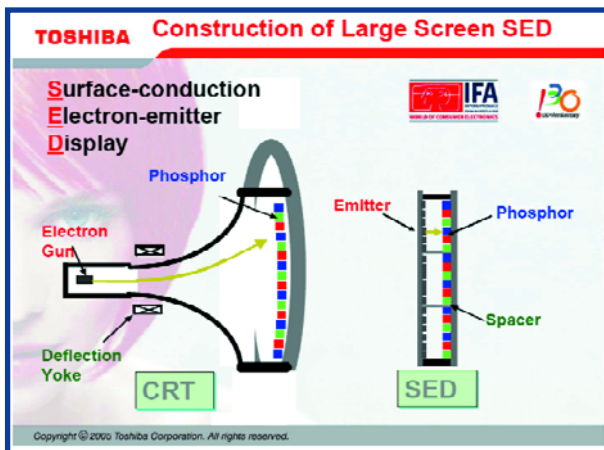
Displays made from organic light-emitting diodes (OLEDs) are one of the most recent flat-screen technologies and have already found a market niche for use in mobile phones and MP3 players.

Development of organic materials began at Kodak in the late 1970s. The key to the technology is semiconducting organic polymers that are applied to a thin glass sheet or plastic film and emit light when a voltage is applied [4]. OLEDs thus do not require background illumination. Organic displays are thin, lightweight and bright, which makes them suitable for use in small portable devices (**Figure 5**). In addition, OLEDs have high switching speeds, which enables them to display moving images quite well. There are approximately 50 manufacturers that supply components or finished products, including Covion, Lite Array, Kodak, Osram, Philips, Pioneer, RIT-display, Samsung, Sanyo, Seiko, Sharp, Siemens, Solomon, Sony, Truly Semiconductors, Universal Display, and Vitex. Intensive research is still being conducted, for example at the Fraunhofer Institute for Photonic Microsystems (IPMS) in Dresden.





**Figure 6.** Philips exhibited an OLED-based flexible display at this year's IFA. (Photo: Philips)



**Figure 7.** A separate mini-CRT for every pixel: SED is a completely new technology waiting to take on the world. (Diagram: Toshiba)

It is expected that in the future it will be possible to produce OLEDs that can be folded and rolled up, which would allow them to provide serious competition to paper (Figure 6). Initial prototypes are currently being presented, but there is still a long way to go before products suitable for mass production are available. Here Europe could have a new opportunity to again make a productive contribution in the display field. Early this year, former German Federal Minister of Research Edelgard Bulmahn announced the 'OLED Research and Development Initiative 2015', with the stated objective of investing around 100 million euros in research during the coming years.

### Displays instead of wallpaper

Philips, which is participating in the programme, is even researching light-emitting wallpaper and drapery. Dietrich Bertram, Manager of OLED Development Light at Philips, is optimistic: 'OLEDs will be significantly more efficient than incandescent lamps, even if their manufacturing costs are several times as high. Light-emitting curtains or wallpaper could be commercially available in three to five years.'

However, there are still a lot of hurdles to overcome before large-format OLEDs can conquer major application areas. The primary problems are excessively short useful life and variable aging of the three pigments (red, green and blue). The blue pigment fades especially quickly. It might take quite a while to achieve the target figure of at least 40,000 operating hours for TV panels. The significant number of transistors required per pixel (two to four) also makes the system quite complex. Furthermore, there is currently no manufacturing technique

available for mass production of large-format panels. Nevertheless, many OLED supporters already regard them as a possible competitor to LCDs, particularly in sizes greater than 2 inches, in good part due to the combination of high resolution and low energy consumption. Once again, the Koreans managed to come up with a real topper. Samsung presented the largest prototype yet produced, with a display diagonal of 101 cm (40 inches), a resolution of 1280 x 800 pixels, and a good contrast ratio. However, such displays are still a long way away from the mass production stage.

### Fit for the future

An important criterion for all display technologies is resistance to obsolescence. CRT-based devices are clearly approaching the end of their product life cycle and will vanish from the market. Plasma technology will primarily remain attractive for large displays. OLEDs have already become established in a small market niche. By contrast, LCDs have reached a high level of technological and market maturity, but they still harbour an enormous development potential. Manufacturers are making substantial investments in research and development. At Sharp, that amounts to the impressive figure of around 7% of their annual global turnover. The growth rates also clearly argue in favour of flat screens, such as LCDs and plasma displays. Analysts expect turnover for both types to jump by more than 30% this year. The German Society for Entertainment and Communications Electronics anticipates that German consumers will spend more than 1.5 billion euros on new displays this year. In the coming year, more than 2.4 million LCDs, 550,000 PDPs, 170,000 front projectors and 80,000 rear projectors could be sold – as well as another 3.2 million CRT-based devices.

The cathode-ray principle may even experience a renaissance, because an entirely new technique is waiting in the wings. Toshiba and Canon are jointly developing a technology called 'surface-conduction electron emitter display' (SED). It promises to yield a resolution of 1920 x 1080 pixels, short response times, low power consumption, large display diagonals (50 inches or more), and high brightness without background illumination. The contrast ratio is said to be 100,000:1. This technique, like that of conventional CRT televisions, is based on directed emission of electrons that cause a phosphorescent layer integrated into the glass surface of the screen to emit light (Figure 7). However, a separate electron emitter is provided for each pixel. The first pilot plant went into production in late August in the Japanese city of Hiratsuka. The Japanese aim to produce 75,000 displays per month by late 2007 and win a market share of 30% for flat-panel displays larger than 50 inches.

(050291-1)

### Useful links:

- [1] <http://arcadecontrols.com/files/Miscellaneous/crtfaq.htm>
- [2] <http://electronics.howstuffworks.com/plasma-display3.htm>
- [3] [www.akihabaraneews.com/en/](http://www.akihabaraneews.com/en/)
- [4] [www.organicsemiconductors.com](http://www.organicsemiconductors.com)

# Electronic W hazardous

People have been busy experimenting with electricity ever since it was 'discovered'. Many good things have come out of these experiments, and the world would look completely different without all our electronic aids. But there's also another side to the picture.

S.H.J.A. Vossen  
and B.J.A.M. van Leersum

Take the radiation from a broadcasting antenna, make it 20 times as strong, and bundle the radiated energy into a narrow beam: you have a powerful weapon in your hands! Such systems are already available to the U.S. army for dispersing crowds. For example, the Vehicle Mounted Area Denial System (VMADS) illustrated in **Figure 1** and **Figure 2** emits strong electromagnetic waves (EM waves) that cause a painful sensation in the skin. It's not known whether there are

any other effects, but those of you who read our electrosmog article in the June issue will certainly realise that other effects are possible. The power of such electromagnetic weapons is naturally scaleable, and it can be quite a bit higher than the example we just mentioned.

## Susceptible

We're accustomed to using a wide variety of electronic devices and sys-

tems in our everyday environment. The amount of electronics used in cars is increasing all the time. Even cyclists and hikers are kitted out with all sorts of gadgets, such as GPS receivers for determining their location and the route to be followed. The use of wireless communication media has also increased enormously, and there's certainly no end in sight to new developments.

All these devices work with electricity, and that means they generate electro-



# Warfare fields!



magnetic (EM) fields. Whether these fields are desired depends on the application. However, there's no question that all electronic systems are also susceptible to external EM fields. For that reason, government bodies set limits to the amount of electromagnetic interference (EMI) equipment and systems can and may generate. These protective requirements are specified in electromagnetic compatibility (EMC) standards, and they are specific to particular products or classes of products.

In Europe, EMC standards are specified in the European EMC Directive (89/336). However, most EMC requirements are limited to frequencies below 1000 MHz, so what happens to or with equipment at frequencies above 1000 MHz is not known.

## Interference signals

There are various ways to generate directed electromagnetic radiation at high power for the purpose of interfer-

ing with the operation of electronic equipment or totally disabling it. One of these technologies is 'High-Power Microwaves' (HPM). EM waves from an HPM weapon are very difficult to defend against in several regards, because they:

- propagate at the speed of light;
- are invisible;
- are not affected by weather conditions;
- are often difficult to detect;
- and the supply of 'ammunition' is practically unlimited.

HPM waves can penetrate into a system in different manners. They can enter via 'front-door' coupling or 'back-door' coupling (see **Figure 3**). With front-door coupling, energy is coupled into the system via sensors and antennas used to detect radio signals. The interference signal can lie inside or outside the frequency band the sensors and/or antennas are normally designed to receive (in-band versus out-of-band coupling). With back-door coupling, HPM energy penetrates the system via ventilation openings, doors, cables, and so on.

HPM is often compared to electromagnetic pulses (EMPs), but an EMP is actually a variation on the idea of high-power microwaves. EMPs are generated by nuclear explosions that cause a natural reaction with molecules in the atmosphere.

## Waveforms

HPM can occur in four forms (see **Figure 4**). The continuous waveform shown in Figure 4a is characterised by its frequency and power. This sort of waveform is usually generated using a resonant microwave tube, such as the



Figure 1. A vehicle-mounted area denial system.



Figure 2. An HPM system fitted in a vehicle.

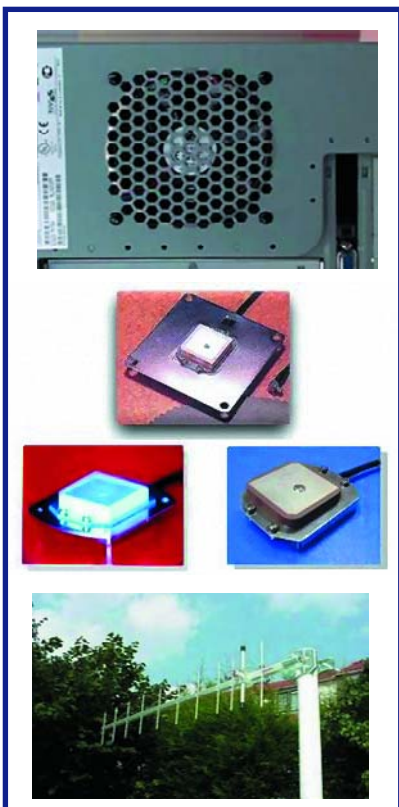


Figure 3. Examples of front-door and back-door coupling paths.

**Table 1. Classification of HPM effects**

Category	Physical effect and consequences
Damage	<ul style="list-style-type: none"> <li>• Discard</li> <li>• Repair</li> <li>• Replace fuse</li> <li>• Repair software</li> </ul>
Denial	<ul style="list-style-type: none"> <li>• As long as the interference signal is present and a short time after the interference signal goes away (no damage)</li> <li>• As long as the user is busy solving problems</li> </ul>
Disturbance	<ul style="list-style-type: none"> <li>• Behaviour altered, no longer usable (no damage or denial)</li> <li>• Minor errors, still usable</li> </ul>
Deception	<ul style="list-style-type: none"> <li>• Modified information paths, insertion of false data</li> </ul>

magnetron used in standard microwave ovens.

The narrowband waveform shown in Figure 4b is the most commonly used form of HPM. Its characteristics are determined by the frequency, peak power, pulse width or energy content of each pulse, pulse repetition frequency, average power, and duty cycle. The advantage of this form is that it's easy to generate a high peak power with a relatively modest total power.

There are two reasons for using a repetitive waveform as an interference signal. The first reason is that it has a higher chance of success because the specific time when interference occurs is time-critical. The second reason is that error-correction systems are often used in systems to combat minor disturbances, which can also occur inside the systems. However, such systems will fail if multiple small disturbances are created in rapid succession.

The types of devices used as sources for this type of waveform include travelling wave tubes, magnetrons, klystrons, and virtual cathode oscillators (vircators).

The third type of waveform is the damped sine wave shown in Figure 4c. Here the important parameters are the dominant frequency, peak power, damping coefficient, and pulse energy. If the waveform is repetitive, the pulse repetition frequency and average power are also important. The advantage of this waveform is that it can be generated using an 'impulse source', in which stored energy is discharged very quickly into antenna. Expensive

vacuum valves are unnecessary with such a generator.

The final waveform (shown in Figure 4d) is called 'ultra-wideband'. Its typical parameters are peak power, rise time, fall time, and bandwidth. This waveform contains a large number of frequencies. However, the peak power of each individual frequency is relatively modest, which reduces the effect on equipment and systems.

This waveform can also be generated without using expensive vacuum valves. However, it requires an antenna that is much more complex than the antennas for the other waveforms (see Figure 5).

### Towards the E-bomb

Systems for generating all the described pulse forms are theoretically conceivable. The emitted power is scaleable, with the upper limit determined by size and the available source of electrical energy. We already mentioned an example of an operational system: the VMADS system.

Another option is to build an HPM system into a ballistic or rocket-powered projectile. From a technical perspective, there are two options for such systems. The first option is to generate HPM using a fully electrical system powered by a source of stored electrical energy, such as a battery, capacitors, or the like.

The second option is to use an explosion-driven HPM system. In the latter type of system, a capacitor generates an initial current in a coil. A metal tube filled with an explosive is located inside the coil. Controlled detonation of the explosive causes rapid compression of

the magnetic flux. At the same time, the surface area and inductance of the coil decrease, which causes the initial current to surge to a very high value (see **Figure 6**). The pulse generated in this manner is a damped sine wave or single broadband pulse. The field is emitted in all directions.

A disadvantage of the 'E-bomb' described above is that it can emit only a single pulse. There is also a risk of injuries or fatalities when explosives are used. Another problem is that up to now, all attempts to use an antenna to radiate the extremely high power that can be generated by an explosion-driven flux compressor have been unsuccessful.

### Social safety and security

We now present several examples that show why HPM could form a threat. These examples are fictitious, and they are intended to stimulate our readers to think about the issue.

#### Scenario 1

We have all recently witnessed the attacks on the public transport network in London.

Suppose HPM had also been used in addition to explosives. That would have made wireless communication between the various emergency services practically impossible, which could have significantly increased the number of victims.

In addition, HPM could have been used to disable the surveillance systems, which would have made it considerably more difficult to track down the perpetrators.

#### Scenario 2

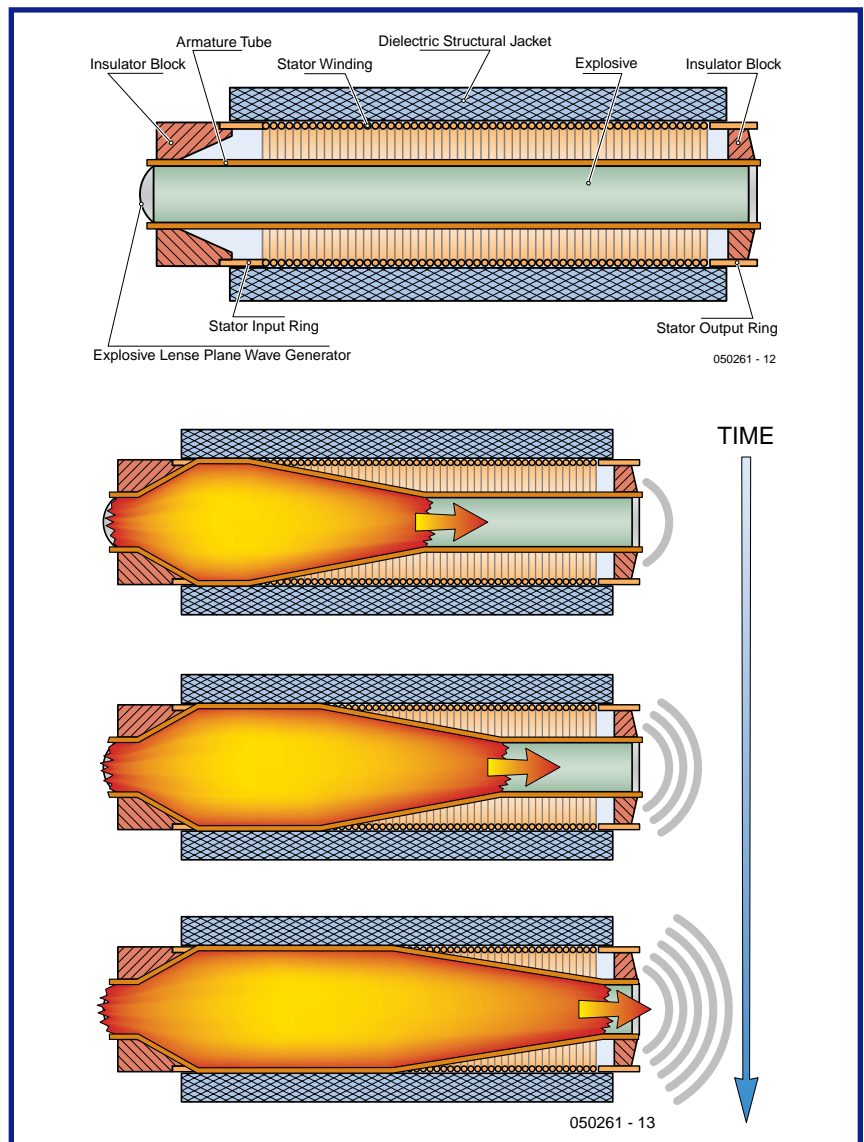
Nowadays, electronic aids are used intensively everywhere in the world. The Internet is also part of this picture. Providers of commercial and financial services naturally take advantage of this by offering all sorts of electronic services via the Internet. The *per-capita* density of computers with Internet connections is very high in most West European countries. In many of these countries, the Internet network is linked to the rest of the world via a central node using a large number of computers. If all these computers were affected by HPM such that they could no longer function properly, the impact would be enormous.

Suppose that on the exact day when salary payments are transferred, the decimal point were to be shifted two

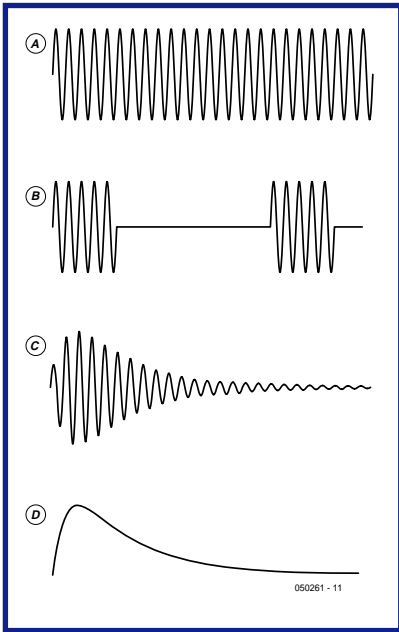
## About the authors

Stefan H.J.A. Vossen has been working in the Observation Systems business unit of TNO Defence, Security and Safety since 2002 (TNO is the institute for technology and physics in the Netherlands). Beside his scientific activities in the field of the effects of electromagnetic fields on people and equipment, he is involved in fostering commercial applications of that knowledge. His subjects of interest include EMC, intentional electromagnetic interference, health, screening materials and applications for such materials, foods, and medical applications. He is also actively involved in developing new technologies and applications (including numerical applications) for TNO in order to deal with future problems.

Bart J.A.M. van Leersum has been working in the Observation Systems business unit of TNO Defence, Security and Safety since 1995. He is engaged in scientific activities in the field of the effects of electromagnetic fields on people and equipment, and he is responsible for knowledge acquisition in his role as research programme manager. His subjects of interest include EMC, EMI, intentional EMI, HPM, antenna technology, integrated topside design, and health-related aspects of EM radiation. His activities range from developing numerical spatial models to formulating and executing test methods.



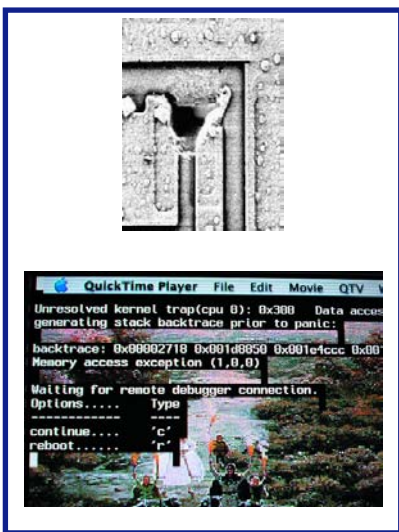
**Figure 6.** An explosion-driven flux compressor. The explosion causes the metal tube to expand, with the result that the coil is shorted out and flux is compressed frontally. That causes an electromagnetic pulse to be radiated.



**Figure 4.** The various HPM waveform options.



**Figure 5.** An impulse radiating antenna developed by TNO, Netherlands.



**Figure 7.** A burned-out diode on a chip (top) and a 'hung' computer (bottom): caused by an internal fault or an external influence?

positions to the left by an intentionally generated glitch. That would cause a lot of confusion and turmoil. Another example is cashpoints or electronic payment transactions using the bankcard system. If the system stopped working during the pre-Christmas shopping season, people would be unable to make their purchases for the holidays. Beside major economic mayhem, that would cause a lot of emotional damage.

**Scenario 3**

This example is probably one of the best-known examples. Suppose an 'E-bomb' (HPM in projectile form) released its energy in a region containing many important electronic nodes. The way an E-bomb explodes is illustrated in **Figure 8**, where the EM wave is represented as white rings in the air. All electronic devices inside the white rings would be unusable. There is a lot of speculation in the media about such E-bombs. However, engineers and scientists are increasingly questioning the feasibility of gen-

HPM in all cases. In addition to the familiar metallic materials, synthetic and composite materials that can provide outstanding protection are now available to help guard against HPM. Normally speaking, such systems are designed to comply with EMC standards. The measures used can be recognised by features such as special cable feed-throughs, screening grilles, and contact springs in computer cabinets.

As indicated in **Table 1**, the effects of HPM can resemble minor disturbances that occur normally in equipment and systems (see **Figure 7**). That makes it especially difficult to recognise intentional sabotage (in case of military applications, for example).

**Worried?**

In this article, we have shown why HPM can cause interference to equipment and systems. Protection is possible, but it requires an awareness of HPM. In addition, it is very difficult to find a single, general-

**Don't try this at home!**

**After reading this article, some of our more experimentally minded readers may be inclined to try a few experiments on their own with an old microwave oven. We emphatically advise against such experiments, because they can create potentially fatal situations!**

erating such high levels of electromagnetic energy from a relatively small bomb.

**Protection**

Generating HPM is probably not particularly difficult (consider the microwave oven, for example). Protecting against HPM is rather more difficult, but it is possible. The most important factor is that persons responsible for equipment and systems must be aware of the phenomenon of high-power microwaves (HPM) and the potential consequences for them. A well-known protective measure is a 'Faraday cage'. That is an excellent solution for an isolated system, but as soon as communication, ventilation or any other sort of interaction must take place via a hole in the cage, it cannot provide adequate protection against

purpose defence against HPM, because one of the specific features of HPM is that the form of threat is not predictable due to the large variety of options.

HPM will doubtless be used on a large scale in the future, because it is a highly promising non-lethal weapon for use in the military theatre and civilian crime prevention. Naturally, people are also afraid that terrorists might employ HPM systems to wreak large-scale damage. Our provisional estimation is that such a scenario is unlikely because it would be difficult to claim responsibility for an HPM attack, in part due to the difficulty of detection and the unpredictability of the effects of HPM. Up to now, terrorists evidently prefer highly violent (and fatal) actions.

(050261-1)

# From A to D v

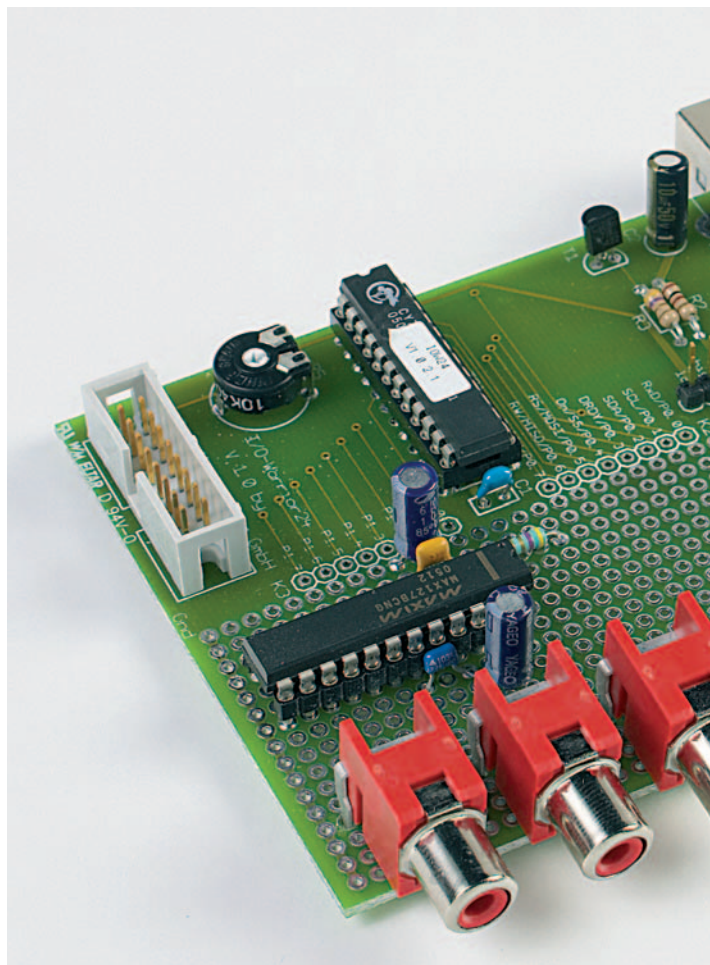
## Eight acquisition channels for

Guido Körber

**Thanks to its ease of use, USB has become a widespread standard. Here we present a data acquisition module with eight channels, using a clever USB chip and a 12-bit A/D converter. Example programs in Delphi make it easy to use the converter in your own projects.**

USB is fast, plug-and-play capable, and can supply enough power for many peripherals: these three reasons explain why this interface is displacing its predecessors in more and more applications. However, the path to using USB in your own applications is not always a smooth one. One possible approach for USB beginners is to use one of the 8051-compatible microcontrollers from Cypress, as we described in 2002 in *Elektor Electronics* [1, 2]. Other USB I/O and interface projects have used microcontrollers from Cypress, Microchip and TI [3, 4, 5].

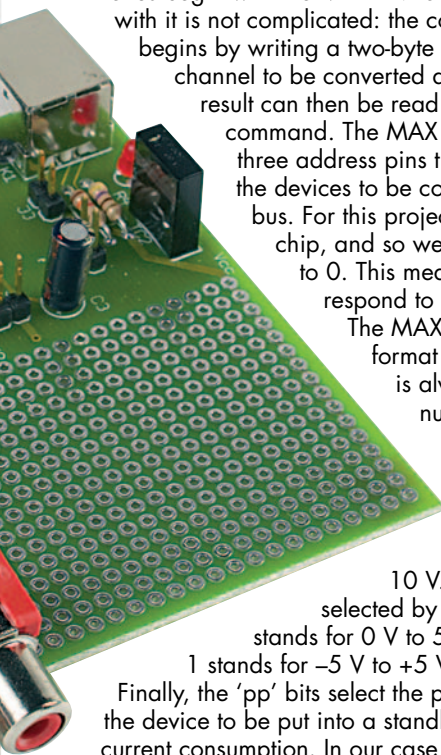
In this project we employ a ready-programmed microcontroller that handles all the management tasks. The 'IO Warrior' chips from Berlin-based Code Mercenaries are a particularly simple and cost-effective way to build a



USB application and a good choice for prototypes, one-off projects or small quantity production (see text box). The devices, however, only offer digital inputs and outputs, a limitation which we can nevertheless overcome by using their built-in I<sup>2</sup>C interface. Using this bus it is easy to connect all kinds of other devices, including A/D converters. In our circuit we use the MAX127, an 8-channel A/D converter with 12-bit resolution. The input range of the ADC can be switched between 0 V to 5 V, 0 V to 10 V, -5 V to +5 V and -10 V to +10 V. The internal reference voltage generator makes it easy to build a unit with reasonable accuracy; if this is not good enough, the pin-compatible MAX128 allows the use of an external voltage reference. There is little else to be said about the circuit itself (see the circuit diagram); we will concentrate more in this article on the software components used.

# ia USB

## your projects



### Reading and writing

Let us begin with the MAX127 chip itself. Communicating with it is not complicated: the control sequence always begins by writing a two-byte command which sets the channel to be converted and the input range. The result can then be read using a two-byte read command. The MAX127 and MAX128 have three address pins that allow up to eight of the devices to be connected to a single I<sup>2</sup>C bus. For this project we are using a single chip, and so we set all the address pins to 0. This means that the chip will respond to I<sup>2</sup>C address \$50.

The MAX127 command has the format '1xxxrbpp'. The top bit is always set; 'xxx' is the number of the input channel to be converted, and 'r' (or 'RNG', for 'range') sets the input range: 0 means up to 5 V, 1 means up to 10 V. Bipolar operation is selected by flag bit 'b' (or 'BIP'): 0 stands for 0 V to 5 V or 0 V to 10 V, and 1 stands for -5 V to +5 V or -10 V to +10 V.

Finally, the 'pp' bits select the power mode, allowing the device to be put into a standby mode to reduce its current consumption. In our case we set these bits to zero. In order to convert channel 0 with an input range of  $\pm 10$  V, therefore, we need to send command \$8C to I<sup>2</sup>C address \$50.

In order to read out the conversion result, two bytes have to be read from device address \$51. The more significant byte is read first. Only the top 12 bits of the result are valid: it must therefore be shifted down by four places. The value can now be suitably scaled according to the settings of RNG and BIP. This is slightly more complex in the bipolar modes, as the 12-bit result is returned in signed two's complement form. Delphi, however, works with 32-bit integers and we therefore have to perform sign extension: if the highest of the 12 bits is set, the remaining 20 bits must also be set. The result is an integer value in the range -2047 to +2047.

The programming language Delphi, which we shall use to drive the converter in our applications, has already had a series devoted to it in *Elektor Electronics* [6]. Since not all readers will be crack Delphi hackers, we have written two example programs to help you use the devices in your own projects. If you do not already have a copy of Delphi, the Delphi 2005 PE version, which can be obtained cheaply or even for free, is recommended.

### Components, Components, Components

The first Delphi example program shows how to install a new 'component' (all source code is available at <http://www.elektor-electronics.co.uk>). Components are a strength of Delphi: a huge number of these modules can be found on the Internet, for example at [7]. Most of these are available for free. In our case we need an HID ('human interface device') component. HID's form a subclass of USB devices, including mice, keyboards, joysticks, and many other devices. The IO Warrior also appears as an HID class device. These components will work under Delphi 6 and Windows 98 (and under Delphi 4 and Delphi 5 with small changes to the project file).

Installation is straightforward. Copy the files to a suitable place and double-click on *HidController.dpk*. The Delphi IDE will appear with the project workspace for the components. Click on 'Compile' and 'Install' and the job is nearly done. The path to the component directory must now be entered into the Delphi IDE so that they can be found: this is done under 'Tools : Environment Options... : Library : Library path'. You can now immediately use the components in your own Delphi projects.

The example program is simple. A *TRadioGroup* is used to set the MAX127 mode, and resulting values are displayed using multiple *TLabel* components. Arrays of components are not directly supported by Delphi, and so we put the *TLabel* components for displaying the results into our own array:

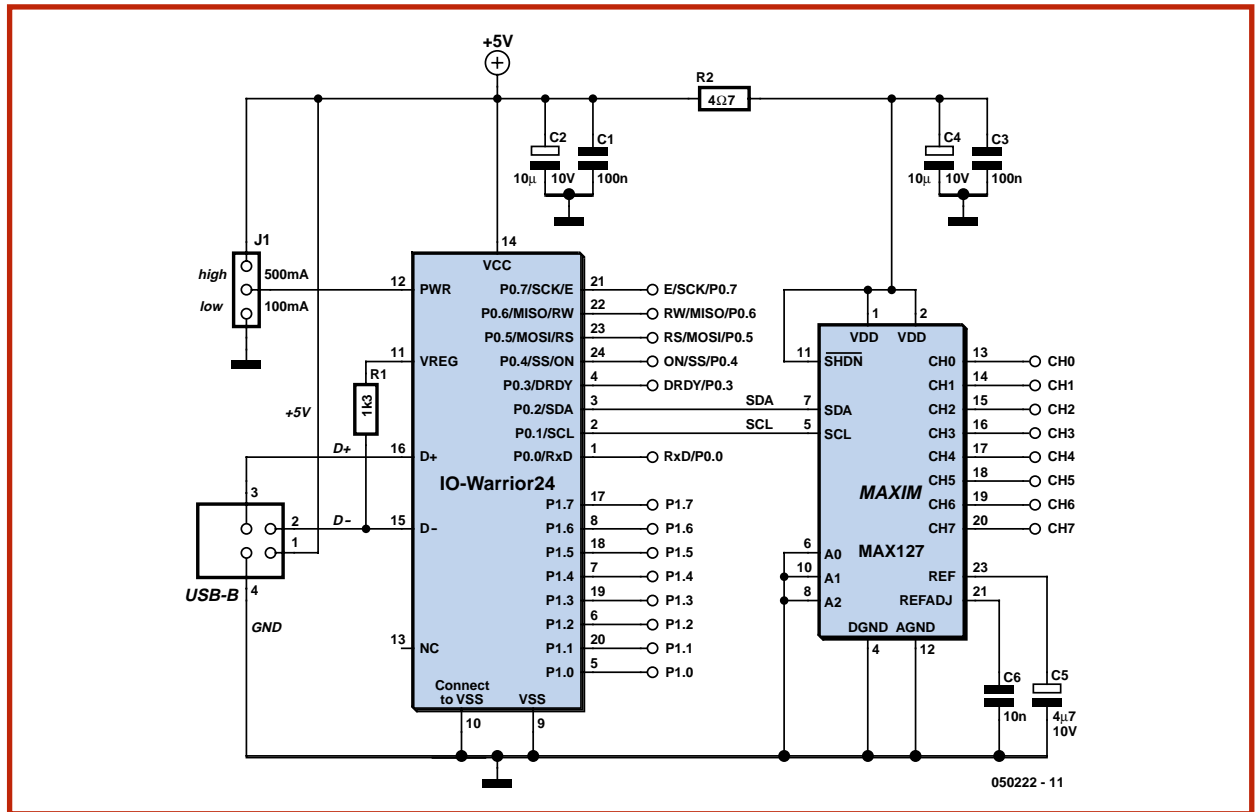
```
procedure TForm1.FormCreate(Sender: TObject);
begin
    // put individual label components in an array
    // so we can index into them
    Values[0] := Label1;
    Values[1] := Label2;
    Values[2] := Label3;
    Values[3] := Label4;
    Values[4] := Label5;
    Values[5] := Label6;
    Values[6] := Label7;
    Values[7] := Label8;
end;
```

### Plug and play

Now we come to the *TJvHidDeviceController* component, which enables access to the IO Warrior. This has an *OnDeviceChange* event which indicates when an HID class device is connected or disconnected. Helpfully, the component simulates the connection of all HID's currently connected when the program is started. The hardest



**Figure 1.**  
The 'IO Warrior' USB chip communicates with the A/D converter over the I<sup>2</sup>C bus.



aspect of managing HID's is that they can be connected or disconnected at any time. A check must therefore first be made to see that the event was not triggered by the disconnection of an IO Warrior already in use; if no IO Warrior is currently in use, then a check is made to see if one is now present, as the event can also be triggered by an IO Warrior device being connected.

The variable *Enabled*, which controls the timer that governs the A/D conversions, is initially set to false. It is only activated when an IO Warrior device is found.

Note that since the A/D converter is written to via the IO Warrior device rather than directly, the I<sup>2</sup>C data have to be assembled into suitable data packets for the IO Warrior. More information on this can be found in the IO Warrior documentation at <http://www.codemercs.com>.

```
procedure TForm1.HidCtlDeviceChange(Sender: TObject);
var
  I: Integer;
  Report: TIICReport;
  BytesWritten: DWORD;
begin
  // has an IO Warrior already in use been disconnected?
  if Assigned(IOWIIC) and not IOWIIC.IsPluggedIn then
  begin
    // switch off read timer
    Kicker.Enabled := False;
    // and deallocate
    FreeAndNil(IOWIIC);
  end;
  // check for new IO Warrior device
  if not Assigned(IOWIIC) then
    if HidCtl.CheckOutByCallback(IOWIIC, @FindIOWComplex) then
```

```
begin
  // IO Warrior found: activate IIC
  FillChar(Report, SizeOf(Report), 0);
  Report.ReportID := $01;
  Report.Bytes[0] := $01;
  IOWIIC.WriteFile(Report, SizeOf(Report),
  BytesWritten);
  // enable read timer
  Kicker.Enabled := True;
end
else
  for I := Low(Values) to High(Values) do
    // no IO Warrior found, indicate value
  unknown
    Values[I].Caption := '?.'?';
end;
```

## Channel sequencing

When an IO Warrior is found its I<sup>2</sup>C function must be enabled by writing a suitable data block. The timer must also be activated to govern the reading of values from the MAX127. The timer function simply steps through all the channels of the MAX127, reading in each case two bytes over the I<sup>2</sup>C bus and suitably displaying the result (see listing in box).

The timer is used to read the MAX127 every 200 ms. It is not possible to run faster than this, as the design of the IO Warrior severely limits the speed of read transactions over the I<sup>2</sup>C bus. It is therefore not really practical to build an eight-channel oscilloscope on the basis of this project!

The assembly of the command bytes for the MAX127 is explained in more detail in the listing (see box):

```
Report.Bytes[2] := $80 or
  (Parameters.ItemIndex shl 2) or (I shl 4);
```

Bit-twiddling is inevitable when dealing with peripheral devices. The format of the byte is 1xxxzy00. The fixed part of this is \$80 (hexadecimal). The start bit must always be set, and the power-down bits must always be zero. The channel number, selected by *l*, is shifted to the left by four bits and inserted into the 'xxx' bits of the byte using an 'OR' operation. RNG ('y') and BIP ('z') are handled as a two-bit quantity. The RadioGroup allows only exactly one RadioButton to be selected, giving its index starting from zero in ItemIndex. Since we have four buttons, this gives the desired two-bit quantity. This is then shifted left two places and inserted into the byte.

Care is required when reading data in bipolar mode as the 12-bit results are signed two's complement values. Conveniently, this is also the case for the integer data type, although in this case the values are 32 bits long. If the most significant of the twelve bits is set, the number represented is negative and sign extension is required, setting the higher 20 bits of the integer to one. The data value can then be scaled and converted to a string for display.

Adapting the program for the MAX128 involves replacing 10.0 or 5.0 respectively by the reference voltage used, or by half of that value.

## Software toolbox

The second example program, which uses the file iowkit.dll from the IO Warrior SDK (freely downloadable from <http://www.codemercs.com>), is very similar to the first. To simplify matters the API ignores the possibility that an IO Warrior might be connected or disconnected. This moves the search for and initialisation of the IO Warrior device into FormCreate, and the read and write functions have a new syntax. The remainder of the code is identical. This example is more suitable as a base for a translation into Visual Basic 6 or Visual C++, since iowkit.dll can also be called from these programming languages, whereas the HID component is limited to use with Delphi. The important part of the example program is therefore now included in iowkit.pas. As with practically all DLLs iowkit.dll is written in C, and the API is in the form of a C

header file iowkit.h. To drive the DLL iowkit.h must therefore be converted into iowkit.pas. This job needs to be done by hand, as the C header file can use all the features of the C language, including C constructions which do not have direct equivalents in Delphi. Space does not permit a full explanation here: the interested reader is referred to Rudi Velthuis' website [8].

In general a C header file consists of simple constants, structures and function prototypes. In Delphi a DLL is directly linked, and so the function declarations must also include the DLL linkage information: this job is done in C by a LIB file, but this has no counterpart in Delphi. The majority of the API normally consists of simple numerical constants:

```
#define IOWKIT_VENDOR_ID          0x07c0
```

which in Delphi becomes a simple constant:

```
const
    IOWKIT_VENDOR_ID          = $07c0;
```

Structures are somewhat more involved, and in the case of IO Warrior we also have to deal with a union:

```
typedef struct _IOWKIT_REPORT
{
    UCHAR ReportID;
    union
    {
        DWORD Value;
        BYTE Bytes[4];
    };
}
IOWKIT_REPORT, *PIOWKIT_REPORT;

type
    PIOWKIT_REPORT = ^IOWKIT_REPORT;
    IOWKIT_REPORT = packed record
        ReportID: Byte;
    case Boolean of
        False: (Value: DWORD);
        True: (Bytes: array [0..3] of Byte);
    end;
```

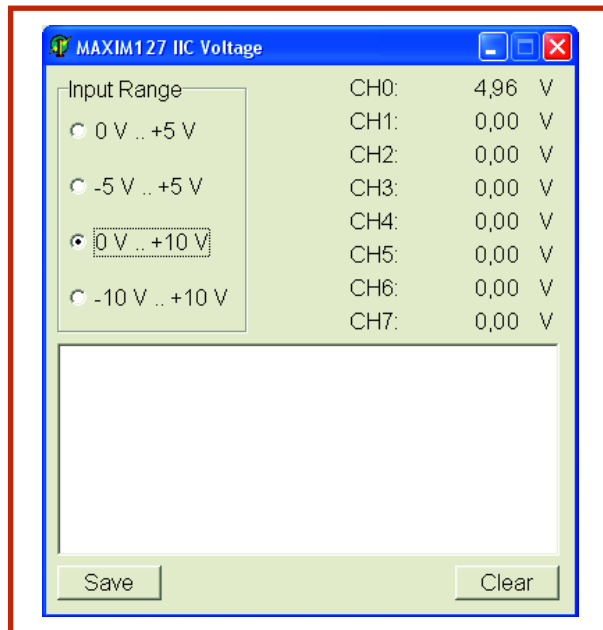
## IO Warrior

The IO Warrior is a Cypress CY7C63743 microcontroller, which offers a USB interface. It is programmed with code from Code Mercenaries Hard- and Software GmbH (<http://www.codemercs.com>). The IO Warrior24 has 16 I/O pins, which can be individually configured as either inputs or outputs as required.

To do more sophisticated things than just toggle a couple of port pins, the IO Warrior offers 'Special Mode Functions'. Using a simple command one of these functions can be enabled on the chip, whereupon the IO Warrior takes over direct control of the I/O pins to implement the desired function. IO Warrior24 supports the I<sup>2</sup>C bus, the SPI bus and driving an alphanumeric LCD module or a matrix of up to 8 by 32 LEDs. IO Warrior40 also supports matrices of up to 8 by 8 switches or pushbuttons.

It is easy to use these chips with your own software. Under Windows 98 or 2000 or later a library allows simple access from many programming languages. Examples are provided in C++, Visual Basic and Delphi with the SDK (available for free download from <http://www.codemercs.com>). There is also support for Linux 2.6 kernels, MacOS 9, MacOS X and Java under both Windows and Linux.

Starter kits are available for both chips, which include all the necessary components as well as a few extras for initial testing on a printed circuit board with a prototyping area.



**Figure 2.**  
Our example program  
is written in Delphi.

## Types in C and Delphi

The fundamental data types are easy to convert from one language into the other:

C	Delphi
char	Char
wchar_t	WideChar
unsigned char	Byte
short int	Smallint
int	Integer
unsigned int	Cardinal
float	Single
double	Double

## From Delphi to C and back

Fortunately in this case, Delphi does have a counterpart in the 'variant record'. The structure name (`_IOWKIT_REPORT`) is not present in the Delphi code: in the C version it is only used in the declaration of a pointer to the structure itself. Delphi can do without this auxiliary declaration, as the declaration of the pointer to the structure (`PIOWKIT_REPORT`) before the structure itself shows. Most of the fundamental data types used by Windows are already built in to Delphi, making this part of the translation trivial (see table).

The above example should make it clear how to declare a pointer type. Sometimes the C header file does not include the declaration of the pointer type, but it will be required in Delphi if such a pointer is ever used as a parameter to a function. It therefore makes sense always to declare corresponding pointer types.

In C the directive '`#pragma pack (push, 1)`' is needed to set the alignment of the structure elements. For packing into bytes Delphi uses a 'packed record' (see text box). Without this, the normal alignment is to eight-byte boundaries, in the interests of compatibility with current C compilers without the need for extra commands.

Functions and procedures are handled in two parts. The declaration is placed in the interface part of the Delphi unit, while in the implementation part the actual function is delegated to the DLL.

```
ULONG IOWKIT_API IowKitRead(IOWKIT_HANDLE devHandle,
ULONG numPipe,
PCHAR buffer, ULONG length);
```

```
function IowKitRead(devHandle: IOWKIT_HANDLE;
numPipe: ULONG;
buffer: PChar; length: ULONG): ULONG; stdcall;
```

```
function IowKitRead; external 'iowkit.dll' name
'IowKitRead';
```

## The 'packed' and 'stdcall' keywords

The keywords 'packed' and 'stdcall' make frequent appearances in the source code. They are often required in Delphi programs which use DLLs or the Windows API, both of which are written in C.

The keyword 'packed' prevents the compiler from optimising the arrangement of data in memory for speed by separating their storage locations. For example, consider a 32-bit processor. Data can be processed most quickly if each word is stored aligned to a 32-bit memory boundary. This leaves many memory locations unused if 8-bit (byte) or 16-bit quantities are stored. If the keyword 'packed' appears, however, the compiler avoids this optimisation and gaps are no longer left between variables. Many DLLs expect data structures not optimised for speed. If a data structure is to be used by a program as well as by a DLL, 'packed' is necessary to avoid any conflicts.

The 'stdcall' keyword is used in conjunction with function calls, and has to do with the so-called 'calling convention': i.e., determining how parameters are passed to a function. Most functions in the Windows API use the 'stdcall' method (but not all: checking the documentation is essential). In this case the parameters are stored from right to left on the stack by the caller (the code which is using the function). When the function or procedure is called, it is the responsibility of the callee (the code containing the called function) to ensure that the stack is tidied up.

Terrible things can happen if the caller and callee use different calling conventions. Frequently the stack will become corrupted and the program will jump to a random location and crash. It will readily be appreciated that tracking down bugs of this kind is an exceptionally tedious process.

When using externally-written DLLs it is therefore always necessary to determine which calling convention has been used and whether structures are 'packed' or not. This will avoid a lot of headaches when it comes to debugging the code.

# Timer procedure

```
procedure TForm1.KickerTimer(Sender: TObject);
var
  I: Integer;
  Report: TIICReport;
  BytesWritten, BytesRead: DWORD;
  N: Integer;
begin
  // just to be on the safe side
  if Assigned(IOWIIC) then
    // step through all MAX127 channels
    for I := 0 to 7 do
      begin
        FillChar(Report, SizeOf(Report), 0);
        // ReportID I2C write request
        Report.ReportID := $02;
        // 2 bytes with I2C start and stop
        Report.Bytes[0] := $C2;
        // MAX127 address byte = ADR 0, write
        Report.Bytes[1] := $50;
        // MAX127 control byte
        // START, RNG and BIP come from the Radi-
oGroup,
        // I = channel number, normal power mode
        Report.Bytes[2] := $80 or
          (Parameters.ItemIndex shl 2) or (I shl 4);
        IOWIIC.WriteFile(Report, SizeOf(Report),
          BytesWritten);
        // read ACK report from IO Warrior and dis-
card
        // (read errors are usually hardware prob-
lems)
        IOWIIC.ReadFile(Report, SizeOf(Report),
          BytesRead);

        FillChar(Report, SizeOf(Report), 0);
        // ReportID I2C read request
        Report.ReportID := $03;
        // 2 bytes
        Report.Bytes[0] := $02;
        // MAX127 address byte = ADR 0, read
        Report.Bytes[1] := $51;
        IOWIIC.WriteFile(Report, SizeOf(Report),
          BytesWritten);
        // read reply from MAX127 over I2C
        IOWIIC.ReadFile(Report, SizeOf(Report),
          BytesRead);
```

```
        // extract value
        // first pack the two bytes into a single
word
        N := (Report.Bytes[1] shl 8) or
          Report.Bytes[2];
        // now shift right four places, because
        // the 12 data bits sit at the top of the
16-bit field
        N := N shr 4;
        // convert value to volts
        // according to the settings of RNG and BIP,
and display
        // to two decimal places in the appropriate
label
        case Parameters.ItemIndex of
          0:
            // unsigned value
            // scale to 0V to 5V
            Values[I].Caption :=
              Format('%.2f', [N * 5.0 / 4096.0]);
          1:
            begin
              // signed value
              // extend sign from 12 to 32 bits
              if (N and $800) <> 0 then
                N := N or Integer($FFFFFF00);
              // scale to -5V to +5V
              Values[I].Caption :=
                Format('%.2f', [N * 5.0 / 2048.0]);
            end;
          2:
            // unsigned value
            // scale to 0V to 10V
            Values[I].Caption :=
              Format('%.2f', [N * 10.0 / 4096.0]);
          3:
            begin
              // signed value
              // extend sign from 12 to 32 bits
              if (N and $800) <> 0 then
                N := N or Integer($FFFFFF00);
              // scale to -10V to +10V
              Values[I].Caption :=
                Format('%.2f', [N * 10.0 / 2048.0]);
            end;
        end;
      end;
    end;
  end;
```

It is easy to see from this how Delphi handles linkage with the DLL (the text box explains the use of 'stdcall'). It is worth noting that the name of the function need not necessarily agree with the name in the DLL, which allows identifier prefixes or suffixes to be made consistent. If the function names have not made available in the DLL, they can simply be exported from it using, for example, 'lowK-itRead@16'.

The biggest problems in converting functions are pointer parameters. In contrast to C, Delphi uses 'call by reference'; in C there are only pointers. In C, then, a pointer can indicate the first element of an array or a call-by-reference parameter pointing to a variable. In Delphi, 'int \*a' might be either 'a: Plnteger', a pointer to the first element of an array, or 'var a: Integer', a simple variable passed by reference. Only by reference to the documentation can this be resolved.

(050222-1)

**Note: PCBs and IO Warrior ICs for this project are available through Readers Services, see SHOP pages or [www.elektor-electronics.co.uk](http://www.elektor-electronics.co.uk)**

## References and links

- [1] 'USB Driver Programming (1)', Elektor Electronics, October 2002, p. 40.
- [2] 'USB Driver Programming (2)', Elektor Electronics, November 2002, p. 30.
- [3] 'USB Interface', Elektor Electronics, September 2000, p. 44.
- [4] 'USB Analogue Converter', Elektor Electronics, November 2003, p. 12.
- [5] 'USB/I<sup>2</sup>C Interface', Elektor Electronics, December 2004, p. 52.
- [6] 'Delphi for Electronic Engineers', Elektor Electronics, from January 2005.
- [7] <http://jvcl.sf.net>
- [8] [www.velthuis.homepage.t-online.de/articles/articles-convert.html](http://www.velthuis.homepage.t-online.de/articles/articles-convert.html)

# Telephone Super

## Oops, Big Brother on the phone!

Anthonie Botha



**If you have a fit looking at your monthly phone bill you might want to know who's on the phone all the time. Also, you may want to start exercising control over which extension in your home is disabled or enabled. The Telephone Supervisor is suitable for up to three phone extensions and comes with smart Windows software that puts you (back) in control of things. One of its most salient features is the ability to log phone calls on the PC.**

# rvisor



Telephone use and misuse is a common source of irritation, confusion and misunderstanding in many households where phones are installed in (children's) bedrooms and studies. To find that the phone is busy when you need to make an urgent call is frustrating to say the least. Another disadvantage of having a couple of phones simply connected up in parallel in the home is that everyone can eavesdrop on a conversation simply by picking up the receiver (or not putting it down after taking the call and the usual hollering up or down the stairs). High time for some regulatory action backed by clever electronics and software.

## The landline

To understand how the Telephone Supervisor works, you need to understand some telephone line basics. What follows is a very simplified explanation of the workings of a reasonably modern, dead standard Exchange. The telephone line is an interesting yet hostile environment. To prevent situations that would interfere with the functioning of the telephone network,

## Telephone Supervisor main features

- Up to three telephone sets
- RJ11 snap-in connectors
- Enable/disable any individual phone
- Choice of various busy tones
- Eavesdropping blocked
- Windows control software
- Call log on PC
- Programmable off-hook delay
- Phone activity monitor
- Status retention in PIC EEPROM

it is imperative to use correct interfacing techniques. Also, in most countries (including the UK) it is not allowed to connect equipment that's not type approved to the public switched telephone network (PSTN).

In a POTS (plain old telephone system) the telephone line carries both DC and AC signals (audio) simultaneously. The DC is used to power the circuitry within the telephone during a conversation, and is derived from a large battery, of a nominal 48 V, located at the Telephone Exchange.

The landline between the Telephone Exchange and the home may be several kilometres long, and has a resistance proportional to the length of the line. The further you are away from the Exchange, the more line resistance. The telephone line is made from a pair of copper wires usually about 0.5 mm in diameter. The resistance of the line varies from 90 ohms to 180 ohms per kilometre.

When the handset is lifted, the telephone signals the Exchange by completing the line circuit. Effectively a switch known as the hook-switch is closed. The circuit between the Exchange and the phone is known as a *loop*. The expressions *off-hook* and *on-hook* are used. During the off-hook condition, the current flowing in this loop is known as the *loop* or *line current*. This current will be in the order of several tens of milliamps. About 20 mA may be assumed to be a typical value. Only a very small leakage current is permitted to flow in the loop when on-hook (i.e., off line). For a nominal 50 V line voltage, the maximum leakage can be assumed to be 50  $\mu$ A.

A detection circuit at the Exchange recognizes that a telephone receiver has gone off-hook when a few mA of line current are drawn from the line, and is effectively signalling the Exchange that it requires attention. The Exchange presents a dial tone to the line, and allocates a dial detection circuit, in readiness for the user to start dialing the number. When this number has been received and decoded by the exchange, it can then start to switch in the correct voice circuits to enable the call to be set up.

The above, analogue, system has been in use for almost three quarters of a century in most countries and although reliable and still in use on millions of phones around the world, it suffers from user-end disadvantages mentioned above. To solve the problems without investing in a home exchange, the Telephone Supervisor was designed.

## Telephone Supervisor

The circuit diagram of the Telephone Supervisor is given in **Figure 1**. The circuit is designed around a 220  $\Omega$  series resistor and an optocoupler. If the phone extension plugged into the Telephone Supervisor is lifted off-hook then the line current it draws will cause a voltage drop across the relevant 220  $\Omega$  resistor (R1, R5 or R9). This voltage causes the LED in IC3, IC4 or IC5 (i.e., in the optoisolator) to light and turn on the associated phototransistor, which in turn switches the transistor that controls one of two inputs RA3 and RA4 on the microcontroller (a PIC 16F628A). The anti-parallel pairs of diodes D1-D2 and D3-D4 etc. prevent the voltage across the 220  $\Omega$  resistor from exceeding about 1.2 V, regardless of the line current. As mentioned in the telephone line basics, situations that would interfere with the telephone network functioning should be avoided. Type IL250 optocouplers isolate the rest of the Telephone Supervisor circuit from the telephone line, thus ensuring that a minimum number of components are effectively connected to the line.

Note: In most European countries, it is mandatory that when a device draws 20 mA from the line, that voltage across the device is less than 9 V.

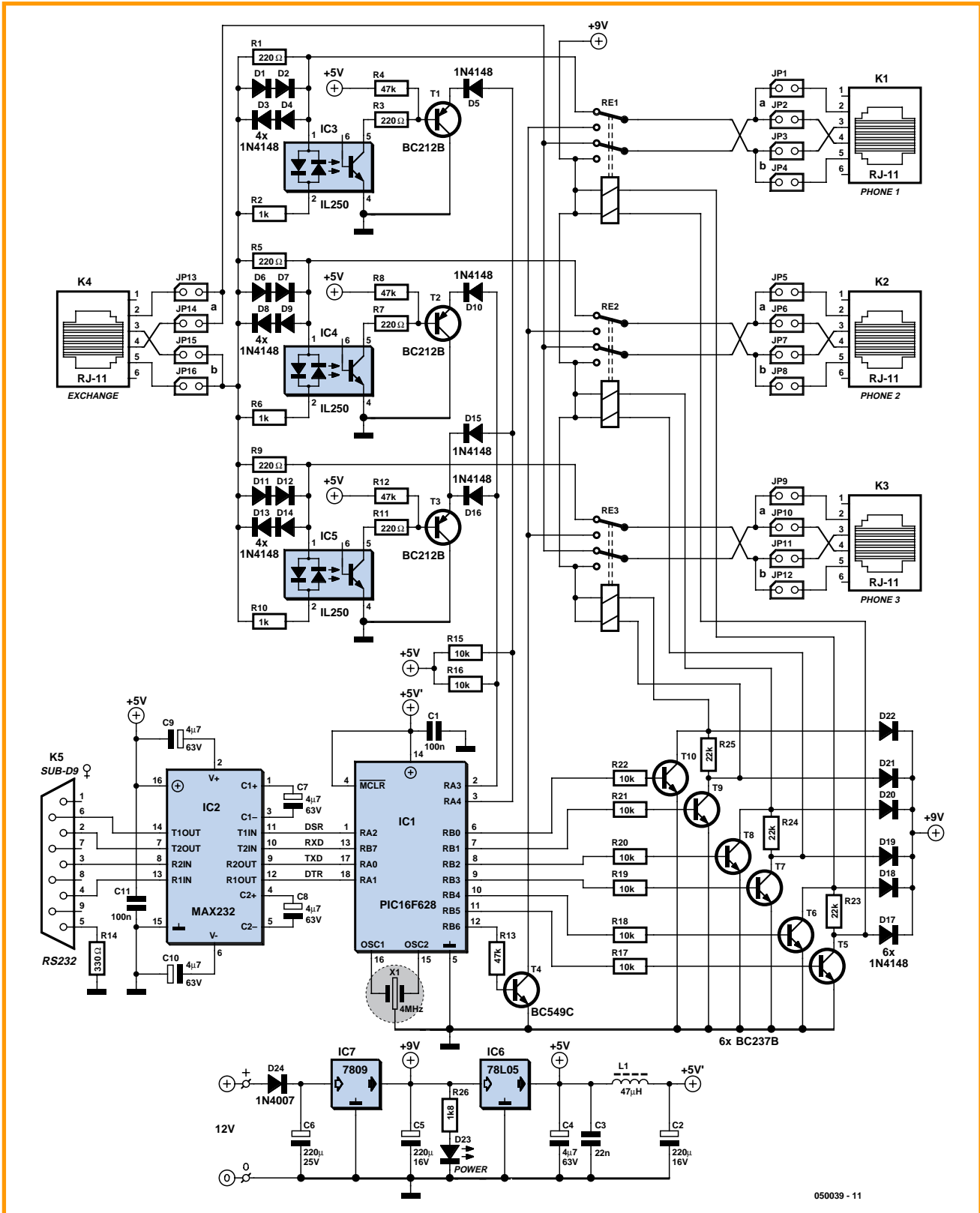
## RS232 Port

The RS232 port that's part of our circuit can be set up for two-way (full-duplex) communications. The RS232 signals are represented by voltage levels with respect to a system common (power ground). On most computers, the RS232 port equals a COM port (for connecting mouse, modem and/or serial printer). Today, RS232 is rapidly super-

seded by the USB port. The data transmission starts with a 'start' bit, which is logic 0. Then each bit is sent down the line, one at a time. The LSB (Least Significant Bit) is sent

first. A 'stop' bit (logic 1) is then appended to the signal to make up the transmission. RS232 logic levels are allowed to vary between +3 V and +25 V to signify a

'space' (logic 0) and -3 V to -25 V for a 'mark' (logic 1). Any voltage in between these regions (i.e., between +3 and -3 volts) is undefined. The RS232-level signals are taken through



**Figure 1.** Three telephone sets supervised by a PIC microcontroller. The jumpers allow for regional differences between line pin assignment on the Phone and Exchange sockets.

an RS232 level converter chip type MAX232 converter them to machine understandable signal levels, i.e., having TTL swing (0 V / 5 V). The RS232 data waveform consists of combination of a start bit, data bit, and stop bit.

The MAX232 is an old faithful that hardly requires further discussion. The chip includes a charge pump generating + 10V and -10 V from a 5 V power supply. It also includes two receivers and two transmitters in the same package.

### PC-PIC communications

As an example, when the PC checks the Telephone Supervisor hardware it employs the command #CallIDCH\* (Call Identification Check Hardware). The Telephone Supervisor receives the string in a binary format and the PIC-resident firmware converts it to a decimal value between 0 and 255. This value determines the subroutine to be jumped to. In this example the software will access the EEPROM memory (0x25). The string NH# and the value mentioned are converted to a decimal value which is then returned to the PC bit by bit.

The PC receives a binary value and converts it to an ASCII string, which in the case of the terminal will be displayed as 'received'. The same principle applies to all the subroutines. The only difference is that when you change a setting, for example, disable phone #1, the software will disable the phone, update the register and only then send confirmation to the PC. Of the control lines on the RS232 interface, DSR is used to monitor the Telephone Supervisor determining on-or-off line status and handshake, while DTR is used for handshaking purposes. The baud rate on the PC connected to the Telephone Supervisor has to be set to 56 kbps.

### What's that PIC doing?

The PIC in the circuit is in control of the phone enabling/disabling functions, line use detection, 'line busy' processing and the communications with the PC. The firmware needed to do all this is available in the form of a source code listing or an executable (object code) file. An extract of the source code listing is shown in **Figure 2**. For all you home PIC burners these files may be downloaded free of charge from our website as file number **050039-11.zip**. In case you can use the hex object code file straight away,

do note the PIC configuration bits shown in the **inset**. Those without access to a suitable PIC programmer may buy the ready-programmed PIC micro through our Readers Services

under ref. no. **050039-41**.

Six of the PIC16F628A outputs (RB0-RB5) are used to drive three bistable relays via transistors T5- T10. There are two coils in the relays and

## PIC source code (extract)

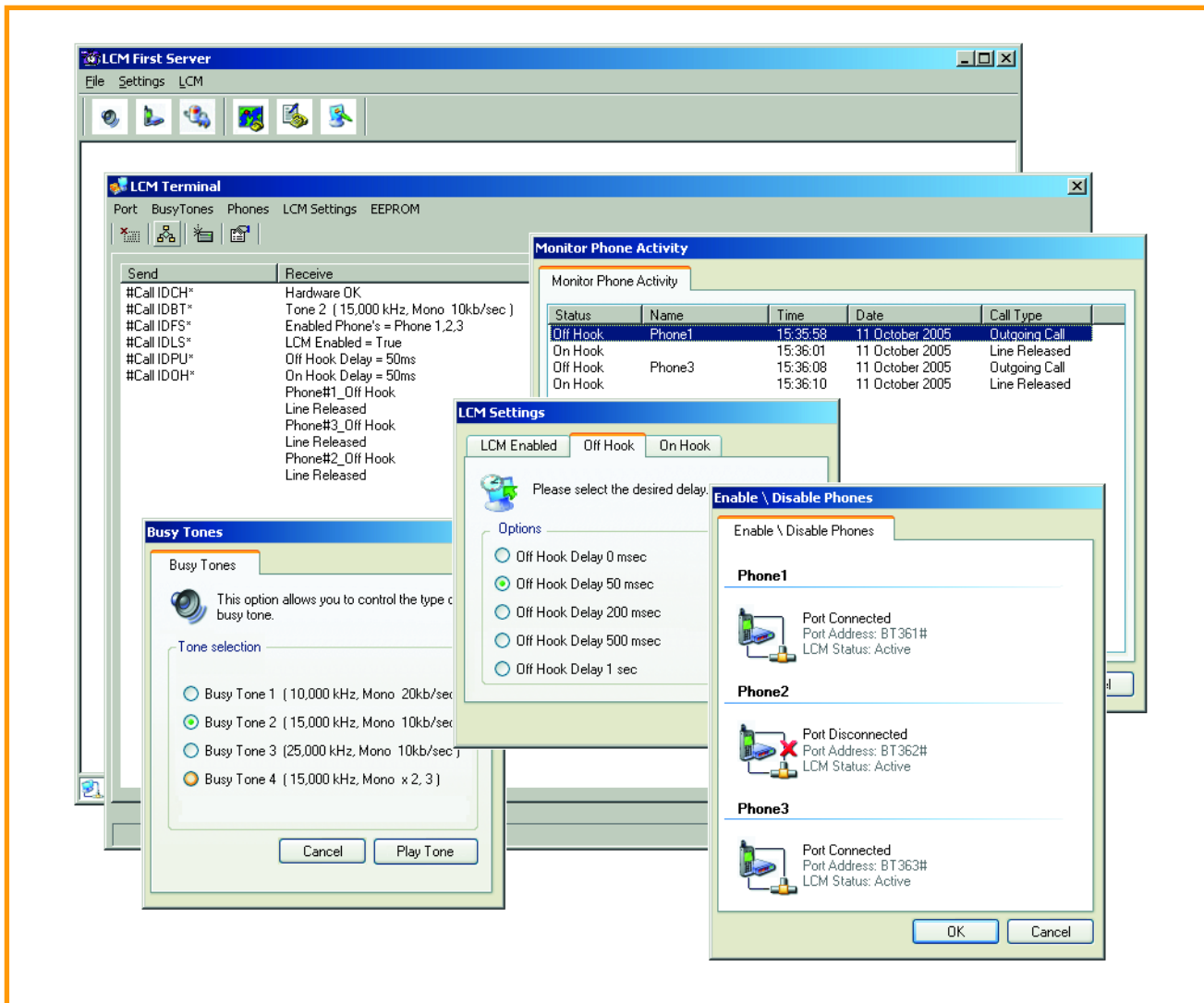
```

; Main Menu
;
Main    bsf          PORTA, 2
        call        D0.01s      ; Delay for 0,01 sec
        bcf          PORTA, 2
        movlw       D'0'        ; Clear From
        movwf       SelMenu     ; Move w to SelMenu
contm0  incfsz      SelMenu, f   ; Increments specified regis-
ter
        movf        SelMenu,w   ; Data into w
contm0A btfsc      PORTA, 0     ; Monitor RA0 for input
        goto        contm1
        btfsc      PORTA, 1     ; Monitor RA1 for input
        goto        contm3
        goto        contm0A
contm1
contm2  btfss      PORTA, 0     ; Monitor RA0 for input
        goto        contm0
        btfsc      PORTA, 1     ; Monitor RA1 for input
        goto        contm3
        goto        contm2
contm3  btfss      PORTA, 1     ; Monitor RA1 for input
        goto        contm4
        goto        contm3
contm4  incfsz      SelMenu, f   ; Increments specified regis-
ter
        movf        SelMenu,w   ; Data into w
        incfsz     SelMenu, f   ; Increments specified regis-
ter
        movf        SelMenu,w   ; Data into w
;
; -----
; To create more menu items, copy the next four lines and paste them
; directly under the last menu item. You need to make a few changes.
; First change the menu number [D'2']. This number should not be
; smaller than 2 and should not exceed 255. This address should run
; concurrently with the address from your user interface on your PC.
; -----
;
; Read file from EEPROM
; Do not change this menu item;
; it is a fixed value on the OCX. By changing
; this the OCX will not function correctly.
;
movf    SelMenu,w      ; Selected menu item
                        ; data into w
sublw   D'5'          ; Subtract w(SelMenu)
                        ; form literal(D'?)
btfsc  STATUS,2      ; Test result
goto   NR0           ; If w(SelMenu) =
                        ; literal(D'?)
                        ; then goto menuitem
                        ; Result
                        ; [Read file from EEPROM]

```

**Figure 2.** Extract of the PIC source code listing.





**Figure 3.** The LCM First Server software in action on the PC.

the devices latch in both directions. Only a short pulse is needed to switch the relay on, using the one coil. A short pulse on the other coil will switch the relay off. This means that all phones that are disabled/enabled will maintain their status even with power failure. PIC port line RB6 is used in conjunction with transistor T4 to generate one of four busy tones. The functions of the other port lines may be summarized as follows:

- RB7: transmit data
- RA0: receive data
- RA1: DTR (Data Terminal Ready)
- RA2: DSR (Data Send Ready)
- RA3 & RA4: monitor the inputs from transistors T1, T2 and T3; these are switched by optocouplers IC3, IC4 and IC5 as explained above.

To prevent exceeding the ring equivalent number allowed for your tele-

phone line, it is advisable to connect two phones and a modem to the Telephone Supervisor. If you want to connect three phones, you will have to physically disconnect one of the phones ringers.

**PC Software: LCM First Server**

The software to use on the PC is called **LCM First Server v. 1.1** where LCM stands for *Line Current Monitor*, the original, 'techy', title of this project. The PC software comes on a CD-ROM with order code **050039-81**, which is available through Readers Services. The operation of the program is explained in great detail in the associated *Software Guide*, a professionally styled and copiously illustrated 7-page MS Word document that's available for free downloading as file number **050039-12**. A compilation screenshot showing the Telephone Supervisor software in

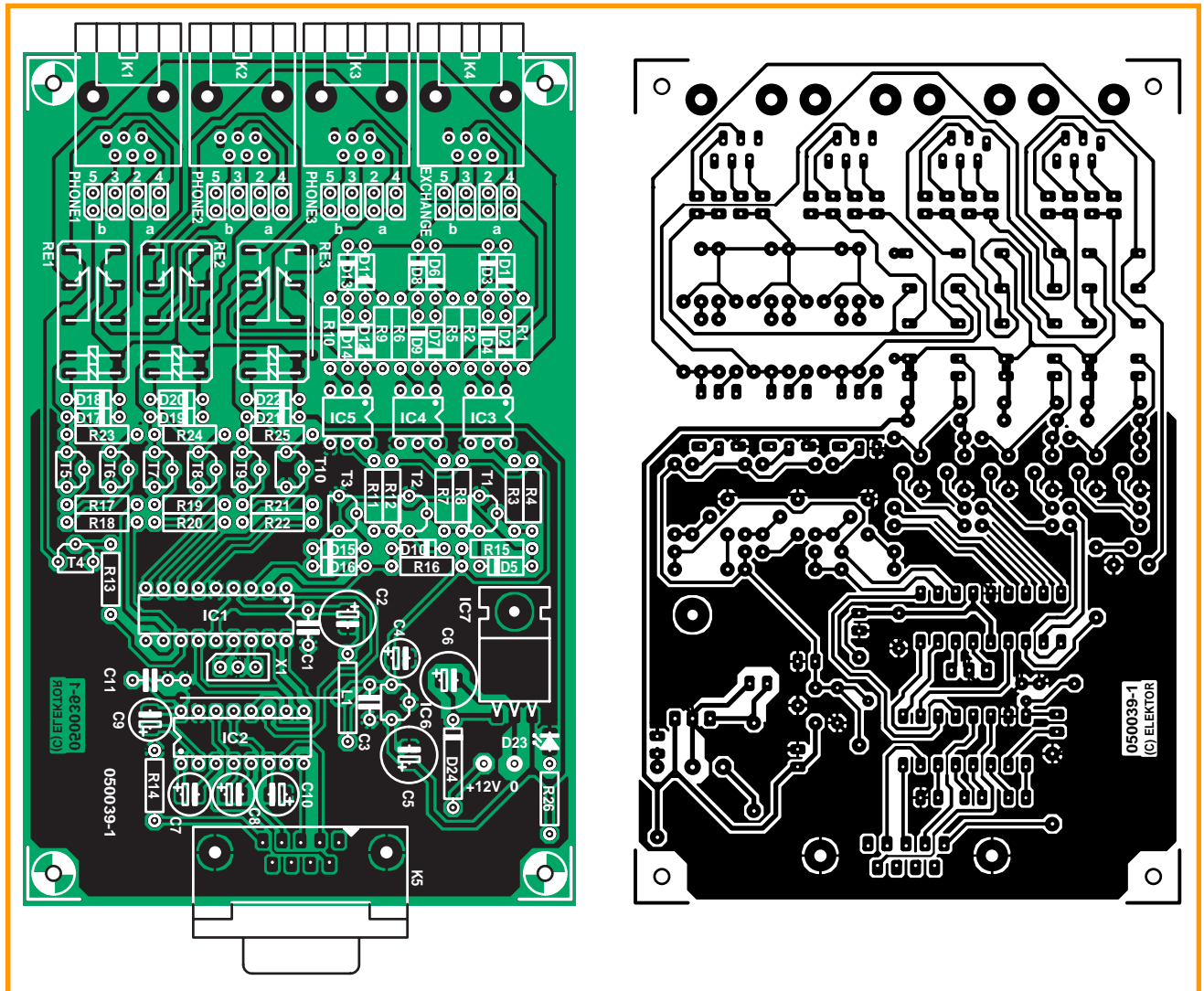
action in various windows and sub-menus appears in **Figure 3**.

The Telephone Supervisor board must be connected to the PC using a **non-crossed** RS232 cable.

**Building it**

The project is not at all difficult to build if you use the carefully designed printed circuit board shown in **Figure 4** and the information in the **parts list**. Only conventional leaded parts are used, no SMD parts to struggle with or lose to mum's vacuum cleaner.

The board is single sided and contains two wire links which must be fitted first on penalty of creating hard to find hardware errors, emails to the editor and unnecessary postings in our online Forum. As you can see from the copper track layout, the 'microcontroller area' of the board has additional



**Figure 4. Copper track layout and component mounting plan of the single-sided PCB designed for the Telephone Supervisor.**  
There are just two wire links to fit on the board!

copper pour to keep stray signals and interference to a minimum.

Provided you apply no more than about 12 V DC to the supply input (on two

solder pins), the TO220-style 7809 voltage regulator, IC7, will not run particularly hot so it may be mounted without a heatsink. Mounting an M3 nut

between its metal tab and the board surface makes for neat, secure and exactly horizontal fitting of this TO220 device, with its three terminals bent at

## COMPONENTS LIST

### Resistors:

R1, R3, R5, R7, R9, R11 = 220 $\Omega$   
R2, R6, R10 = 1k $\Omega$   
R4, R8, R12, R13 = 47k $\Omega$   
R14 = 330 $\Omega$   
R15-R22 = 10k $\Omega$   
R23, R24, R25 = 22k $\Omega$   
R26 = 1k $\Omega$ 8

### Capacitors:

C1, C11 = 100nF (C1 5mm lead pitch)  
C2, C5 = 220 $\mu$ F 16V radial  
C3 = 22nF, lead pitch 5mm  
C4, C7-C10 = 4 $\mu$ F 63V radial

C6 = 220 $\mu$ F 25V radial

### Semiconductors:

D1-D22 = 1N4148  
D23 = LED, low current  
D24 = 1N4007  
T1-T3 = BC212B  
T4 = BC549C or BC550C  
T5-T10 = BC237B  
IC1 = PIC16F628-20/P, programmed,  
order code **050039-41**\*  
IC2 = MAX232  
IC3, IC4, IC5 = IL250 (H11AA4)  
IC6 = 78L05  
IC7 = 7809

### Miscellaneous:

JP1-JP16 = 2-way pinheader and 8 jumpers  
K1-K4 = RJ11 PCB mount socket

K5 = 9-way sub-D socket (female), angled pins, PCB mount  
X1 = not fitted, see text  
RE1, RE2, RE3 = 12V PCB relay, bistable, two energising solenoids 2 x 400 $\Omega$ , two changeover contacts, e.g., DS2E-ML2-12VJ Panasonic (Schuricht # 407220; www.schuricht.de)  
2 wire links  
CD-ROM, LCM First Server 1.1, order code **050039-81**\*  
PIC source & hex code files, file **050039-11**\* Free Download PCB, ref. 050039-1 from The PCBShop

### Inductors:

L1 = 47 $\mu$ H

\* See Elektor SHOP pages or [www.elektor-electronics.co.uk](http://www.elektor-electronics.co.uk)

an angle of 90 degrees.

All electrolytic caps on the board are radial types hence have to be fitted vertically. Care should be taken to get these devices correctly polarised on the board, so make sure you know where the positive and negative leads (1) are and (2) have to go on the board. The same goes for the diodes, in respect of their cathode and anode terminals. Sure, the ICs are also polarised components so don't insert them the wrong way around.

Position X1 on the board remains empty. Initially this was for a 4-MHz ceramic resonator device. An adaptation of the PIC software however allowed for the PIC's internal 4 MHz clock to be used.

All four RJ11 phone sockets are fitted in a neat row at the board edge. Incidentally, we recommend using sockets for all integrated circuits including the optocouplers.

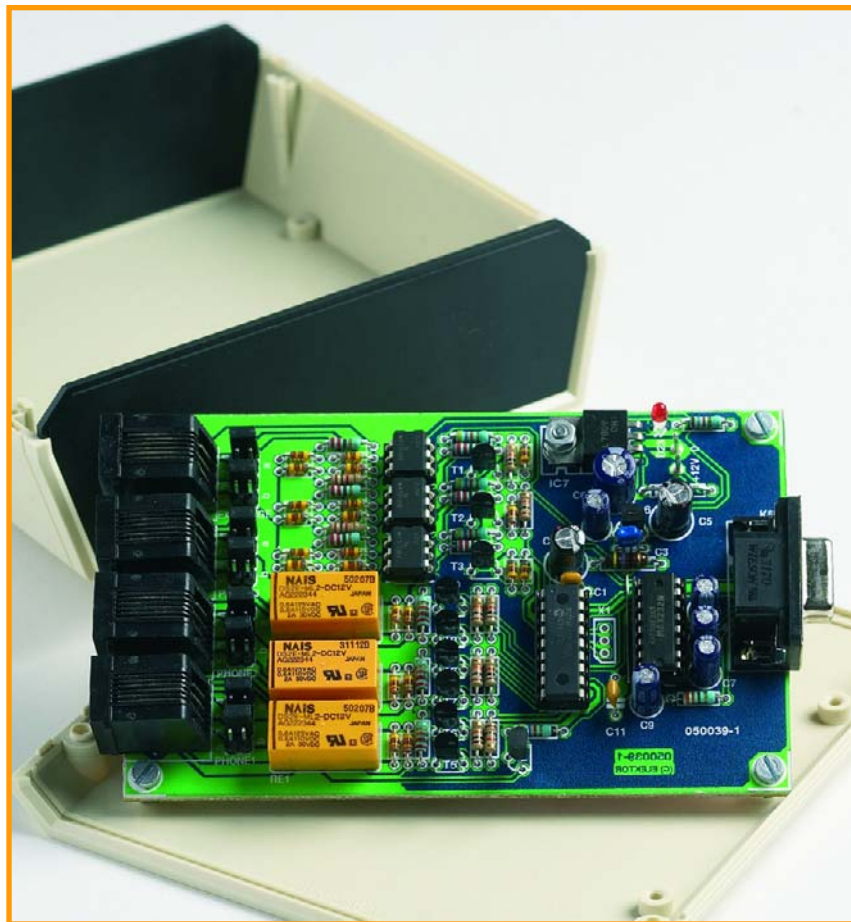
Jumper clusters JP1-JP4, JP5-JP8 and JP9-JP12 have to be set in accordance with the pin/signal assignment of the RJ11 connectors to the phones. Unfortunately the assignment of the phone line signals (here, called 'a' and 'b') to pins on the socket differs from country to country hence may take some figuring out. The same goes for the 'Exchange' socket, K4. As a matter of course, only one jumper may be fitted for the 'a' line, and one for the 'b' line, so JP1 and JP2, for example, are **mutually exclusive**. For the sake of convenience the pin numbers of the RJ11 sockets are printed on the PCB overlay. Our prototype worked with four jumpers installed in position '3' and the other four in position '4' (line 'b' on RJ11 pin 3; line 'a'; on pin 4).

The finished board should be given a thorough visual inspection before powering it up for the first time. We recommend using the LCM Terminal utility from the LCM First Server software to check if the hardware and PC connection are functional. When this is successful, the PC software can be used to download the default configuration into the PIC on the board. This functionality is explained and illustrated in the *Software Guide*.

(050039-1)

**Note:** this circuit is not type approved to BABT standards and in the UK may not be connected to the public switched telephone network (PSTN).

Anthony Botha – LCM050039@hotmail.com



# Christmas Gifts

With Christmas almost upon us it's that time of the year again to find or make original presents for friends and relatives. For your inspiration we found twenty or so gifts that are sure to delight any electronics enthusiast, including you, as the recipient, of course! For subtle guidance of your friends in their choice of Christmas presents (for you), pass this issue of Elektor around.

## Handy 3-in-1 lab aid



For anyone with too little space in the home lab or workshop, Velleman's LAB1 may present a solution. LAB1 packs an adjustable powers supply, a multimeter and a temperature-controlled soldering station in a single enclosure. The manufacturer's design is well

thought out as two separate transformers are available for the power supply and the solder iron, while the multimeter is battery powered for proper electrical isolation.

Seen at: [www.velleman.be](http://www.velleman.be)



## Electronic Experimenter's Box

They're back! Experimenter's boxes for 'fast and fun' construction of circuits without soldering. A great gift for the budding electronics fan. Several box sizes are available. The box shown here is suitable for a

whopping 130 experiments. Similar boxes are available from toy shops and electronics retailers.

Seen at: [www.velleman.be](http://www.velleman.be)

## Programmable LED Badge



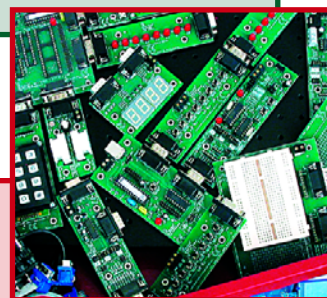
This programmable LED badge can act not only as a name badge but also as an eye-catcher in discos and pubs. Up to 50 characters stored in memory are displayed on a 21x7 LED display. The unit is powered by a Lithium button cell.

Seen at: [www.rockingstone.nl](http://www.rockingstone.nl)

## E-blocks

The E-blocks modular construction system allows beginners as well as experienced engineers to design and build microcontroller circuits faster than ever before. The core of the system is a USB Multiprogrammer, a board that's suitable for a wide range of microcontrollers and ready for connection to all kinds of extension and application boards. Programming is modular, too, using pictograms and ready-to-use chunks of software.

Seen at: [www.elektor-electronics.co.uk](http://www.elektor-electronics.co.uk)



## Instant Loudspeakers



Using these SoundPad sticks you can transform almost any surface into a loudspeaker; a door, a tabletop or just a thick piece of plywood. Of course, the sound quality is strongly dependent on material and shape, but SoundPad sticks are great fun to experiment with. SoundPads contain a loudspeaker voice coil with terminals that can be secured to a surface using self-adhesive foil.

Seen at: [www.thinkgeek.com](http://www.thinkgeek.com)



## Solder starter kit

A nice starter kit for electronics hobbyists, containing a 25-watt solder iron, solder tin, a solder stand, pliers and two mini kits, one for flashing LEDs and one for a LED sound to light unit. Start soldering straight away and learn the tricks.

Seen at: [www.velleman.be](http://www.velleman.be)

# gadgets, gizmos and wannahaves



## LEDs for Maglite flashlight

USA firm Terralux specializes in replacement lamps for the world famous ultra-rugged Maglite flashlights. However, Terralux actually supplies white LEDs, with full mechanical and electrical compatibility with Maglite's original lamps. The LEDs are mounted on a mini board that also holds the drive electronics. Versions are available for several Maglite flashlights and light strengths

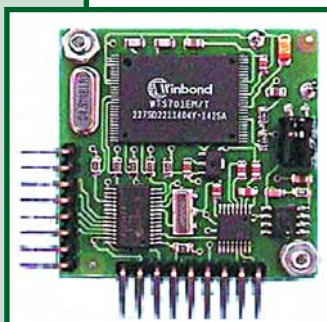
Seen at: [www.terraluxcorp.com](http://www.terraluxcorp.com)



## Voice Synthesizer

The SP03 board is a small PCB with a complete voice synthesizer on it, using the WTS701EM/T from Winbond as the core device. By way of an RS232 interface you send ASCII text to the board. The text is reproduced by a voice from a small built-in loudspeaker. The board measures just 4x4 cm, runs off a 5-V supply and is easily added to an existing microcontroller board.

Seen at: [www.rockingstone.nl](http://www.rockingstone.nl)



## Polarity Checker

Using PoleChecker from audio guru Van Den Hul you not only detect the presence of direct and alternating voltages in a safe way, you can also connect all equipment in your audio system for the best possible sound reproduction. The tester is batteryless and even has an LCD screen providing an indication of the value of the voltage measured.

Seen at: [www.vandenhul.com](http://www.vandenhul.com)



## Cold Fusion

Excellent for small repair jobs in awkward places, this cordless solder iron from Conrad Electronics. The device is powered by four penlight batteries. The crux is in the two-part tip: it's made of a conductive material called Athalite. The tip remains cold until you place it onto a conductive surface, for example, a solder spot on a PCB. A hefty current then starts to flow, rapidly heating the solder spot.

Seen at: [www.conrad.nl](http://www.conrad.nl)



## Light-emitting Sticks

Okay, these Tritium Trasers have nothing to do with electronics per se, but they may turn out to be useful 'must-haves' in some occasions. The remarkable thing about these sticks is that they emit light over a period of 10 (that's right, ten) years without a battery! These are opaque tubes with a fluorescent layer inside, filled with boron-silicate and then thermally sealed using a laser. Available in different colours, they look great on your key ring.

Seen at: [www.smart-elements.com](http://www.smart-elements.com)



## Shocking Roulette

If you are bored with charades or monopoly and want to play a different game under the Christmas tree this year you might consider Shocking Roulette. We're talking about the Russian variant involving the gun with just one bullet. The device has four holes for each of the contestants to insert a finger in. After pressing a button, the LEDs with the contestants start to flash and after a while one LED remains on. The 'lucky winner' gets an electric jolt! Anyone for tennis?

Seen at: [www.thegadgetcompany.nl](http://www.thegadgetcompany.nl)



## Manual Power for Mobile Phone

Who remembers PowerBall, a ball with an internal flywheel intended as a fitness trainer for hand and wrist muscles? Some users actually became addicted to PowerBall. Now, we found a successor: Manual Power. This too, is a gyroscope you have to keep spinning. The new model has a built in generator allowing you, while juggling the device, to generate electrical energy for the internal flashlight, or to charge your mobile phone battery.

Seen at: [www.gadgetzone.nl](http://www.gadgetzone.nl)



**Vintage Receiver for Mobiles**

Not terribly practical, but still a good gimmick: a vintage telephone receiver you can connect to a mobile phone. A far cry from the latest Bluetooth headset your friends are flashing! Just imagine the amazement of passers-by at the bus station seeing you talk into this vintage receiver. The receiver is a virtual copy of the Western Electric model 500 telephone set and may be connected to the 2.5-mm jack socket available on most modern mobiles.

Seen at: [www.thinkgeek.com](http://www.thinkgeek.com)



**Floating Globe**

(Very) long-time Elektor readers may remember a circuit published in the 1970s that made a metal globe (of the pencil sharpener type) 'float' inside a magnetic field. Such a gadget is now available commercially and the floating globe still causes 'awe and wonder' among the uninitiated. The model we saw has an impressive diameter of about 18 cm, which is sure to impress your Christmas party guests.

[www.gadgetuniverse.com](http://www.gadgetuniverse.com)



**Mini DAB Receiver**

The Philips DA 1000 is a portable DAB receiver weighing in at less than 100 grams. It has a backlight for a brightly illuminated display and a joystick to control it all. DAB (digital audio broadcasting) is the digital alternative to analogue VHF FM broadcasts. The system has proved to supply excellent sound quality. DAB was rolled out a few years ago in the UK and now has nationwide coverage.

Seen at: [www.maplin.co.uk](http://www.maplin.co.uk)



**Portable DRM Receiver**

The digital radio system called DRM (for Digital Radio Mondiale) rocketed into popularity among our readers mainly through the Elektor DIY DRM receiver published in March 2004. It does, however, require a PC to work. One of the first commercial all-portable DRM receivers is now offered by Mayah Communications. The radio contains a DSP module for the decoding of DRM signals and doubles as an analogue receiver. At a price, however, of about 350 pounds!

Seen at: [www.mayah.com](http://www.mayah.com)



**Check your own Car**

All modern cars have an OBD-2 connector supplying all kinds of data when suitably 'provoked'. The system also allows certain vehicle data to be changed (within limits) which is interesting if you dabble in car repair. Elektor's very own OBD-2 Analyser comes as a kit of parts. You connect it between a PC or laptop and the OBD-2 socket in your car. Next, you're allowed a glimpse at the car's internal electronics!

Seen at: [www.elektor-electronics.co.uk](http://www.elektor-electronics.co.uk)



**Bright Feet Slippers**

This may well be the ultimate gift for the really spoiled electronics enthusiast: feet slippers with built-in lighting. Never get lost again in the dark or stumble around waking up everybody on your way at night to the fridge or workshop. Available in several sizes, this novel footwear is pretty ingenious. A pressure sensor detects when you put on the slippers, while a timer provides a courtesy light when you take them off again. The slippers are powered by two Lithium batteries you can easily replace.

Seen at: [www.brightfeetslippers.com](http://www.brightfeetslippers.com)



**MindReader**

The 20Q MindReader is a clever toy that reads your mind after you have answered 20 questions. You may think that's not possible, but thanks to a smart algorithm this gadget is capable — in most cases — of guessing what (object) you are thinking of. That is... well anyway, try it and marvel at the results!

Seen at: [www.gadgethouse.nl](http://www.gadgethouse.nl)





### VW Microbus plays LP records

Certainly one of the hottest items in this overview, this miniature Volkswagen bus that plays your vinyl records. Put the bus on the LP and it will drive around playing the record through its built-in loudspeaker. The vehicle is powered by a 9-V battery. A warning, though! The supplier calls the product: 'Vinyl killer record playing VW van', so we have our doubts about what's left of the precious record when the bus is at the end of its groovy journey.

Seen at: [www.hfr.com](http://www.hfr.com)

### High-end at 30 dollars

At first blush the Sonic T-amp does not appear much more than a plastic case with a Tripath switching amplifier module inside. Judging from reviews however ([www.tnt-audio.com/ampli/t-amp\\_e.html](http://www.tnt-audio.com/ampli/t-amp_e.html)) the small amplifier excels in sound reproduction, and has been compared to amplifiers costing upwards of 1 kdollar. The thing runs off a battery pack — a mains adapter is available as an option.

Seen at: [www.si-technologies.com](http://www.si-technologies.com)



### Universal USB/HID Cable

Connecting a hard disk externally to a computer can be very handy, for example, when you need a one-time backup device. Sure, external hard disks with USB or FireWire connectivity are nothing new (nor are sleek cases for them), but why not use that old hard disk gathering dust? The advantage of this USB2.0-to-IDE cable is that the IDE side has two connectors, so 2.5-inch as well as 3.5-inch hard drives may be hooked up.

Seen at: [www.usbgeek.com](http://www.usbgeek.com)



### LED Replacement Lamps

The traditional lamps in our homes are gradually phased out and replaced by other light sources. Especially white LEDs are on the rise. Conrad supplies nifty replacement lamps for the well-known halogen spotlights at home, in 230-V and low-voltage versions. They have the same shape as halogen lamps and contain an array of 18 white LEDs. Also available in several colours.

Seen at: [www.conrad.nl](http://www.conrad.nl)

### Weather Station with PC Link

Weather stations for use in the living room come in many shapes and sizes, from small to large and from dirt cheap to astronomically priced. The crux of this one is the complete outfit (it comes with three outdoor sensors) and the RS232 link to the computer. Using the supplied software you can view the weather changes on your PC screen. A version with a touch screen is also available.

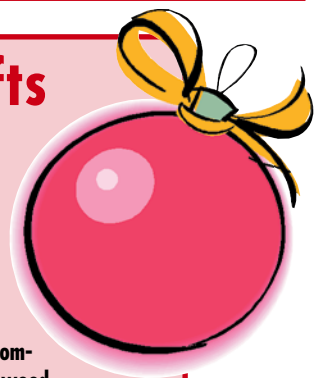
Seen at: [www.weershop.be](http://www.weershop.be)



### Alternative gifts

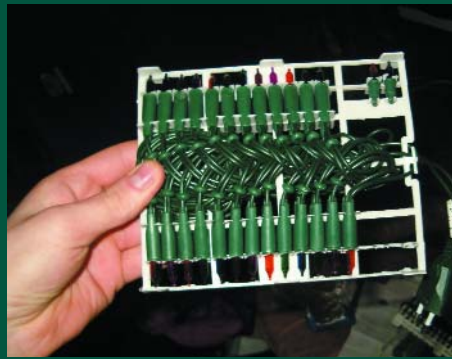
Every year the same gifts: a calendar, a pen (with inscription!) or a bottle of wine. Nothing wrong with these, of course, but far from original. If, after browsing these pages, you still haven't found anything to your liking and also lack the inspiration for other ideas, try something completely different. What about a nice wooden salad bowl with matching cutlery, possibly complemented by an oil-and-vinegar dressing set? Not just practical, but healthy, too! A nice set of candle holders is sure to create the right ambient lighting during the festive season.

If you think that's real corny, why not surprise your friends or beloved ones with tickets for a rock concert, a karting event, a balloon trip or an anti-skid course? Success guaranteed, but a tad more expensive than your ordinary Christmas presents.

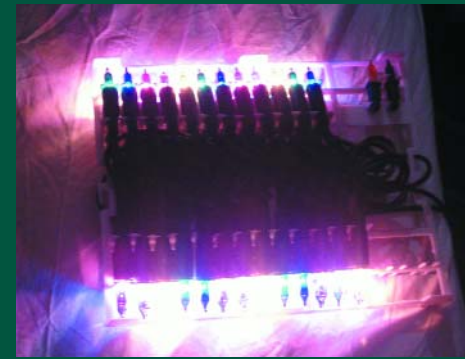




'Okay let's get ready for Christmas. To get myself into the right mood (and brighten things up a bit during these dark days), I decided to hang up Christmas lights in my room. But as anyone who knows me can tell you, I tinker with just about any sort of electronics I get my hands on.



I found these Christmas lights at a clothes outlet. 50 lamps in five colours for the stupendous price of one pound. So I took six strings right away. Here you can see what's inside the box: 50 Christmas lamps, including two spares. "It's amazing, Mike!"



Hey, they really work! You can see the five colours clearly here. The problem with this sort of colourful lights is... well, that they're just too colourful. It seems too American to me, too gaudy. That's certainly not what we want. But don't worry, that's easy to fix.

# Colourful Christmas



Jeroen Domburg

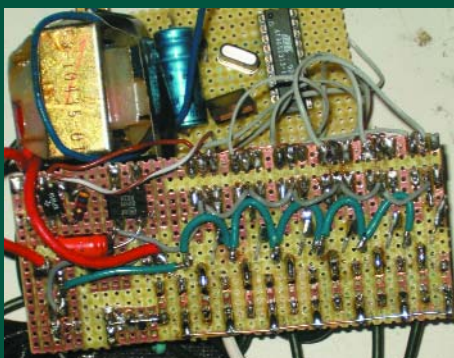
The dark days of winter are on their way again, so it's time for some cheerful lighting for the Festive Season. The author picked up six Christmas light strings for a song and reworked them a bit. The result can be used for many sorts of occasions other than Christmas, so it can improve the ambience in your room for the rest of the year as well.

The *Elektor Electronics* staff really enjoyed this idea and the implementation. Jeroen managed to create attractive mood lighting using very limited

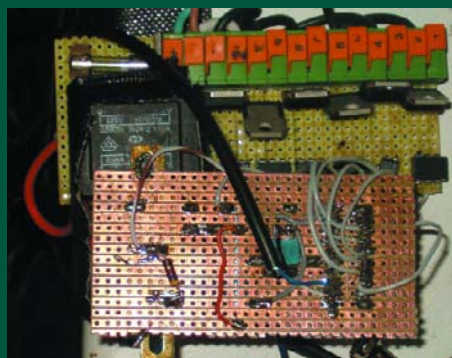
resources and even less money. Our contribution is a schematic diagram for a mains controller and a few tips that may help simplify the construction. For

completeness, we also describe how the circuit works.

You will need the following components for his project (see **Figure 1**):



...by using this bit of hardware. Most of you probably don't have any idea what this is, so I'll just tell you: this is a microcontroller-driven, computer-interfaced, triac-switched, electrically isolated, six-channel phase-control dimmer. There!



That means you can attach six different light fixtures to it, and each of them can be individually dimmed using a computer. The six Christmas light strings are a perfect match.

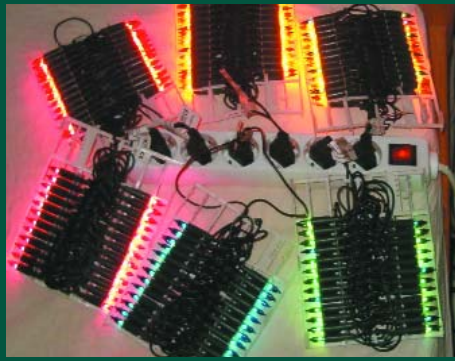


Of course, this is all at 230-V mains potential, so it must be fitted into an enclosure. Fortunately, these days you can get a cheap enclosure for free by devouring, like I did, the contents of a tub of custard. (FYI: it was chocolate custard.)





Step 1: remove all the lamps from the light strings. That's 312 lamps in total, including the spares. Step 2: sort the lamps by colour and then plug them all back in. You have to admit it looks a lot more chic already, doesn't it? But we're not done yet: besides being chic, I'm an EE



(Ed: electrical engineering) student. And the fact that the lamps cannot be easily switched on or off, and beside that have only one brightness level, is naturally a major obstacle to the ultimate Christmas experience. Happily, that can also be fixed.



First we bundle all the lamps into a single, massive illuminated backbone. That eliminates the effect of sorting the lamps, but it can be completely restored...

# Light Strings

## PC-controlled mood lighting

- a microcontroller (Atmel AT90S2313)
- a 5-V power supply for the microcontroller
- a 12-V power supply for the triac drive circuitry
- an interface to a serial port

The author used a data cable for a Siemens C35 mobile phone for the PC interface, but a MAX232 can easily be integrated into the circuit diagram (see **Figure 3**).

The author also used several other 'exotic' components. That simply reflects what he had on hand. It's also better to use optotriacs instead of optocouplers. A suitable choice is the Sharp S202S11 (see **Figure 3**). That also allows TR2 to be omitted, as the 12-V supply for the optocouplers is no longer necessary. The second winding of TR1 can then be used to power IC9. The microcontroller is also a bit on the old side. If you can't find it, you can

also use the ATTiny2313, which is pin- and code-compatible with the AT90S. Make sure the fuse declarations are correct when you program it: FUSE H=0xDF, FUSE L=0xCF. The dimmer portion of the circuit is quite simple. There is a transformer for the 5-V supply, and a second transformer for the 12-V supply and zero-crossing detector. The zero-crossing detector allows the microcontroller to operate synchronized to



The custard tub and dimmer in the final location. The cable to the six light strings runs upward, the mains cable runs downward, and the RS232 connection to my server runs to the top right.



Suspending the strings: my UPS is hefty enough to hold one end.



The suspension point at the other end. The result: the different colours can now be dimmed individually using a computer, so you can use a web page to put together your own colour composition and create your very own, unique Christmas experience.'

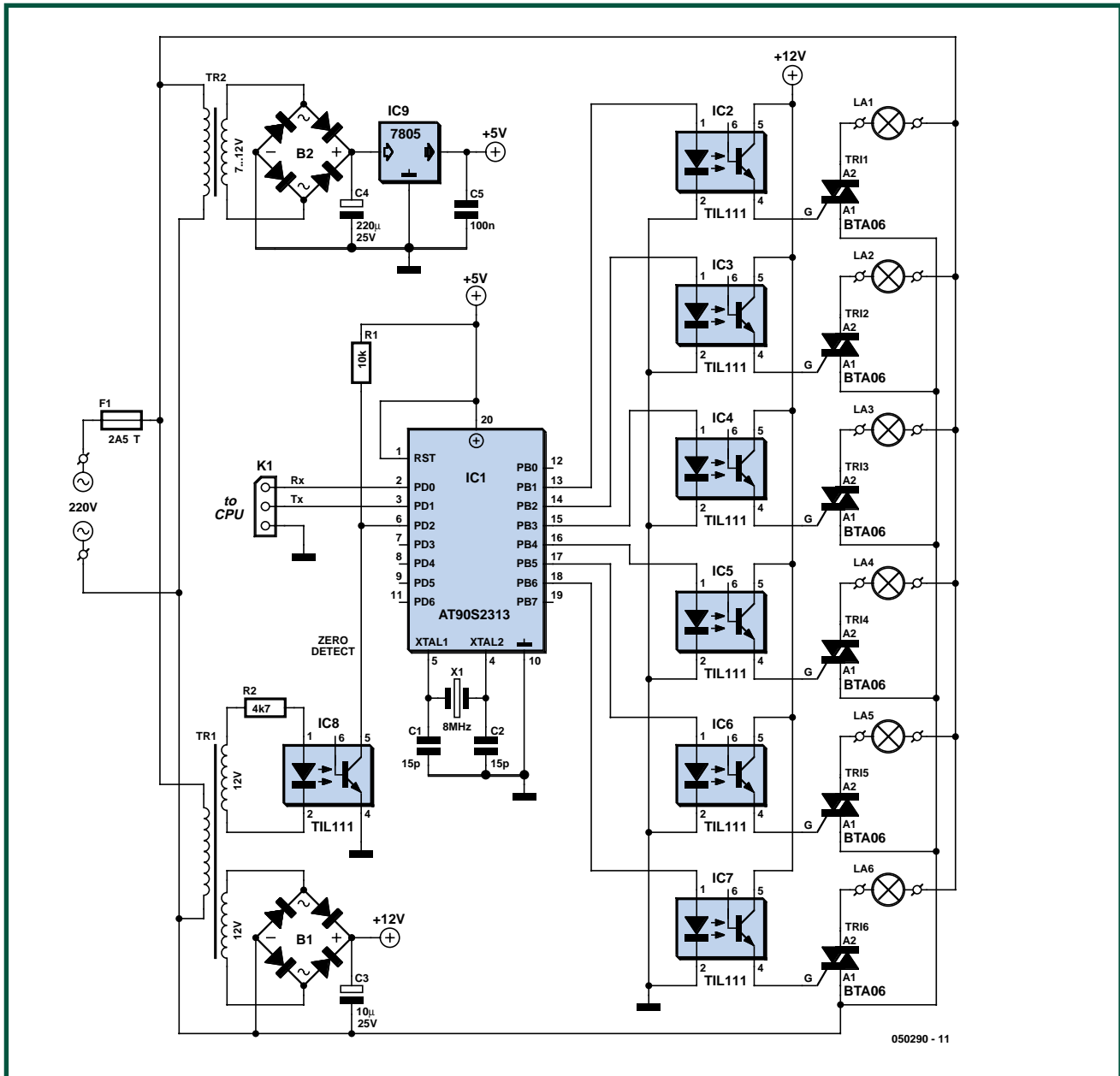


Figure 1. Although the schematic diagram is fairly large, it's quite simple in principle. The microcontroller is connected via K1.

the 50-Hz mains voltage. As already mentioned, one of the transformers and the 12-V supply can be omitted if you use optotriacs.

The microcontroller drives the triacs. When the microcontroller applies a pulse to an optocoupler input, the triac conducts until the mains voltage passes through zero.

A six-channel phase-control dimmer is implemented in the microcontroller software. It can be controlled via the serial port. The microcontroller causes a portion of the sinusoidal mains waveform, which is divided into 200

adjustable steps, to be applied to a string of Christmas lamps via a triac. That allows each string to be dimmed with a resolution of 200 steps.

The source code for the microcontroller and the accompanying PC program can be downloaded from the *Elektor Electronics* website (<http://www.elektor-electronics.co.uk/>).

The software for the PC amounts to a simple controller for a six-channel dimmer. The only thing you have to do, besides adjusting the six dimmer sliders, is to configure the Com port. There aren't any bells and whistles. Communication between the PC and

the microcontroller is quite simple. Configure the port for 19,200 baud, no parity, 8 data bits, and 1 stop bit. Two bytes are transmitted each time a dimmer value is changed. The first byte begins with a '1', followed by six bits that specify which channel (which light string) is to be changed. The final bit is the most significant bit of the new dimmer value. The second byte starts with '0', followed by the remainder of the dimmer value. This can be shown schematically as follows:

Byte 1: 1 c5 c4 c3 c2 c1 c0 d7  
 Byte 2: 0 d6 d5 d4 d3 d2 d1 d0

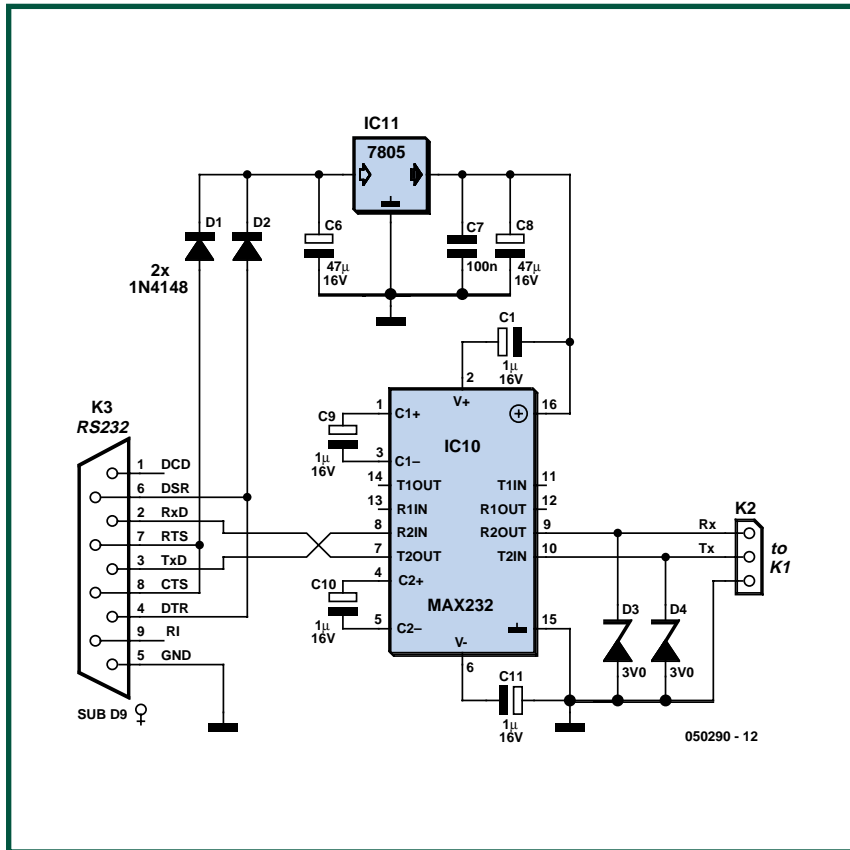


Figure 2. MAX232 wiring and connections. If you don't happen to have a spare Siemens C35 data cable, you can communicate with the microcontroller using this circuit.

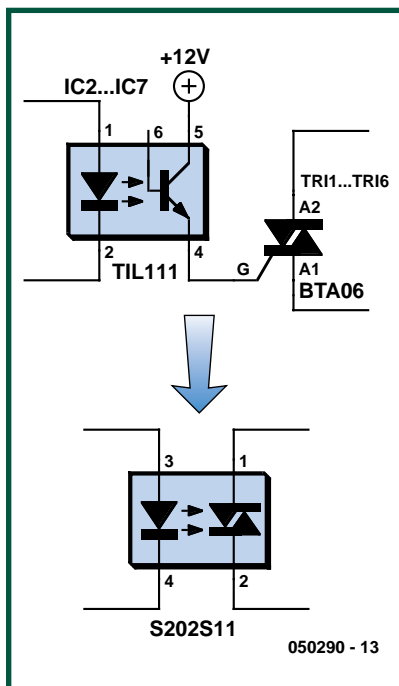


Figure 3. The optocoupler-triac combination can be replaced by an optotriac as shown here. No snubber network is necessary if you use the S202S11.

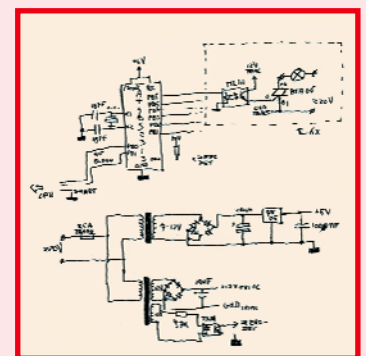
## About the author



Jeroen Domburg is a student of Electrical Engineering at Saxion Hogeschool in Enschede (Netherlands). He is an enthusiastic hobbyist and interested in microcontrollers, electronics and computers. Jeroen designs illuminated news displays as a part-time job, and he is presently working on a project involving networked modules fitted with individual microcontrollers.

Website:

[http://sprite.student.utwente.nl/~jeroen/kerstlampjes\\_art.html](http://sprite.student.utwente.nl/~jeroen/kerstlampjes_art.html)



As shown in **Figure 2**, you have to connect DTR to DSR (pin 4 to pin 6) when you make the serial interface cable. The same applies to RTS and CTS (pins 7 and 8). That provides the handshaking necessary for proper data transport. Use a 1:1 data cable if you need to extend the cable.

The MAX232 is powered off its supply voltage from the DSR and RTS lines (pins 6 and 7). If you fit diodes to these lines, they can do an excellent job of powering a 7805 voltage regulator IC.

The usual safety measures are applicable to this circuit, due to the fact that it is powered directly from the 230-V mains. A proper enclosure is thus not an unnecessary luxury. Please consult the instructions on the 'Electrical Safety' page published regularly in *Elektor Electronics*. We cannot endorse using an empty custard tub (as used by the author) as a 'zero-cost' enclosure.

(050290-1)

# Save Energy by Rev

## Remote switching with mini R/C cars



Bernd Oehlerking

**Miniature radio controlled cars are great fun for the armchair rally enthusiast but once the novelty has worn off or the car suffers a mechanical failure any true electronics enthusiast is more likely to reach for their smallest size Phillips screwdriver rather than toss the car straight into the dustbin. This design shows how just such a model R/C system can be adapted to act as a (W)LAN Router 'watchdog' to switch the Router on or off depending whether any networked PC's are present.**

Radio controlled models are getting smaller and cheaper; diminutive pocket-sized radio controlled cars can nowadays be found for as little as 5 to 10 pounds (probably less on Ebay). Take a closer look under the bonnet of these matchbox minis and you will be surprised at what you get for your money. A table at the end of this article lists the most important parts.

With the help of a little 'reverse engineering' and a few additional compo-

nents the radio control link can be pressed into service in a completely different field: wireless networked PCs usually connect to the Internet via a Router. For convenience the Router will be permanently switched on so that any PC has immediate wireless access to the Internet when required. The circuit suggested here uses a receiver circuit taken from a radio controlled car system to switch the Router on only when there is at least one PC (fitted with an R/C transmitter) switched on

and in range of the network. The circuit draws less current than a Router so in small networks there will be a worthwhile energy saving.

### Reverse Engineering

RE (Reverse engineering) is the process of examining finished equipment to work out how and why the unit was designed in such a way. The aim of the exercise is usually to reproduce (improve/adapt) the design while

# erse Engineering

avoiding any possible copyright infringements (thanks to [www.wikipedia.org](http://www.wikipedia.org) for help with the definition). This is in fact precisely the approach we used to investigate the workings of the model cars.

The R/C system has two channels, forward/reverse commands on channel 1 and left/right on channel 2. Transmission occurs on allocated channels either in the 27 MHz or 40 MHz ISM (Industrial, Scientific and Medical) band. The transmitter has four miniature pushbuttons on the PCB which allow for forward, reverse, left or right commands. Two AAA size batteries power the transmitter while the car itself runs on the energy stored in a small NiCd cell which requires topping-up from a charging unit before each race. The nominal cell voltage is 1.2 V with a capacity of 60 mAh and this stores enough energy for around one minute of activity. Steering is achieved with the help of two powerful Neodymium magnets mounted in the front of the car. An electrical coil positioned between the magnets exerts a pushing or pulling force on the magnets depending on the direction of current through the coil and this will have the effect of steering the car hard left or hard right. When there are no steering signals received, current through the coil is zero and a centring spring ensures the wheels return to the straight ahead position.

With this knowledge of the remote control unit's operation the transmitter can be adapted to send out RF signal pulses periodically when a network (LAN or WLAN) connected PC is switched on. The remote control receiver can then be used to switch the network Router. As long as it receives an RF pulse say every two minutes, it will know there is at least one PC in range and the Router will remain switched on. It functions as a sort of watchdog; keeping the Router switched on whenever at least one PC is in range and then switching it off when no PCs are detected.

## The transmitter

The transmitter PCB is shown in **Figure 1**. The upper right-hand push but-

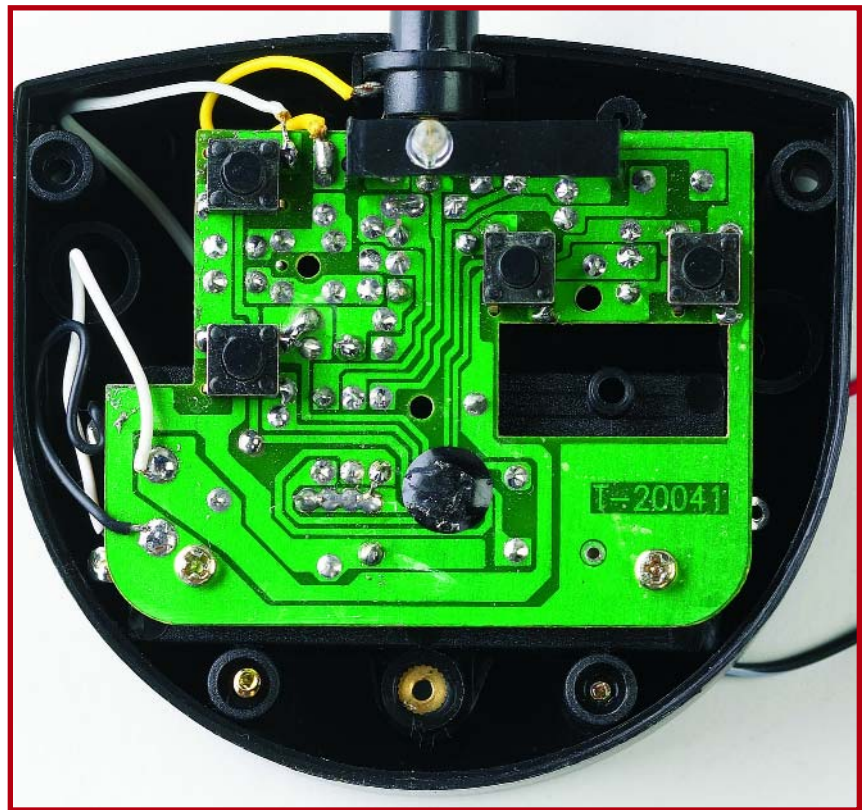


Figure 1. The remote control transmitter PCB.

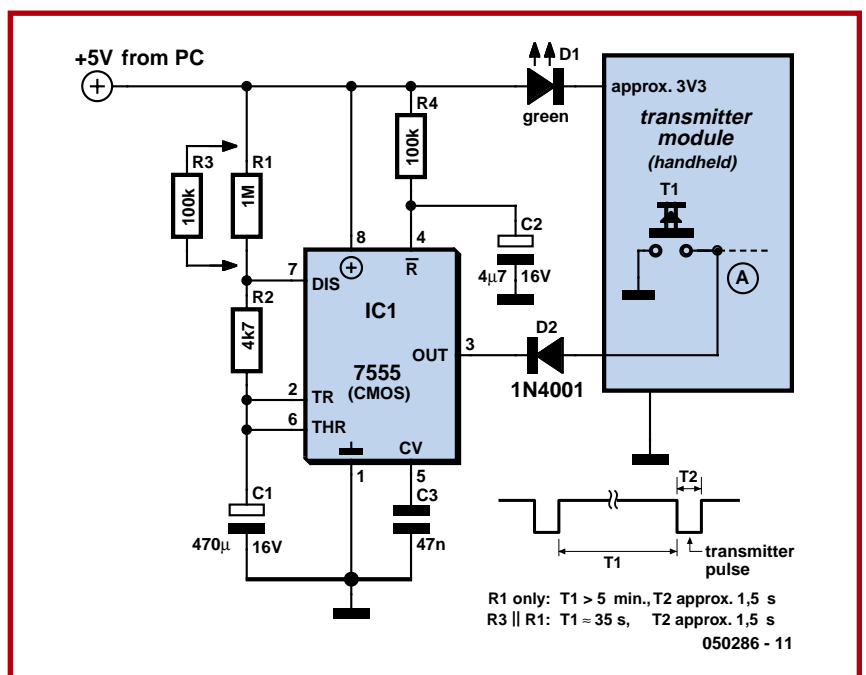


Figure 2. The modified transmitter circuit showing the transmitter PCB module.

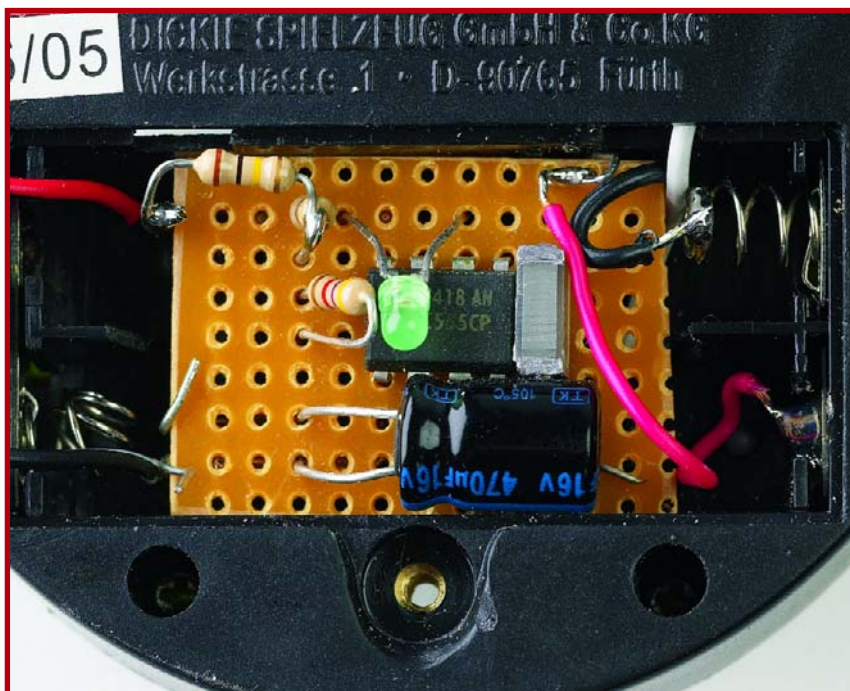


Figure 3. The additional circuitry fits into the transmitter battery compartment.

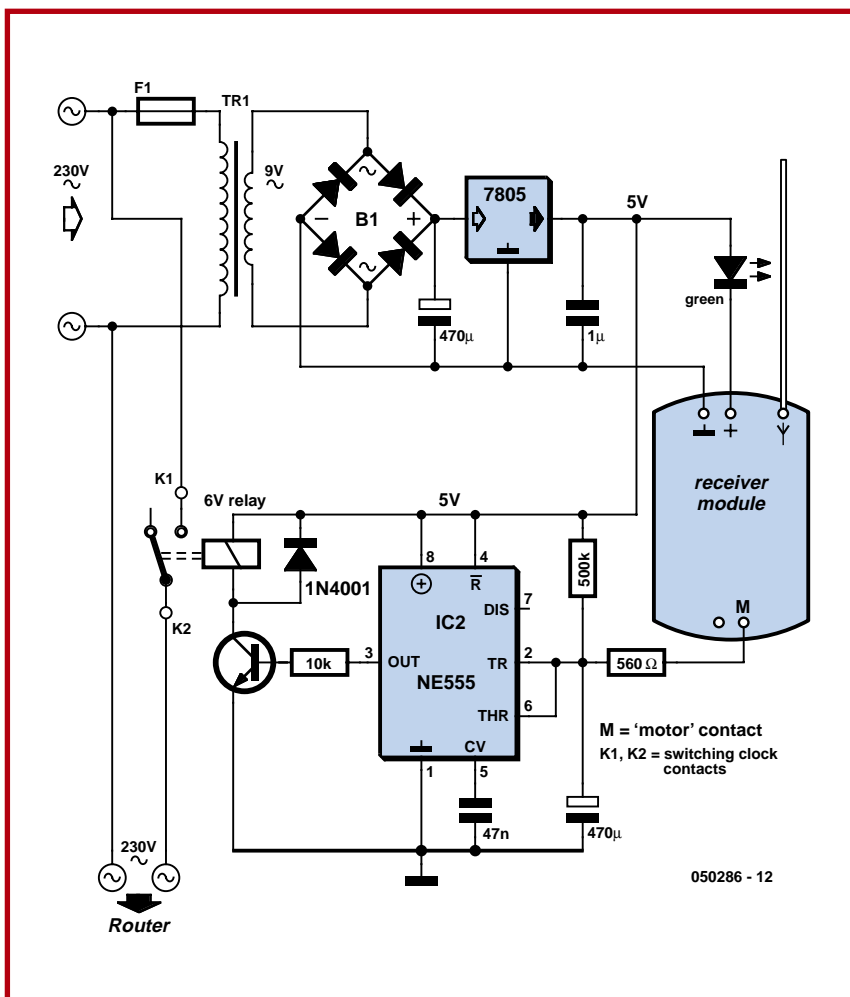


Figure 4. The modified receiver circuit showing the model car receiver module.

ton is used for making the car move forward. When the button is pressed a pulse is transmitted that is decoded in the receiver to switch the motor in the forward direction. The push button connects the input to ground (active low) so it is important that our interface also does the same. The connection is shown as point 'A' connected to T1 (the 'forwards' button on the transmitter) and switched low by pin 3 of the timer integrated circuit (IC1).

The 5 V supply for the CMOS NE555 is sourced from the PC power supply. A 'Y' cable can be used to connect directly to the power supply flying leads or if you would prefer not to open up the computer a keyboard adapter connector can be used to tap into the 5 V supply from the PC keyboard socket. LED D1 reduces the transmitter PCB supply voltage to around 3.3 V. When the PC is switched on capacitor C2 produces a reset pulse on pin 4 of the IC. The output on Pin3 will go low and enable the transmitter briefly. The receiver will detect the resulting RF pulse and switch on the Router (assuming it is not already switched on). It may be necessary to increase the value of C2 if this first RF pulse is too short to switch on the Router. The NE555 is configured as an astable multivibrator so it will repeatedly pulse the transmitter on and off as long as it is powered up and the voltage on C2 has risen above the threshold voltage. The values of R1, R2 and C1 control the astable timing; a value of 1 M $\Omega$  for R1 will produce an output high (transmitter inactive) time of more than 5 minutes with a low time (transmitter on) of approximately 1.5 s. The off period can be reduced to around 30 s by connecting a 100 k $\Omega$  resistor in parallel to R1. Ensure that the receiver time constant is longer than the transmitter time constant otherwise the Router will be continually cycled on and off.

The control circuit with the NE555 is built on a small piece of perforated board and fitted into the transmitter's battery compartment (Figure 3).

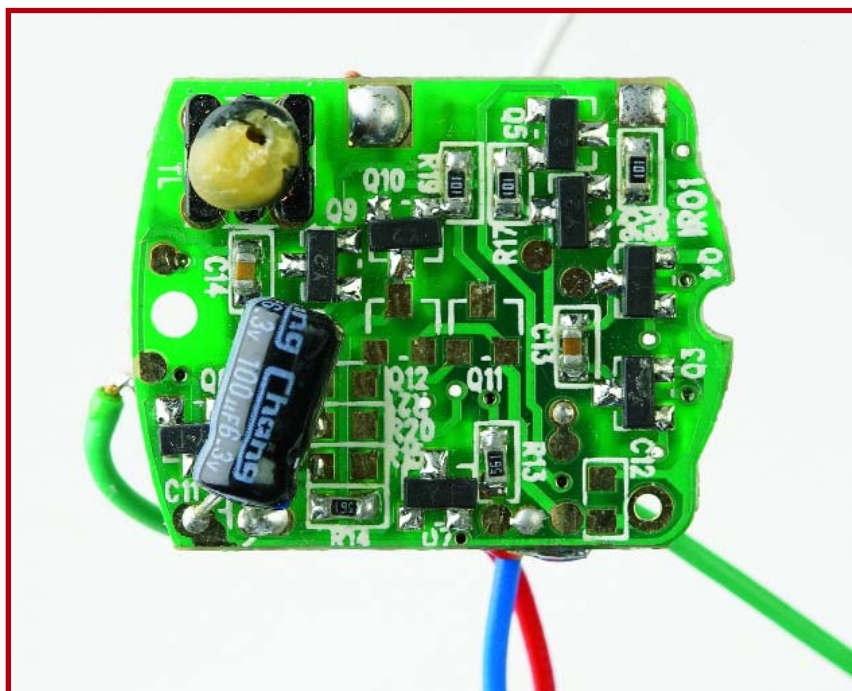
### The receiver

The entire receiver circuit is fitted into the enclosure of a mechanical time switch. The time switch typically uses a single pole switch to interrupt the mains connection to its in-built mains socket. The receiver circuit in Figure 4

uses a relay contact in parallel to the time switch contact. It is also possible to mount the receiver in any suitably sized plastic enclosure with a mains plug and socket.

A small mains transformer together with a bridge rectifier and 5 V regulator provide the supply for the monoflop configured NE555. The green LED is connected in series with the 5 V supply and provides a voltage drop so that approximately 3.3 V is available to power the receiver module (**Figure 5**). Before any modifications are attempted on the mains time switch it is **vital to read the warning at the end of the article and be aware of the dangers!**

Once the unit is powered up the 470  $\mu$ F capacitor will start to charge up to the supply voltage via the 500 k $\Omega$  resistor. As we mentioned before, this capacitor charging time must be greater than the transmission pulse interval of the transmitter. When a pulse from a transmitter is detected the 'M' output of the receiver will be switched to ground. The M connection was originally used to switch the electric motor ground return but in the new application it provides a discharge path for the capacitor via the 560  $\Omega$  resistor. This produces a high level on the output (pin 3) of the NE555 so that the relay pulls in and switches the Router on. Without any pulses received from any PC's the capacitor will charge-up towards 5 V. When the voltage across the capacitor reaches 2/3 of the 5 V supply voltage the relay contacts are released and power to the external equipment (the Router) will be interrupted. Supply current to the receiver flows through the LED and each time a pulse is received the increase in current causes the LED to light a little brighter and give a visual indication of a received pulse.



**Figure 5.** The R/C car receiver PCB used in the circuit shown in Figure 4.

## Warning! High Voltage

The transformer, mains fuse, relay contacts and connections to the mains wiring (Figure 4) are carrying lethal voltages. It is imperative that they are enclosed within a properly insulated enclosure and that all safety guidelines are adhered to.

Please refer to the Electrical Safety page printed regularly in this magazine.

### Practical tip

Before you devote too much time on this project first build the transmitter and test the system to make sure it has sufficient range to cover your PC network with the receiver powered from 3.5 V. Switch the transmitter to forward

and take the receiver around the area checking that the motor keeps turning. If the range is sufficient check the two motor connections to see which is switched to ground.

050286e

## List of components

Model car	Remote control transmitter	Charger unit
Receiver PCB 1.2 V/60 mAh NiCd cell Small DC motor Coil (steering) 2 Neodymium Magnets 1 rear axle 2 front wheels Bodywork screws	Transmitter PCB, Telescopic aerial 2 x 1.5 V batteries Screws Enclosure with battery compartment	Charger PCB 3 x 1.5 V batteries On/Off Switch Enclosure

# E-blocks and Flow

## Programming, simulating and testing have never been this easy!

Evelien Snel & David Daamen

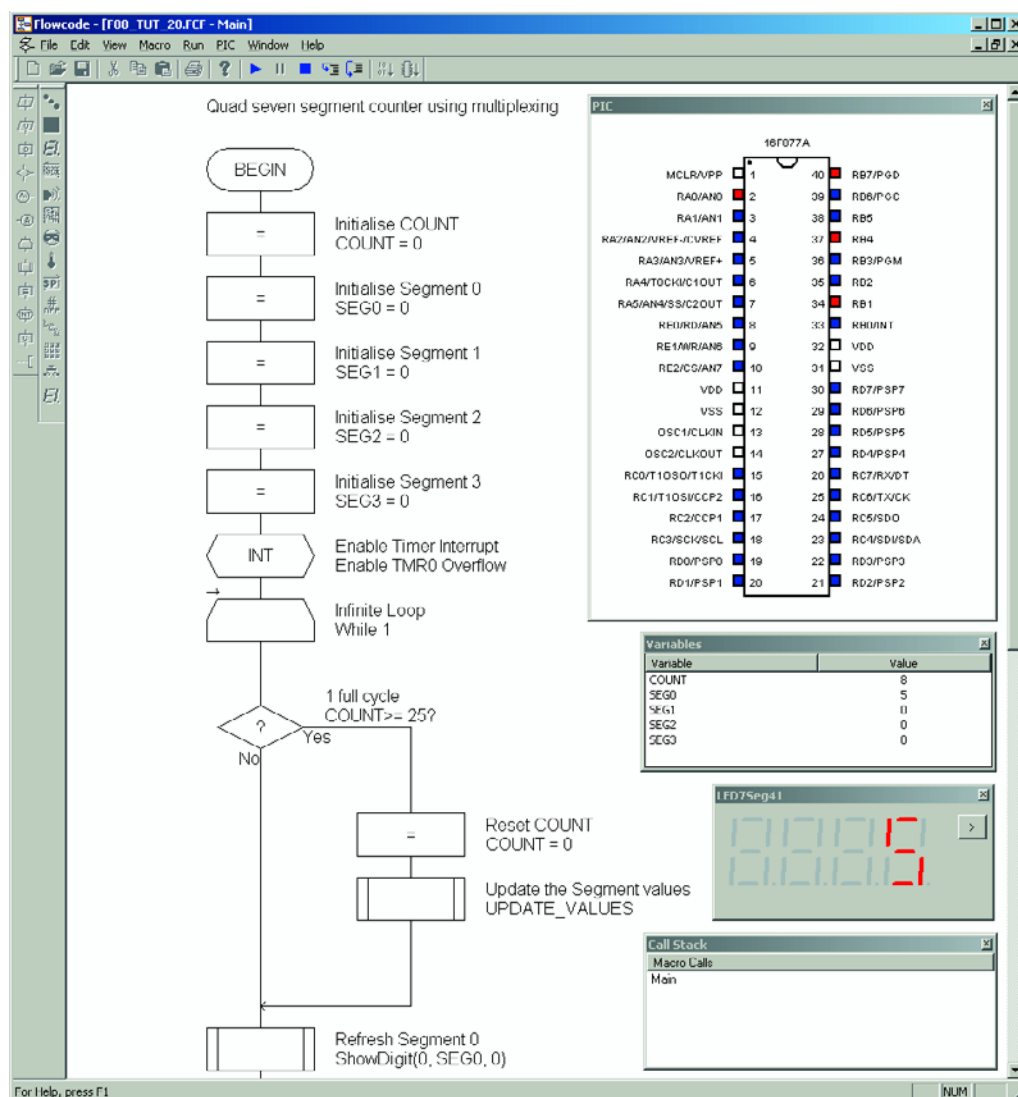


Figure 1. The Flowcode environment: simulate before programming!

Last month we introduced you to E-blocks. We'll now take a closer look at Flowcode, the programming software that complements the modular design of E-blocks perfectly. Even if you don't yet have any E-blocks it is still worthwhile to read further. This software happens to be suitable for other PIC designs as well!



# code

It is of course a bit difficult to describe a programming tool if you don't have access to the hardware. Although this article is based around E-blocks, Flowcode can also be used to program other hardware that uses PIC controllers. But why should you? When you use Flowcode along with E-blocks you'll find that you save yourself a large amount of development time. A large number of E-blocks come with a fully programmed macro for use with this programming software. This means that you no longer need to have a detailed knowledge of how to interface these peripherals, so you can concentrate on the main program!

## Go with the flow

Flowcode is a program that makes it easy to write microcontroller applications, simply by dragging icons onto a program flowchart. These programs can drive various peripherals (such as LEDs and LCDs) that are connected to the microcontroller.

The Flowcode environment consists of a workspace containing flowchart windows, several toolboxes with icons for the flowchart and external components, three windows where the status of the microcontroller and the connected components can be inspected, and two windows that display the variables and macro calls during the simulation (**Figure 1**).

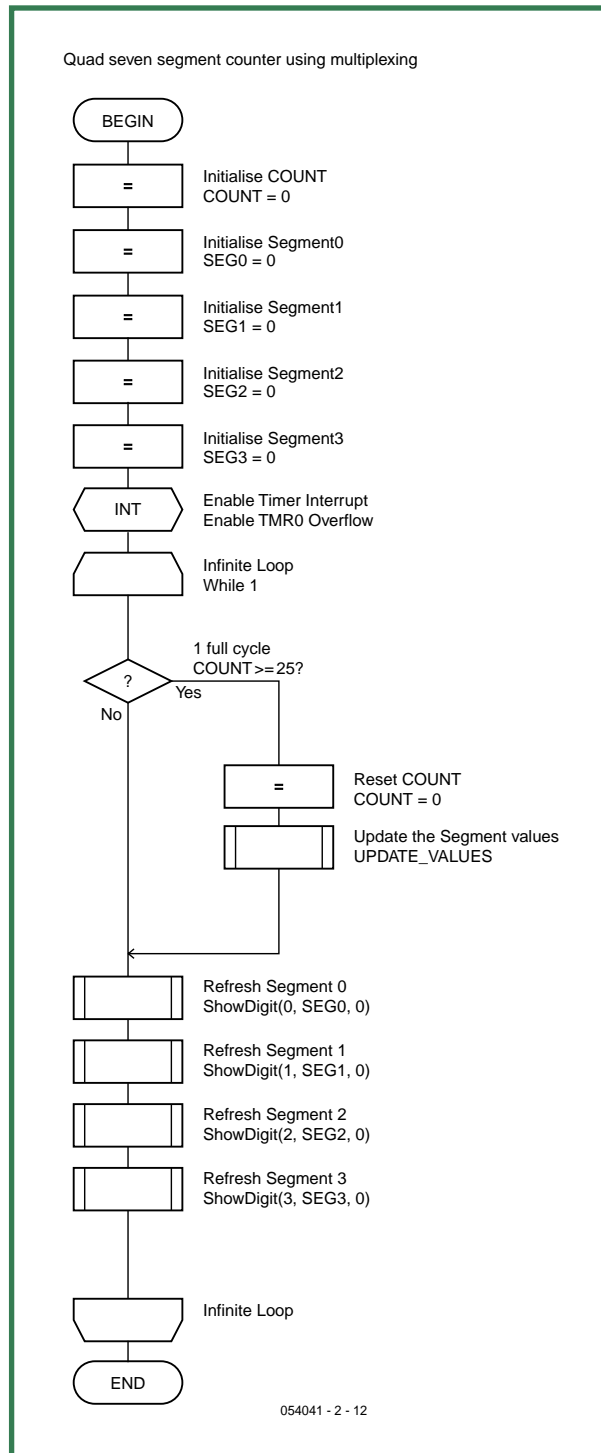
To create a new program you should follow these steps:

1. Open a new flowchart, then specify the type of microcontroller that the software should work with.
2. Drag icons from the toolbox onto the flowchart to give the program a body.
3. Add peripherals to the project by clicking on the icons on the components toolbox. Adapt their properties and specify how they're connected to the controller.
4. Simulate the application to check that it works as expected.
5. Transfer the application to the microcontroller. The application is first automatically translated into C, then into assembler code and finally into object code, which is then used to program the controller.

## Macros make life easier

Macros are a powerful element of Flowcode. These are parts of the program that are represented in the flowchart as a single block. In reality, each macro is a miniature flowchart on its own. The use of macros offers many advantages:

- Sections of programs that appear more than once only have to be typed in once.
- The flowchart is easier to follow because many of the details are hidden inside macros. The flowchart then only shows the main program tasks.
- Macros can be saved separately (exported) and reused at a later stage in another program by importing them.



**Figure 2.** Flowchart for the counter from example 20.

## Numerous examples

Flowcode comes complete with a large number of examples (*tutorials*). Let's take a look at tutorial 20, a counter with a multiplexed 4-digit 7-segment-display. The display is driven via two I/O ports of the PIC. This example is interesting because it shows how easy it is to drive such

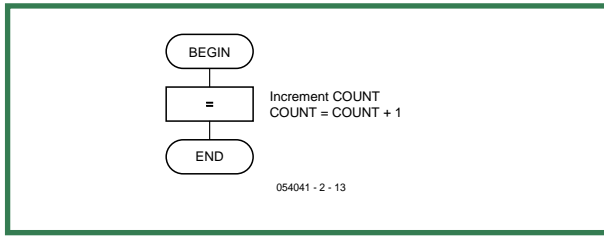
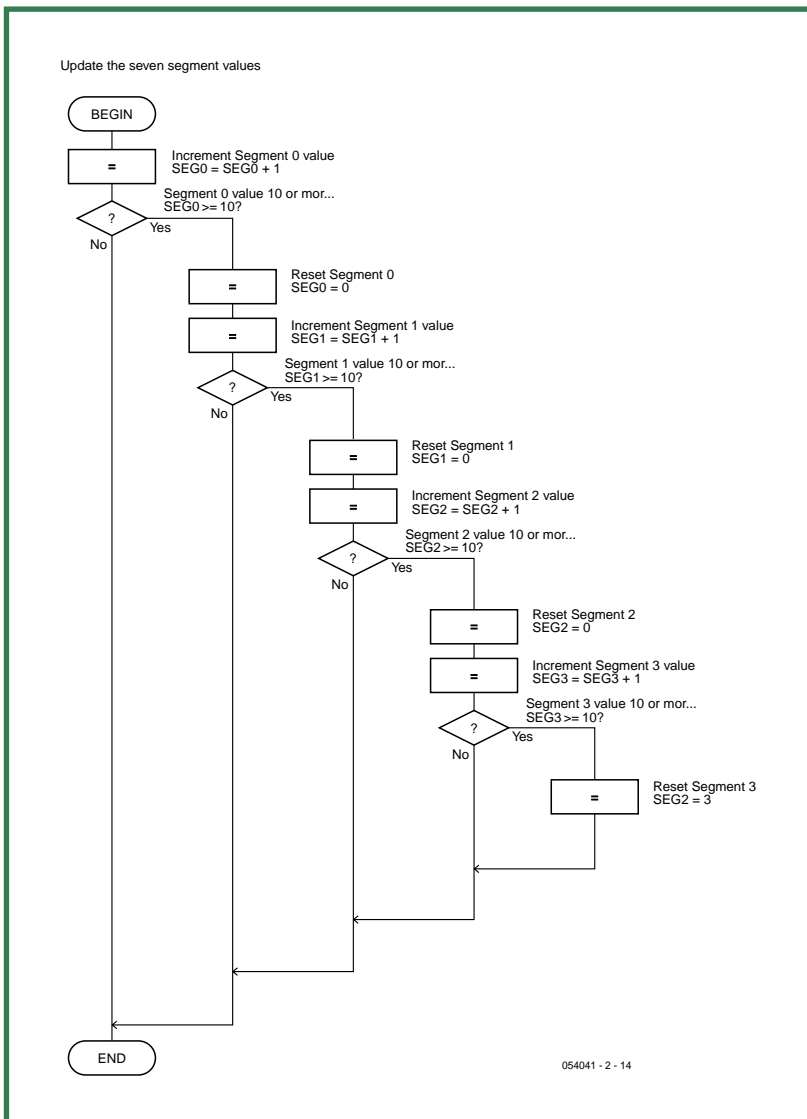


Figure 3.  
Flowchart for the macro INTERRUPT\_TMRO.

a display with Flowcode, despite the fact that we're dealing with a total of 32 light-emitting segments! The flowchart for this program is shown in Figure 2. The program starts with five 'calculations', where the five variables we use in the program are given initial values. Then the interrupt routine is installed and the program enters an endless loop, where the 7-segment displays are driven sequentially. In this loop the value to be displayed is incremented at regular intervals.

The program branch begins with a 'condition'. When the value of the variable COUNT is greater than or equal to 25 the right-hand branch is taken, otherwise the program goes straight on. In the right-hand branch the value of the variable COUNT is reset to 0 and then the macro UPDATE\_VALUES is called. This macro increments the dis-

Figure 4.  
Flowchart for the macro UPDATE\_VALUES.



played count by one by adjusting the variables SEG0 to SEG3. The two branches then meet up again and the four digits are lit up one after the other, again using a macro. We have then reached the end of the loop and the microcontroller jumps back to the start.

### Missing Code?

The observant reader will now wonder if something isn't missing from this program, since it isn't clear how the value of COUNT can ever become greater than 25. COUNT has been set to 0 and from then on never appears to change! Incrementing the value of COUNT is the task of the interrupt routine in the program. This can be found from the menu Macro>Edit/Delete. When this menu is selected a window opens with the names of the macros used in the program. In this case we're interested in the macro INTERRUPT\_TMRO. When we select this from the list and click on Edit another flowchart is displayed (see Figure 3). And here is the piece of code that appeared to be missing! The only task of this interrupt routine is to increment the variable COUNT.

We can take a look at the other macros in the same way. The flowchart for the macro UPDATE\_VALUES is shown in Figure 4. It shows that a lot of work is required to increase the values of SEG0 to SEG3. First the value of SEG0 (which is the least significant digit of the displayed value) is incremented by 1. This is followed by a conditional branch. As long as SEG0 is less than 10 nothing else has to be done. In this case the program carries straight on. When SEG0 is equal to 10 it is reset to 0 and SEG1 (which is for the second digit) has to be incremented. SEG2 and SEG3 are eventually incremented in the same way.

The macro ShowDigit is responsible for driving the actual segments of the display, but this pre-programmed macro cannot be inspected by the user.

### Connecting and programming the PIC

Does the simulation work? When you use E-blocks you are only a few steps away from a working prototype. The E-block with the 7-segment displays (refer to the Elektor website for more information) can be connected directly to the E-blocks Multiprogrammer. Remember to connect a supply wire between V+ OUT on the processor board and V+ on the display board.

Most of the tutorials are created for use with 16F84/16F88 type PICs, but you could also use a PIC 16F877 with the Multiprogrammer board, for example. Before you can send the program to the PIC you have to ensure that the Flowcode is aware of the type of target processor. This is done using the three top options from the PIC menu of the program.

Once everything has been set up correctly all you need to do is click on PIC>Compile to PIC from the menu. The program is then translated into C, converted into ASM code, transformed into object code, and finally converted into HEX code, which is sent to the microcontroller via the USB connection. Once the code has been transferred, the PIC will immediately start executing it: the counter on the 7-segment display starts to increment!

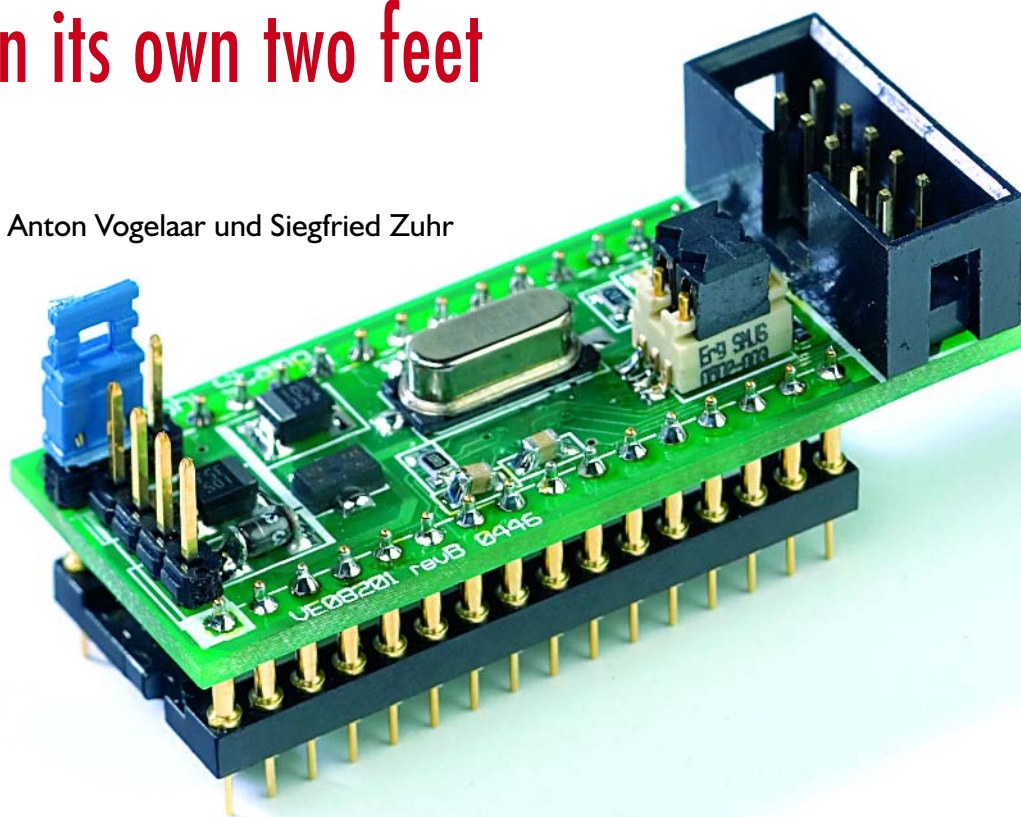
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More information and the complete E-blocks catalogue can be found at: <http://www.elektor-electronics.co.uk/eblocks>

# DELPHI FOR ELECTRONIC ENGINEERS

## Part 10 (final) The DelphiStamp stands on its own two feet

Detlef Overbeek, Anton Vogelaar und Siegfried Zuhr



**In this final part of the Delphi course we will continue with the development of the sprinkler system started in part 9. More valves are added to the system, as is a water pump. On the software side we will add a timer function. The end result is a 'grown-up' sprinkler system that will prove its worth during the summer.**

In the previous part we started the sprinkler system project. We created a basic system, which was first simulated in Delphi. The program was then stored in the Delphi Stamp. Here we made use of the evaluation kit, specifically the LCD, the pushbutton, a second pushbutton (connected to the second analogue input) and the LEDs, which were used to indicate the state of the outputs. In that system you could select individual valves, how long they stayed open for and how often the cycle should be repeated. In this instalment the object is to enhance the project with the addition of more valves, a water pump and the facil-

ity to start the sprinkling cycle at a later time (for example during the night).

We would like to call up and modify the settings via a PC, using a monitoring/configuration program. (The program for the Delphi Stamp is developed in Delphi, then cross-compiled and stored in the Delphi Stamp. This then functions completely independently. The monitoring/configuration program is a separate application. This program runs on a PC and uses an RS232 cable to read and modify the settings of the Delphi Stamp program, effectively controlling it remotely).

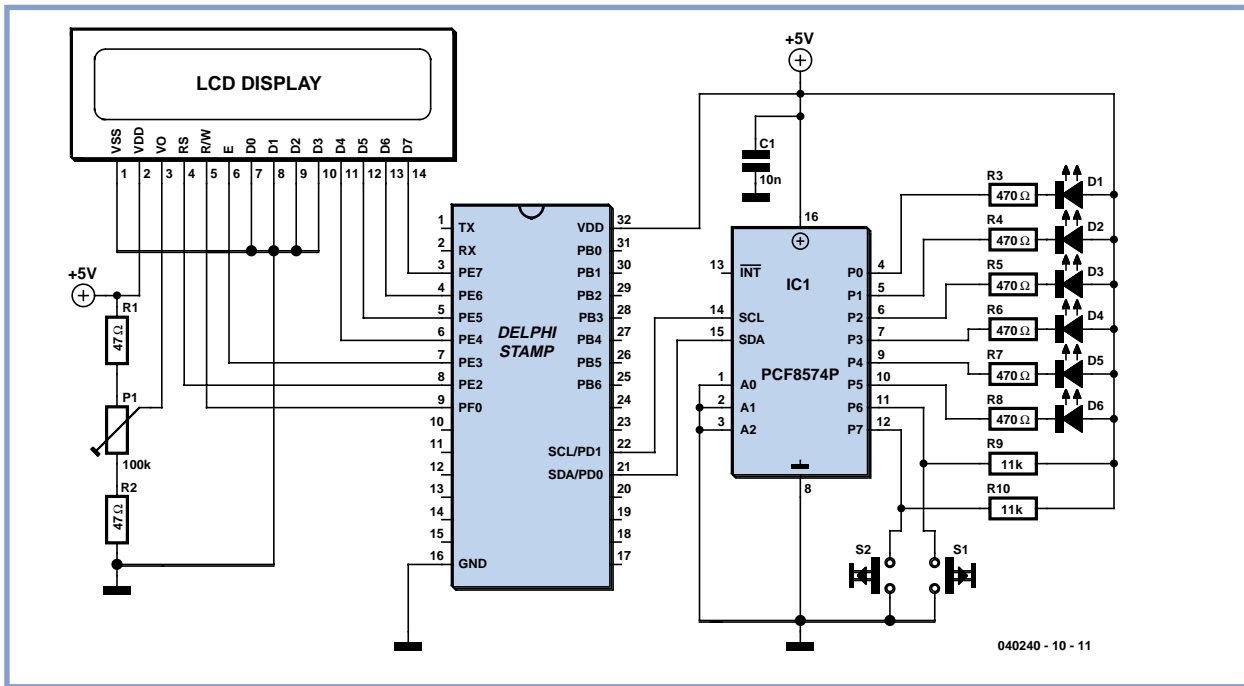


Figure 1. The circuit diagram for the hardware used in this project.

There are two ways in which the project can be expanded:

We can either use the existing I/O capabilities of the Delphi Stamp or we use the I<sup>2</sup>C port to communicate with the extra hardware.

In this case we decided to use the I<sup>2</sup>C interface, and the necessary pushbuttons and outputs are connected via an I/O chip to the Delphi Stamp. For this we use a PCF8574, which has 8 I/O lines that can be written to or read from. A maximum of 16 of these chips can be addressed on the bus, which means that the system can be easily expanded to have up to 16 x 8 = 128 IO lines. When this is later used on a standalone basis (without the evaluation board), the only connections needed are for the Delphi Stamp, the LCD, the I/O chip and the power drivers (Figure 1).

## The software

We'll use the source code of the last instalment as the basis for developing the software. The simulation has to be expanded with the I/O chip, two pushbuttons and six outputs. These are added to the existing control panel in the Graphical User Interface (Figure 3). The underlying code has to be modified in several places.

## The menu structure

We have to add two buttons to the form of the program. We'll use Speedbuttons for these (because they have a 'Down' property; when clicked, this property becomes True).

Two procedures and a function are added to the unit Udrivers: TWI\_init (Two Wire Interface = I<sup>2</sup>C), PCF8574\_Wr (Write) and PCF8574\_Rd (Read). In the simulation they emulate the actions of the drivers in the Delphi Stamp. The init doesn't do anything in the simulation and is therefore empty.

PCF8574\_Wr is responsible for updating the colour of the LEDs on the screen. PCF8574\_Rd reports the state of

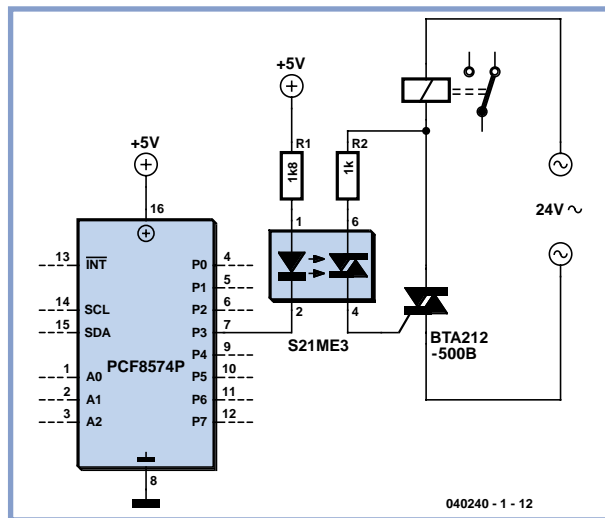


Figure 2. An example of the valve driver, using 24 V<sub>ac</sub>.

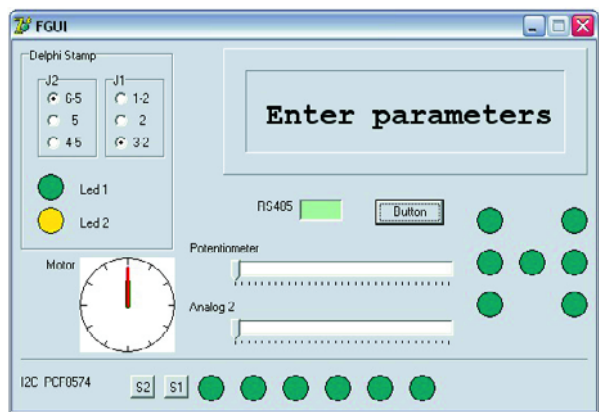


Figure 3. At the bottom-left: the two buttons and six LEDs.

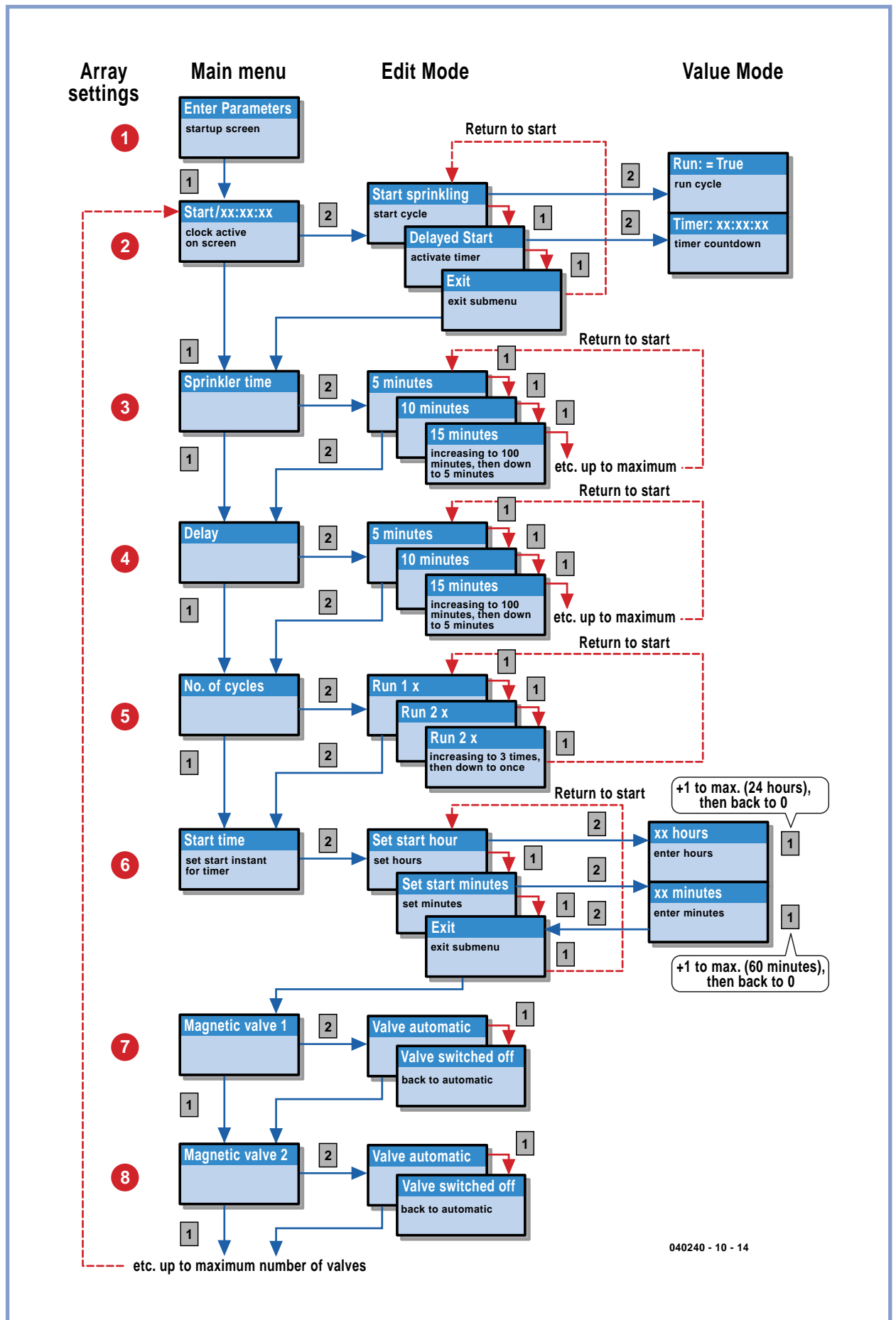


Figure 4. All the functions in the menu.

the pushbuttons. It does this by looking if the 'Down' property is set to True. If this is the case it will be reflected in the return value of the function.

That covers the expansion of the simulation.

The core of the program, the unit UControl, requires more attention. We want to increase the number of valves from three to five, and use the sixth output to drive a water pump to provide our own water pressure. We also have to add an entry to the menu for setting the start time.

The array that holds the menu entries is therefore increased to hold 10 entries.

In the code for the menu we have to take account of the new size of the array. The menu entry 'Starting time' is added between 'Number of cycles' and the first valve (**Figure 4**). In this way, when we add more valves at a later stage we can add them on after the last valve and we won't have to change the structure of the menu.

A sub-menu is added to the Start entry in the menu. From here we can choose between 'Start direct' and 'Start delayed'. 'Exit' is used to return to the main menu.

A similar menu can be found in the 'Starting time' menu entry, with the options 'Set start hour', 'Set start minute' and 'Exit'.

For the display of text on the LCD we have added the procedures 'ShowStart' and 'ShowTimer'.

For going through the menu in a vertical direction (via button 1), Menulevel 1 has to be adapted. This now has a sub-menu with three options.

The valves are now dealt with one position further, from >4 to >5 in the comparison (If MenuLevel > 5 then). Position 5 now deals with incrementing the values for the starting hour and minutes. When the hour becomes greater than 23 the variable is reset to 0 and the minutes are reset when the value goes beyond 59.

The time is stored in two variables: S\_hour and S\_min.

We will come back to these later on.

For going through the menu horizontally (via button 2) we have to change Menulevel 1. When button 2 is used to open the menu, the initial value is read from the array. This will be equal to 1, which corresponds to the 'Start direct' option. Button 1 can now be used to go through the sub-menu, where option 2 is for 'Start delayed' and option 3 is for 'Exit'.

When button 2 is pressed again, a jump is made to the left or right in the menu structure, depending on the current position (edit value).

When the edit value is >2 then the 'Exit' option is performed and the next item from the main menu will appear. If this isn't the case then when editmode = 1 the system will be started by setting the variable Run to True. When editmode = 2 the variable Timer is set to True.

These variables affect the actions of the program later on in the procedure ControlExe.

But first we have to complete the menu. When setting the timer the menu is navigated in a similar manner, but this time when button 2 is pressed a second time we move another level to the right, into the Value-mode. The text on the display is provided by 'ShowTimer'

In Value-mode button 1 is used to increment the value.

The value of the edit-mode determines whether S\_hour or S\_min is incremented. When button 2 is pressed a third time we go back one level to the left.

At the end of the sub-menu we can return to the main menu via an 'Exit' option.

We will now explain the function of the variables S\_hour and S\_min. Together they make up the time at which a cycle should be started. This has to be compared with the current time, which is stored in the variables T\_hour,

T\_min and T\_sec. The Delphi Stamp doesn't have a real-time clock; hence we use a simple counter to increment these variables. The PC is used to set the correct time of the clock.

This takes us directly to the next item. To implement this the PC has to be able to write to the memory of the Delphi Stamp. This isn't a problem, since we can use M485.DLL, which communicates with the 485-server in the Delphi Stamp. Just three extra lines in the unit Umain for the Delphi Stamp project (so not in the simulation project!) are all that's needed to start the server.

But how do we determine the location in memory for these variables? If we add them to a new unit and have this as the first unit in Umain for the Delphi Stamp, then they will be placed at the start of the available memory. If we look at the memory structure for the Delphi Stamp, we first see the BIOS. This goes up to \$17F, which means that the first usable address will be \$180. This is therefore where the first variable is stored, and the rest follow on from here.

We therefore create a new unit called UMem.

We add the following variables to this:

**T\_hour, T\_min, T\_sec** of type Byte, which are used for the display of the current time.

**S\_hour, S\_min** of type Byte, which are used to store the starting time.

From UControl we move these variables here:

**Settings : Array[1..10] of Byte**, for storing and reading the settings.

**Run** of type Byte, to keep track of the status. (0 = False, >1 = True).

**Timer** of type Byte is added to determine the status of the timer function.

And that's all that is required.

## More on UControl

We add the unit UMem to the Uses section of UControl so we can make use of the variables.

Some code is added to the procedure ControlInit for the initialisation of the I<sup>2</sup>C (TWI\_init) and the new variables.

We also set default values in all of the menu entries here.

Most of the changes are made within the procedure ControlExe.

To start with, some code is added to keep track of the time. The procedure ControlExe is called every 100 ms. We then count to 10 to obtain one second, then to 60 for the minutes and again to 60 for the hours. When the hours reach 24, everything is reset to zero and a new day begins.

The clock is displayed on the bottom line of the main menu. The code that deals with the bottom line has been modified for this. When the timer function has been activated the bottom line will show the word 'Timer' followed by the time remaining. This is calculated by a separate piece of code using the values of T\_hour/T\_min and S\_hour/S\_min.

The changes in the menu are made by adapting the section that deals with EditMode. In Menulevel 1 the routine ShowStart is added and in Menulevel 5 ShowTimer replaces ShowValve, which moves on to Menulevel > 5. When it's time to start the cycle we set Run to True. At this moment in time we also make a note of all the settings. Up until then they could still be changed (externally). An extra bit of code has been added to read these settings when the Run-mode begins. This occurs just

before the cycle is started.

And now for the I/O. The reading of the pushbuttons is replaced by the reading of the I<sup>2</sup>C chip. From the returned value we can determine which buttons are pressed and which procedure has to be called.

The procedure SetValve also has to be adapted for use with the I<sup>2</sup>C chip. In here a binary number is written to the chip using PCF8574\_Wr, with the value depending on the valve that needs to be activated. Along with the valve, the bit for the pump is also turned on. At the end of a cycle everything is turned off.

This concludes the changes needed in the program.

If we press button 2 from the 'Start' option we reach a sub-menu with the option 'Start sprinkling'. Pressing button 2 again will start the cycle.

We see that the left-hand LED turns on as will the right-hand LED of the first enabled valve, which is normally valve 1 (assuming that no parameters have been changed and valve 1 was turned off). At the end of the sprinkling time the next valve is turned on. At the end of the cycle the last valve is turned off, as well as the pump.

The last topic is the starting of the timer.

If we go to the option for 'Starting time' in the main menu and then press button 2 we reach a sub-menu to 'Set start hour'. If we press button 2 again we go another level down in the sub-menu and can now adjust the value for the starting hour using button 1. When you have set the required value, button 2 will return you to the previous sub-menu. Button 1 can then be used to step to the next option to 'Set start minute'. In here we can set the starting minute and exit using button 2. With button 1 we step to the 'Exit' option and then press button 2 to return to the next option in the main menu.

The starting time has now been set. If we now go to the 'Start' option of the menu and press button 2, we can use button 1 to choose the 'Delayed start' option. Pressing button 2 will activate this and the display will show 'Timer xx:xx:xx', indicating how much time is left before the cycle will start. Pressing button 2 again will exit from this mode.

When the timer is turned on, the internal variable Timer is set to True. In ControlExe the starting time is continually compared with the current time and the display is updated.

When the result of the comparison equals zero, Timer is set to False and Run is set to True to start the cycle. At the end of the cycle the system turns itself off.

Please note that soon after the initialisation of the time-variables it can happen that the cycle starts immediately when the timer mode is turned on. The comparison of the times works by comparing the variables T\_hour/S\_hour and T\_min/S\_min. If the timer mode is selected within the first minute after turning on the Delphi Stamp these values are all still at 0, with the result that the cycle starts.

## To the Delphi Stamp

The unit UControl, which was created and tested in Delphi, has to be copied to the directory where the project for the AVR compiler is stored. The unit UMem is new as well, so also has to be copied.

We then run AVRpas and start a new project. Make sure that all settings are correct (refer to the description in the previous article) and give a name to the project. Add the file UMain and make this the main file.

You should then open the other files in the editor via

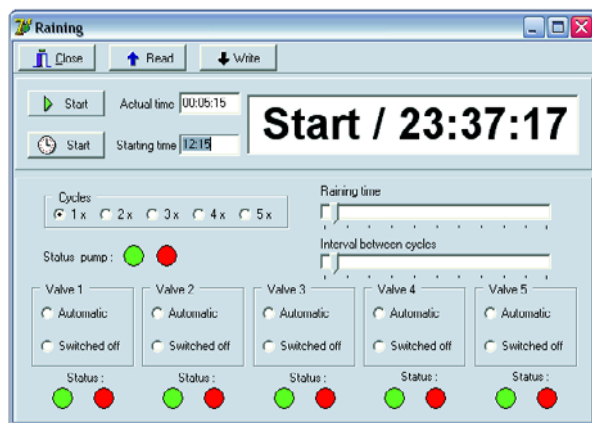


Figure 5. The monitoring/configuration program.

File/Open and add UDrivers.pas, UControl.pas and the unit UMem. The I<sup>2</sup>C driver has been added to the unit UDrivers. This has been kept separate on purpose to show how easy it is to add new modules whenever they are required. The enhanced version is called UDriversEx and is included in the project via the 'Uses' section of Ucontrol.

Compile these two files via Compile/Current editor file. Sometimes there may be a few error messages because some of the Delphi functions aren't included in AVRpas. These can often be corrected by making simple modifications, giving a successful compilation.

Compile the project: Project/Main Project file. The code has then been generated and you can exit from AVRpas.

The file created by the cross-compiler, which contains the binary code, now has to be stored in the Delphi Stamp. For this we'll use an RS232 connection and the program Mon485, which connects to the M485 server running on the Delphi Stamp. Copy the program across to the Delphi Stamp, which then becomes a fully independent device.

## Monitoring via the PC

The monitoring via a computer is done with a separate program. By 'monitoring' we mean that the program can read and display all settings.

In this case we can also send new settings to the Delphi Stamp via the Write button.

During normal operation the program will be in Read-mode. All parts of the system can be found again in the monitoring program: the LCD display, the settings, the two start options and the status of the outputs. Added to these are the actual time (from the PC) and buttons for reading the settings or write them to the Delphi Stamp. This program communicates via the M485 protocol with the Delphi Stamp and can retrieve the stored settings. The buttons marked Start and Timer Start are used to set the Delphi Stamp in either Run or Timer mode.

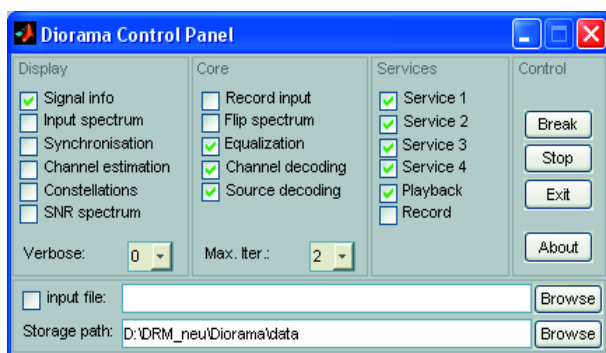
The description of this application for the Delphi Stamp concludes the course in Delphi for Electronic Engineers. We hope that you've found it very informative.

More information about the Delphi Stamp can be found at [www.vogelaar-electronics.com](http://www.vogelaar-electronics.com). Further details about this course and the programs are at [www.learningdelphi.info](http://www.learningdelphi.info).

# Tune in with Matlab

Wolfgang Hartmann and Burkhard Kainka

**DRM broadcasts provide unparalleled programme quality on short, medium and long wave frequencies. Diorama is a new open-source DRM decoder program developed at the University of Kaiserslautern, Germany. With the addition of a little hardware it can decode these long range transmissions and play them in real-time on a PC. A strongpoint of this implementation is its use of MATLAB which provides an insight into the nuts and bolts of signal processing.**



**Figure 1.**  
Additional information  
is displayed via the  
control panel.



**Figure 2.**  
Received signal  
information.

Radio broadcasts using the DRM (Digital Radio Mondiale) digital format are becoming more commonplace but commercial receivers are still a little thin on the ground and needless to say very expensive; a good enough reason to add a low cost RF front-end to your PC (e.g. the *Elektor Electronics* DRM receiver [1]) and decode the signals with software.

Diorama is a complete open-source DRM receiver decoding program operating in real-time that has been developed by Torsten Schorr and Andreas Dittrich at the Institute of Telecommunications at the University of Kaiserslautern [2]. The program is similar to the 'Dream' software that regular readers will recognise from our earlier articles on DRM receivers [1]. Diorama is implemented using the numerical computing environment MATLAB. This approach enables the signal decoding process can be interrupted and examined at any point to gain valuable understanding of the signal processing behaviour. The program requires version 5.2 of MATLAB (release 10) or higher. A graphical user interface for adjustment and display of system parameters is optional. The input signal spectrum, synchronisation variables, received S/NR and many other variables are shown in the standard online display. In addition it is possible to display the received signal along with the recovered output data.

## First Impressions

For those who do not have the full version of MATLAB there is an alternative EXE version of Diorama that only requires a runtime version of MATLAB (MCRInstaller). We tested this version here in Windows XP. Once *diorama.exe* is started it runs in the background in a DOS window. The Diorama Control Panel is also dis-



# A look at the new open-source DRM decoder program Diorama

## The concept

By Torsten Schorr and Andreas Dittrich

MATLAB was chosen for this project to handle the received data stream because it provides an interpreted script-like programming language that facilitates an efficient step-wise methodology for application software development and incorporates useful debugging tools. In addition MATLAB incorporates many useful mathematical signal processing tools and functions for data visualisation.

Use of the internal signal processing routines of MATLAB together with a little native code where necessary (for the more processor-intensive tasks) ensures that Diorama executes fast enough to be able to decode the DRM signal in real time.

In addition the user is able to manually interrupt program execution and observe internal data and variables with the

help of the MATLAB integrated visualisation tools. Program execution can be stepped and break points inserted. Changes to the program code can be easily made which take effect immediately when Diorama is restarted without the need to recompile the code. Development and debugging of the new algorithms for DRM decoding proved to be relatively simple and much faster using this development environment. This environment is also a useful educational tool because the operation of many telecommunications algorithms can be illustrated with Diorama.

MATLAB is also available as a compiler version. Depending on the release version of the compiler, it can either produce binary files (in this case DLLs) or files using MATLABs own file format. In both cases an executable (.exe) file is generated which runs like any other software applications on the PC. The necessary libraries including signal processing, visualisation tools and a virtual processor for the MATLAB specific format are contained in a runtime environment which must be installed in parallel to the Diorama program.

played but this can be closed if you prefer the application to 'disappear' from the screen. Diorama handles signal decoding only, tuning and setup of the DRM receiver hardware is performed by an additional program such as *DRM.exe* for the *Elektor Electronics DRM-RX* [1].

With the Control Panel (**Figure 1**) it is possible to view additional data. Signal info (**Figure 2**) identifies the received station and any additional data services from the station. Data such as the signal to noise ratio are also displayed. The received signal input spectrum is shown in **Figure 3** and **Figure 4** gives the three-dimensional 'signal constellations' of the received carriers.

The quality and robustness of the decoding process is comparable to the Dream software. When the received signal to noise ratio drops below the level where the signal can be reliably recovered the software outputs artificial noise on the audio so that it is possible to distinguish this condition from a temporary break in signal modulation.

A strongpoint of the software is the handling of information pages sent by DRM broadcast stations. The pages can be viewed using your normal Internet browser application. Received images are stored in a folder and can be retrieved later if required.

(050207-1)

## Literature and Links

[1] 'Build your own DRM receiver',  
Elektor Electronics, 3/2004, P. 12

[2] <http://nt.eit.uni-kl.de/forschung/diorama>

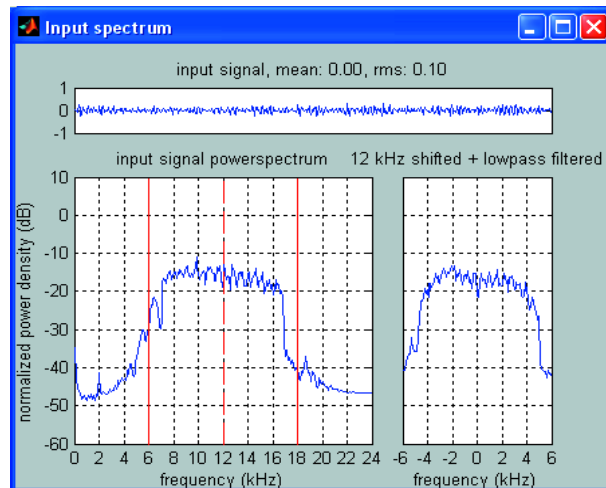


Figure 3.  
The signal spectrum display gives a clear impression of the input signal.

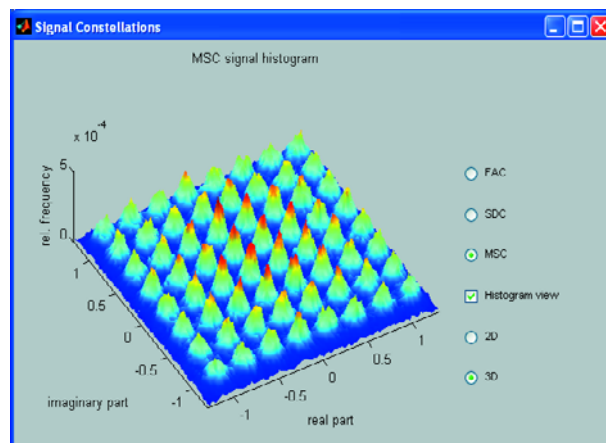


Figure 4.  
The receive Signal Constellations shown in 3D.

The content of this note is based on information received from manufacturers in the electrical and electronics industries or their representatives and does not imply practical experience by Elektor Electronics or its consultants.

# CURRENT SENSING USING THE ZXCT10xx

Gregor Kleine

Measuring high-side current becomes a piece of cake when you use the ZXCT10xx range of devices from Zetex. The chips can produce a proportional output voltage referenced to ground by sensing current through a user-defined shunt resistor.

The semiconductor manufacturer Zetex has recently introduced a new family of current sensing ICs. These devices operate from a wide supply voltage range between + 2.5 to 20 V and can be used in many applications including overload protection, battery chargers, cooling fan current monitoring or switch-on surge limiting. The four variants perform the same function but have different output characteristics; the measured current can be output as a scaled current or voltage and one variant has an in-built comparator.

## Current sensing with three external components

The basic configuration using a ZXCT 1010 and current sensing resistor (shunt) R1 is shown in **Figure 1**. This device output current at I<sub>OUT</sub> is a scaled down measurement of the load current through R<sub>L</sub>. Resistor R2 is connected between I<sub>OUT</sub> and ground and converts the output current into a voltage V<sub>OUT</sub>. Internally the ZXCT1010 contains an op-amp, transistor and a 100 Ω resistor. The op-amp is configured so that when a voltage is developed across the sense resistor it will cause the transistor to conduct and divert sufficient current through its I<sub>OUT</sub> pin so that the voltage across the op-amp inputs is reduced to zero. The voltage across the internal 100 Ω resistor will therefore be the same as the drop across the sense resistor (V<sub>SENSE</sub>).

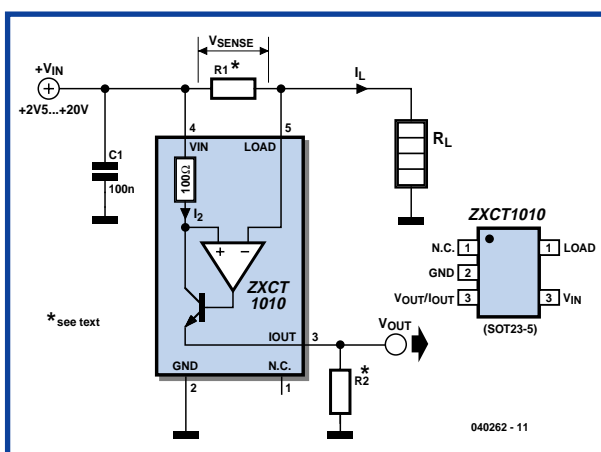
This relationship can be expressed mathematically:

$$I_L \times R_1 = 100 \Omega \times I_2 = V_{SENSE}$$

Rearranging for I<sub>2</sub>:

$$I_2 = I_L \times R_1 / 100 \Omega$$

We can assume that the op-amp takes so little current at its inputs that all of I<sub>2</sub> passes through the transistor and



**Figure 1.** The ZXCT1010 in a basic current sense circuit showing the internal block diagram and chip pin-outs.

out of  $I_{OUT}$ . The voltage ( $V_{OUT}$ ) produced across the external resistor  $R_2$  can now be expressed in terms of the other variables:

$$V_{OUT} = I_{OUT} \times R_2 = I_2 \times R_2$$

Substituting the expression for  $I_2$  above:

$$V_{OUT} = V_{SENSE} \times (R_2 / 100 \Omega)$$

$$V_{OUT} = I_L \times R_1 \times (R_2 / 100 \Omega) \quad [1]$$

The ZXCT1010 requires a value of  $R_1$  so that the load current produces a sense voltage of approximately 100 mV. The low sense voltage reduces power dissipation in  $R_1$ . As an example, assuming a load current  $I_L$  of 5 A,  $R_1$  can be calculated from:

$$R_1 = V_{SENSE} / I_L \quad [2]$$

$$R_1 = 0.1 \text{ V} / 5 \text{ A} = 20 \text{ m}\Omega$$

In most cases it will be convenient to make this low value resistor using an etched track on the PCB. The required track length and width can be calculated providing the thickness of the copper layer is known (see 'Printed current sensors').

Once the value of  $R_1$  has been calculated it is now possible to choose the value of the scaling resistor  $R_2$  so that it gives the required output voltage for the load current of 5 A. For example we will pick an output voltage of 500 mV. Rearranging equation [1] for  $R_2$ :

$$R_2 = V_{OUT} / [(I_L \times R_1) \times 100 \Omega] \quad [3]$$

$$R_2 = [0.5 \text{ V} / (5 \text{ A} \times 0.02 \Omega)] \times 100 \Omega$$

$$R_2 = 500 \Omega$$

Equation [1] becomes:

$$V_{OUT} = 0.1 \text{ V} \times (I_L / 1 \text{ A})$$

It is important to choose  $R_2$  so that the value of  $V_{OUT}$  cannot be greater than the supply voltage  $V_{IN}$ . In practice the maximum value of  $V_{OUT}$  should always be a few volts less than the supply voltage.

Capacitor  $C_1$  filters supply-borne high frequency noise and should always be present in any circuit using a ZXCT10xx device to ensure stable operation and reduce any tendency for the device to oscillate.

## Current in/voltage out

The ZXCT1021 and ZXCT1022 devices are basically the same as the ZXCT1010 but have a built-in scaling resistor ( $R_2$ ) and therefore have a  $V_{OUT}$  rather than an  $I_{OUT}$  pin. The resistor ratio of  $R_2 / 100 \Omega$  in equation [1] is replaced by  $15 \text{ k}\Omega / 1.5 \text{ k}\Omega = 10$  for the ZXCT1021 and  $15 \text{ k}\Omega / 150 \Omega = 100$  for the ZXCT1022. The equation for  $R_1$  then simplifies to:

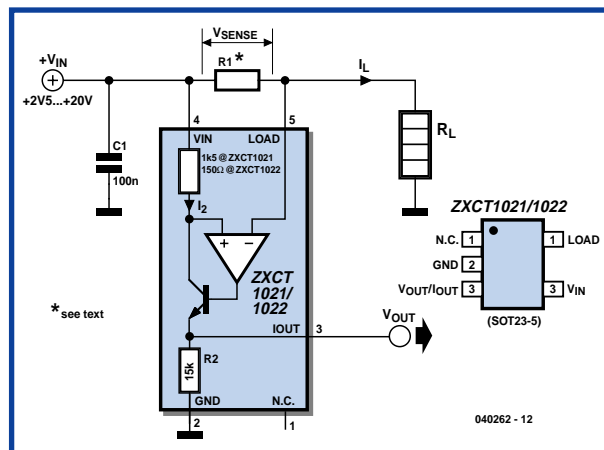
For the ZXCT1021:

$$V_{OUT} = 10 \times I_L \times R_1$$

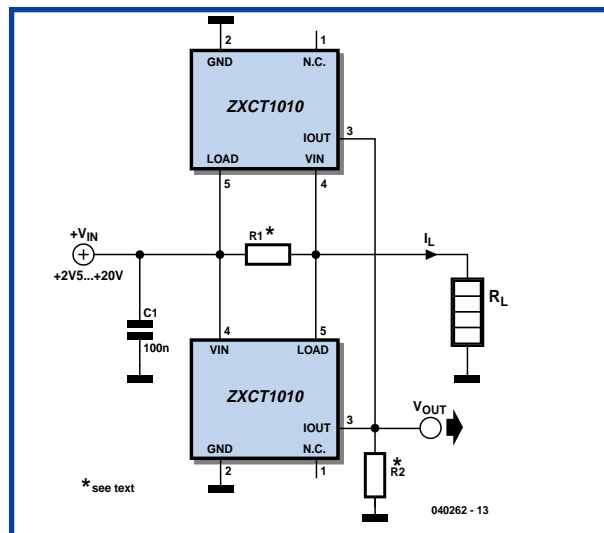
For the ZXCT1022:

$$V_{OUT} = 100 \times I_L \times R_1$$

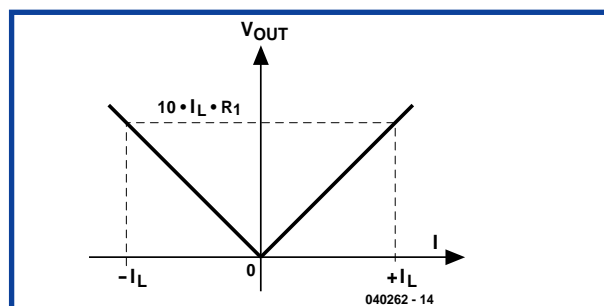
The ZXCT1021 produces an output voltage of 1 V for a drop of 100 mV across the shunt resistor  $R_1$  while the ZXCT1022 produces the same output for a drop of 10 mV across  $R_1$ .



**Figure 2.** Both the ZXCT1021 and ZXCT1022 have a built-in scaling resistor  $R_2$ .



**Figure 3.** Bipolar current sensing configuration.



**Figure 4.** The characteristic of output voltage versus bipolar current.

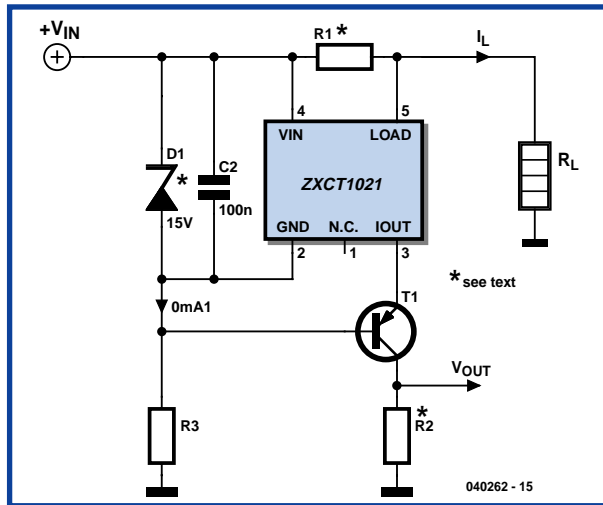


Figure 5. Current sensing with a supply greater than 20 V.

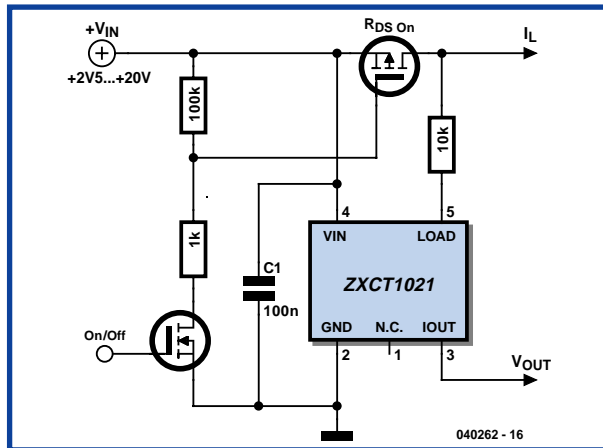


Figure 6. The RDS(on) of a switched MOSFET can also be used for sensing current.

### Bipolar sensing

The ZXCT1010 can only sense current flowing in one direction, when the current changes direction  $I_{OUT}$  remains at zero. Where an application calls for current sensing in both directions (e.g. monitoring the charge and discharge current of a rechargeable battery) it is necessary to use a **bipolar current sense** configuration. **Figure 3** shows how two ZXCT1010s can be connected using the same sensing resistor R1 and output scaling resistor R2. The upper ZXCT1010 in the diagram has its VIN and LOAD inputs swapped around the sense resistor. Both R1 and R2 can be calculated using the formulae given above. For applications requiring the forward/reverse currents to be independently monitored the two  $V_{OUT}$  signals from each ZXCT1010 can be separated and connected to its own scaling resistor R2. Both the ZXCT1021 and ZXCT1022 have a in-built 15 k $\Omega$  scaling resistor but their tolerance is so wide ( $\pm 30\%$  according to the data sheet) that these devices would, in most cases be unsuitable this type of configuration. **Figure 4** shows the  $V_{OUT}$  to load current relationship.

The ZXCT1010 chip employs high side sensing without the need to disrupt the earth return. The device is also suitable in circuits where the supply rail exceeds 20 V but

Type	Function	Technical Data
ZXCT 1009	Forerunner to the ZXCT 1010	ZXCT 1010 has a lower Offset
ZXCT 1010	Current sense with current output.	$V_{SENSE}$ typ. 100 mV Bandwidth 2 MHz supply current 4 $\mu$ A Package outline SOT 23
ZXCT 1021	Current sense with voltage output.	$V_{SENSE}$ typ. 100 mV $V_{OUT} / V_{SENSE} = 10$ Bandwidth 300 kHz supply current 25 $\mu$ A Package outline SOT-23-5
ZXCT 1022	Current sense with voltage output.	$V_{SENSE}$ typ. 10 mV $V_{OUT} / V_{SENSE} = 100$ Bandwidth 300 kHz supply current 25 $\mu$ A Package outline SOT-23-5
ZXCT 1030	Current sense with voltage output and built-in comparator.	$V_{SENSE}$ typ. 100 mV $V_{OUT} / V_{SENSE} = 10$ Bandwidth 10 MHz $V_{CC} = +2.2$ to 20 V supply current 270 $\mu$ A Package outline MSOP8

a few extra components are required (**Figure 5**). The zener diode ensures the supply to the ZXCT1010 does not exceed 15 V while the remainder of the supply voltage is dropped across the collector-emitter junction of T1. It is important to check that this does not exceed the transistor  $V_{CEO}$  rating. The voltage level of the IOUT pin will be one diode drop (0.7 V) above the base potential of T1. The high current gain of T1 enables us to ignore the base current and assume that the emitter and collector currents are equal. The scaled output voltage  $V_{OUT}$  is once again produced by  $I_{OUT}$  through R2 and can be calculated as before. The value of resistor R3 is calculated to allow a current of 0.1 mA through the zener diode. The ZXCT1010 draws just 4  $\mu$ A and the current gain of T1 ensures that its base current will also be comparatively small. The transistor is used in a common-base configuration.

The chip can also be used in conjunction with a MOSFET to both switch and sense the current to a circuit (**Figure 6**). The MOSFET drain-source resistance ( $R_{DS(ON)}$ ) is typically around 10 m $\Omega$  and is used to sense the load current in this circuit. The load resistor connected to pin 5 is only required if the output voltage drives an electrically noisy circuit that may generate voltage spikes greater than the maximum 20 V supply limit of the chip.

One thing to bear in mind with this circuit is that the value of  $R_{DS\ ON}$  has quite a wide spread and is also a function of temperature. When the MOSFET is switched off  $V_{OUT}$  rises to its maximum value because the drain-source voltage rises to a maximum and the current sense IC interprets this as maximum load current condition.

The type ZXCT1030 has a built-in comparator with an internal reference voltage and comparator input level (Comp\_in). In addition to the usual  $V_{OUT}$  it has a digital

comparator output (open collector) pin Comp\_out that switches low when the pre-set threshold at Comp\_in is exceeded.

(040262-1)

**References:**

Data sheets from: [www.zetex.com](http://www.zetex.com)

ZETEX Application Note No. 39

ZETEX Design Note No. 77 (High Voltage Transients)

## Printed current sense resistors

The current sensing element R1 has a relatively low value and can be cheaply made from a zigzag length of PCB track. The resistivity of copper is:

$$\rho_{Cu} = 0.0175 \Omega \cdot \text{mm}^2 / \text{m}$$

The copper layer thickness of a standard PCB is typically 35  $\mu\text{m}$ . The resistance of R1 can be calculated from the length of copper track  $l_{Cu}$  and its cross sectional area  $A_{Cu}$ :

$$R1 = \rho_{Cu} \times l_{Cu} / A_{Cu}$$

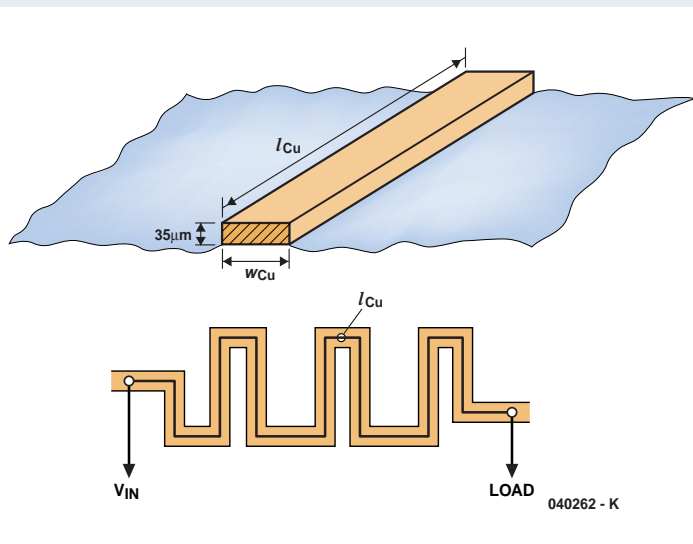
The cross sectional area  $A_{Cu}$  is given by the copper layer thickness and track width  $w_{Cu}$ :

$$A_{Cu} = 35 \mu\text{m} \times w_{Cu}$$

For example, assuming we require a resistance for R1 of 0.1  $\Omega$ . The calculated current flow indicates that a 0.2 mm wide track will be acceptable. Plug the value for R1 into the above formula and using a cross sectional area of  $35 \mu\text{m} \times 0.2 = 0.007 \text{mm}^2$  we arrive at a PCB track length  $l_{Cu}$  of 40 mm.

The track must be able to pass the current without getting too hot. The table indicates maximum current rating for a given track width:

Trackwidth $b_{Cu}$	Maximum current $I_{Lmax}$
0.1 mm	0.5 A
0.2 mm	0.7 A
0.3 mm	1.0 A
0.5 mm	1.2 A
0.8 mm	1.5 A
1.0 mm	1.7 A
1.5 mm	2.0 A
2 mm	4 A
3 mm	6 A
5 mm	8 A
10 mm	12 A



The last consideration is how well copper performs as a resistor. The bad news is that it has a relatively high positive temperature coefficient i.e. as it gets hotter its resistance increases linearly by 0.4%/°C. A temperature change from +5° C to +45° C will result in a 16 % change in resistance! The good news is that the ZXCT10xx family of devices have a negative temperature coefficient. This characteristic is not linear and is not as pronounced as copper (0.25 % / °C between +5 °C and +45 °C) but it does go some way to offset changes bought about by heating R1. The device will need to have good thermal coupling to R1 to get maximum benefit from this effect.

**The copper track sense resistor R1.**

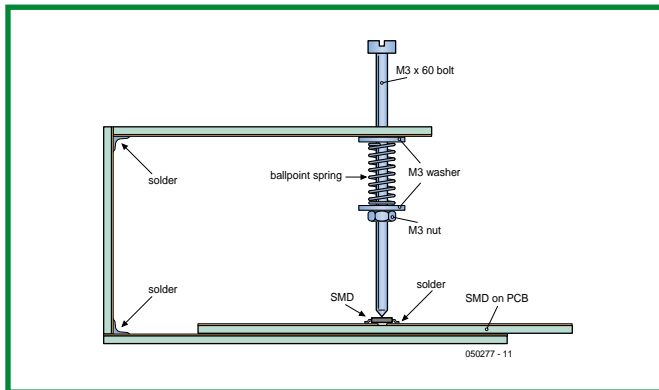
## SMD soldering aid

**Gert Baars**

When soldering SMDs (surface mount devices) onto a circuit board, it is often difficult to keep the tiny component correctly positioned. With two hands in use, one holding the soldering iron and the other, the solder tin, you really need a third hand to keep the SMD in place. Fair enough, SMDs with a lead pitch of 0.05 inch stand a good chance of success if you melt-and-move a little to first secure the two corner pins of the IC to make sure it's properly aligned on the solder pads. Smaller ICs with a lead pitch of just 0.65 mm or even 0.5 mm are far more difficult to handle and really suitable for machine mounting only. A possible solution to the problem is to secure the IC to the board with a drop of hobby glue. Next, you align the IC using a magnifying glass and allow the glue to set. This may last up to a couple of hours.

The author having run into this problem often enough, an idea came to mind to make a simple but effective little tool that's easy to produce at home.

We're looking at a kind of miniature clamping device capable of holding an SMD in place with sufficient force to allow it to be soldered, but less pressure than to crush the device! The first version consists of three strips of PCB material, an M3 nut, a pressure spring and some washers and

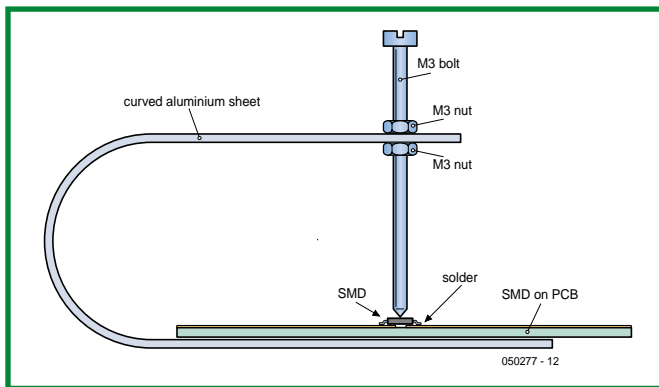


nuts. The drawing shows that A, B and C are pieces of unetched board material secured to form a U-shape. At point 'A', a 3-mm hole is drilled at the end. A 60-mm long M3 bolt with one end filed into a tip is inserted into this hole. The bolt end protruding from the upper board strip (A) takes an M3 washer and a spring. The spring is conveniently

salvaged from a ballpoint pen and should have relatively low pressure tension. Next, the long M3 bolt takes a washer and a nut, causing the spring to push the screw downwards. With a little adjustment of the nut, a setting can be found at which the screw exerts a little pressure on the IC on the board underneath it — just enough for our purpose. The

drawing really speaks for itself. The tool is simple to use — first, put the SMD roughly in position on the board and lift the bolt a little. This is easiest done by pushing up the tip side. Slide the board under the bolt, aligning the IC under the tip. Because the bolt will have some play, the IC can be moved exactly onto its footprint using the tweezers, a matchstick or a small screwdriver. All the while, the bolt will exert enough pressure on the IC to enable you to solder the corner pins without shifting the SMD, but also allowing enough play to move the IC about a little while aligning. Should the IC start to slide off in the wrong direction, the spring pressure has to be increased a little by turning the nut up a little. The sizes of the materials used may be selected to personal requirements. The author's first version of the tool is intended for smaller PCBs and has the following dimensions:

- A = 15x60x2 mm;
- B = 15x45x2 mm and
- C = 15x75x2 mm.



In principle, it is also possible to machine the U piece from a single piece of metal sheet by bending two right angles and a curvature. If the material used is neither too thick or too short, it will exhibit enough tension of its own so a spring will not be required.

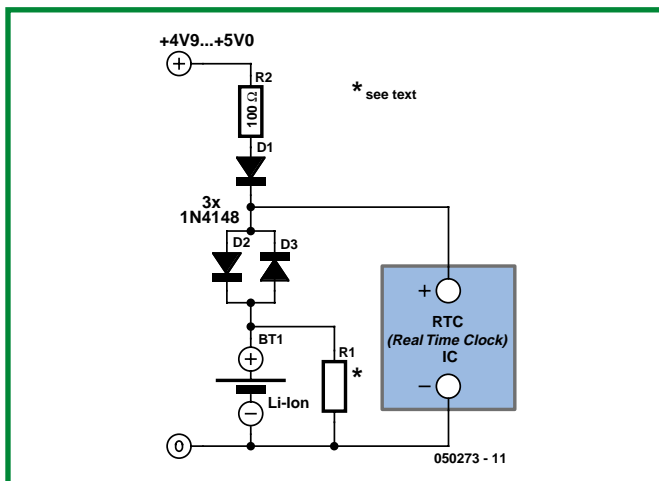
(050277-1)

## Simple Li-Ion battery charger

**Elbert Jan van Veldhuizen**

After two to three years of active use most mobile phone batteries will have lost a lot of their original capacity, and are best replaced. However, such a discarded battery may have enough capacity left to power, for example, a real-time clock (RTC) for many months in the event of a power outage. What's more, the battery is 'surplus to requirements' and therefore free.

Normally, a good amount of electronics is needed to charge Li-Ion batteries in a couple of hours. However, the most important



aspect to keep in mind during the charging process is the danger of overcharging, as that may lead to explosion. **Figure 1** shows a simple circuit for slow charging while preventing any risk of overloading the battery. The circuit consists of just four components. The battery is charged to about a quarter of its capacity in one day, to 50% in one week and 80% in one month — sufficient we reckon for equipment that's on all the time. Depending on the exact type, a fully charged Li-Ion battery supplies between 4.1 V and 4.2 V, or 3.6 V when empty. When charging, the circuit employs the non-lin-

ear characteristic of a diode. With a flat battery, the charge current flows through diodes D1 and D2, causing a voltage drop of 0.7 V across each diode. A current of 5 mA then flows through the diodes and the battery. At a battery voltage of 4.2 volts, the drop across the diodes is down to 0.4 V, causing a current of 15  $\mu$ A

through the battery. With R1 at 270 k $\Omega$  the charge voltage cannot exceed 4.2 V because the diode current then balances the current through R1. For 4.1 V Li-Ion batteries, R1 needs to be changed into 100 k $\Omega$ . The amount of self-discharging of the author's battery was found to represent an internal parallel resist-

ance of 50 k $\Omega$ , making R1 superfluous and limiting the charge voltage to about 4.0 V. The exact value has to be determined for each individual battery.

The rest of the circuit speaks for itself. Once the 5-V supply voltage is present, the current flows to the RTC via diode D1. When the voltage is interrupted, the IC

is powered from the battery via diode D3. R2, finally, affords short-circuit protection.

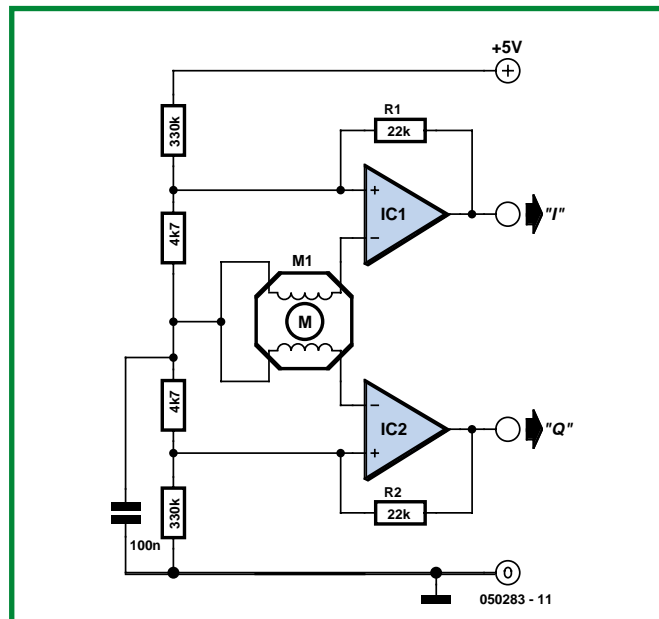
Caution! The circuit must be powered by a regulated supply voltage not exceeding 5 volts. Higher voltages present a risk of battery explosion and must be avoided.

(050273-1)

## Build your own rotary encoder

Gert Baars

The cheaper variety of rotary encoders, including those from Bourns, are mechanical devices rarely capable of generating more than 25 pulses per revolution (ppr). If more ppr are desired, an optical encoder is usually a better alternative. Devices exist in this class with up to 256 ppr but then the price is well beyond the reach of the hobbyist. A mechanical (pulley/string) transmission to increase the ppr of mechanical encoders is possible in theory but at the cost of an awkward amount of torque. Also, the simplest solution (apparently) of turning the mechanical encoder faster than usual is not viable as it will stress the device beyond its limits. Another alternative is to turn a small stepper motor into an encoder. After all, a stepper motor has permanent magnets inducing voltages in the rotor coils. Without going into too much detail, a stepper motor requires two signals with a phase difference of 90 degrees. The voltages generated per coil can then be said to represent a 'Gray



code', that is, two voltages 90 degrees out of phase. Smaller motors salvaged by the dozens from old printers and flatbed scanners are particularly suited to our purpose as they usually turn smoothly and have a small cogwheel attached allowing a larger wheel to be driven. A 1:10 transmission for example

easily results in a rotary encoder with 150 or so ppr, which may be very suitable for tuning a receiver in 100 Hz steps. Some printers and flatbed scanners have stepper motors with 1- or 2-wheel gear reductions on the spindle. The motor used by the author gave an effective reduction of 1:13 using two wheels. A

6-mm spindle was provisionally mounted on the second cogwheel, and turning the spindle resulted in 180 pulses per revolution.

In this circuit, voltages supplied by the coils in the stepper motors are converted into square wave signals having TTL levels. As with a 'real' Bourns encoder, Gray encoded signals are output at 90 degrees phase difference. The two opamps inside the TL072 case are configured as comparators. Thanks to their high gain, even small voltages are reliably processed, enabling your logic to respond when the spindle is turned slowly.

The additional hysteresis created with R1 and R2 is required in view of the 'output' signals typically supplied by the stepper motor.

This simple circuit is the poor man's equivalent of a very reliable, high resolution rotary encoder and may also be used to decode speed and direction of fast turning spindles on, for example, electric motors. Mechanical encoders simply aren't suitable for that purpose.

(050283-1)

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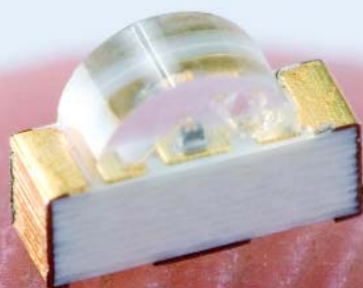
# Right-angle LEDs

## ...a good (soldering) exercise

Karel Walraven

**The miniaturisation of components does cause the odd bit of trouble at Elektor Electronics as well.**

**While developing last June's Electrosmog Tester our lab suffered a few unpleasant setbacks. Read along...**



For the Electrosmog Tester featured in the June 2005 issue of this year we looked for LEDs that radiated light towards the side instead of upwards, which is usually the case. Normally this is not an issue. With a standard leaded LED you can easily bend the legs so that the LED can point in any desired direction. However, with this project we wanted to keep things small and cheap. There are LED-arrays available that can be mounted on the side, but the price of those cannot be called attractive at all. That's why we started looking in the area of SMD LEDs.

By coincidence we stumbled upon a 'right angle LED' from one of the larger manufacturers. To be honest, we didn't know that components with this name existed, and we couldn't quite image what they were. It wasn't immediately clear in which direction the light left the LEDs. The method of mounting was

also a cause for debate. The LEDs had copper surfaces at the ends and on the bottom, while we would have expected conductive surfaces along the long edges. This is, after all, the side of the LED that is in contact with the copper on the PCB. But it wasn't like that.

We quickly ordered a few and made the footprint for the PCB. Everything looked fine. Soldering by hand was not a problem. The LEDs are of good quality and are quite bright. There is also a clear mark that indicates the cathode, so making a mistake is nearly impossible.

When the first batch went into production we were still in high spirits. But soon there was a phone call from the contract assembler. The footprint for the LEDs was not correct. On the PCB, the LEDs were rotating on their pads and were pointing in all directions, because the pads were too long and too close

together. This required some further investigation. We studied the datasheet again, and sure enough, the footprint in the datasheet was correct. We had made a mistake. Out of habit, when drawing the footprint we placed the pads with the long sides parallel. That was completely wrong in this case. Now we also understand why the contact surfaces are on the ends... To add to our misfortune, we had to solder some thousand fiddly SMD LEDs by hand...

A new batch and new opportunities. With the now corrected footprint everything will be all right, we thought. But, and you can see this coming, this was not to be. Another phone call from the contract assembler: all the LEDs are the wrong way around, the cathode and anode were swapped. We didn't understand that. Surely every component can be placed on the PCB

rotated at any angle? Since when do all transistors and electrolytic capacitors have to be placed in the PCB all pointing in the same direction? This is true, and applies to all components, **except** to right angle LEDs. You can turn them around, of course, but then they will shine their light into a different (and therefore wrong) direction. If the LEDs come with the cathode on the left out of the tape, then the cathode stays on the left and there is nothing that can be done about it. The surface mount assembly machine cannot turn components upside down. Well, there is no end to our misfortune. For the second time we had to solder a thousand fiddly SMD LEDs by hand, and design a new PCB... Everything turned out all right in the end. We learned our lesson (SMD LED soldering). And, as they say: "Practise makes perfect".

(050226-1)



# Analogue Multimeters

Jan Buiting

The great thing about using an old analogue multimeter is that you find yourself actually *thinking* before taking a measurement. Questions you ask yourself should include: what value can I expect to see; what range should I select; will the object of my measurement damage the meter, and, where do I plug in the test leads on the meter? Youngsters used to using DMMs with multi-digit displays and sleek, rugged cases will laugh their heads off and simply connect their meter to *any* circuit with *any* polarity in *any* way and wait for *any* error signal, preferably texted to their mobile phone with a nice ringtone to go with it. What do you *mean* you have to know what you measure?

While not depreciating the huge technical progress vested in digital multimeters, nor their accuracy, ruggedness and low cost, the instruments make sloppy engineers because it is no longer necessary to know what the circuit you're measuring is actually doing. Typically, the DMM user will initially marvel at the reading on the display and only then attempt to understand the circuit he or she is dealing with, I guess the two analogue multimeters pictured here differ some 10-15 years in age, the **Simpson Model 260** (series 79) being the oldest. Its black, ABS case is very rugged, with a carrying handle that doubles as a tilt stand. With this meter you sure have to know what you're doing as there are no fewer than four pairs of input sockets for the test leads to plug into, plus a rotary switch with positions +DC, -DC; AC/DC and 50V/amp/250mV. In good US tradition, the back panel has a 250+-word safety statement including more *don'ts*, *cautions*, *warnings* and *disclaimers* than useful instructions how to use the instrument. The moving coil meter is proudly identified as a 'taut band suspension' type, while the meter load is stated as 20 k $\Omega$ /V for DC and 5 k $\Omega$ /V for AC. As usual with

these multimeters, high current (10 A) and high voltage (1,000V) measurements require the test leads to be relocated into separate inputs.

The Simpson meter is powered by a 1.5-V and a 9-V battery and has no active parts like FETs.

The ranges on this instrument are 1mA, 10mA (A), 100mA, 500mA, 2.5V (1V), 10V, 50V ( $\mu$ A), 250V, 500V (1000V), R $\times$ 1, R $\times$ 100; R $\times$ 10,000, off/transit.

The meter shown is in mint condition — I recently saw one on Ebay fetching about 50 dollars. Genuine 'AVO' meters are now collectibles!

The **Philips PM241** pictured here comes straight out of the box, having been in safe storage for I guess about 30-35 years. It is a typical example of mid-1970s case styling using an anodized aluminum front panel that's *not* scratch-proof. The meter scale has a mirror band to prevent reading errors due to the parallax effect. In practice, you close one eye and adjust your viewing angle until just one needle is seen. Again laughter from the DMM generation but a quick test shows that the reading accuracy obtained in this way is better than 0.5 percent. The PM241 is powered by the same batteries as the Simpson 260 and even has a small spool of resistance wire inside to replace the fuse protecting the 3 A range.

A narrow pushbutton we thought was labelled '0.4 x 1' in the centre of the rotary switch initially puzzled us but then it turned out that pressing it in the current ranges causes the meter sensitivity to increase by 1/0.4. Weird but useful. This allows a volts scale to be used for better accuracy. The ranges of this beautiful meter are 300 $\mu$ A, 3mA, 30mA, 300mA, 3A, OFF,  $\times$ 1 $\Omega$ ,  $\times$ 100 $\Omega$ ,  $\times$ 10k $\Omega$ , 300V (1200V), 120V, 30V, 12V, 3V, 1.2V, 0.3V (0.06V). Separate test lead inputs are available for the 60 mV and 1200 V ranges. I could not resist installing batteries in the PM241 and put it through its paces. It worked perfectly on all ranges



with better accuracy than I will ever require.

The Simpson and Philips meters both have a 'reset' pushbutton operating as circuit breaker to clear an overload condition. In practice, you will hear a click sound when you make a gross mistake in connecting up the meter.

Finally, two advantages of analogue multimeters over their digital counterparts should not be left

unmentioned. Firstly, the old meters will show a *trend* which is useful in adjustment work — the movement of a needle being easier to resolve than rolling digits. Second, most of these oldies will double as a relative fieldstrength meter for transmitter alignment well into the VHF range — just switch to literally any AC range and use one test lead as an antenna.

(055084-1)



# QUIZZ'AWAY



Martin Ohsmann is a Professor of Electrical Engineering and Information Technology at FH Aachen and a long-time contributor to *Elektor Electronics*. Through Quizz'away he aims at stimulating thought, speculation, construction and simulation as well as raise interesting questions.

### LEDs detect light

As is generally known, LEDs are used to generate light. That the same devices can also detect light is a less known fact. However, the currents and voltages generated in this way are generally so small as to make practical use almost impossible.

Nonetheless we will concentrate on this 'out of the ordinary' use of LEDs. To measure the current generated by an LED, we use the transimpedance amplifier shown in **Figure 1**. Its function is to turn the current  $I$  generated by the LED into a proportional voltage  $U$ , and more specifically at zero bias voltage on the LED. The conversion factor is 1 V per 100 nA. Offsets, if any, may be compensated using the preset in the circuit.

We now take a red, a green and a yellow LED and connect them to the circuit one by one. A 0.6-watt miniature bulb is used as the light source. The currents generated are listed in

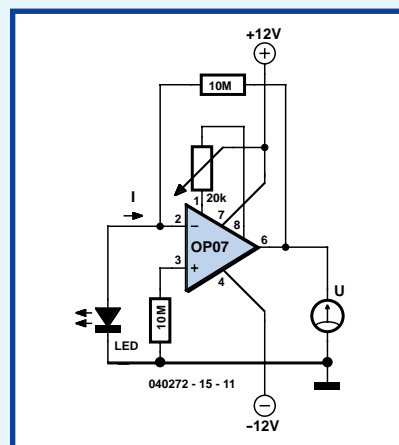


Figure 1. Transimpedance amplifier.



Figure 2. LEDs detecting instead of generating light.

## Solution to the October 2005 problem

(p. 78; vanishing voltage)

When dimensioning opamp circuits, it is common practice to assume infinite open-loop gain  $H$  supplied by the opamp. However in the case of the problem we need to see how this assumption can be upheld. Because the circuit operates at a relatively low frequency, OP1a amplifies input voltage  $U_e$  by 10, while OP1B amplifies  $U_m$  by 100. This makes  $U_b$  into an output voltage, amplified by OP1a's open-loop gain  $H$ . So we can write (except for the sign, in view of the inverting action):

$$U_b = 10 U_e = H U_m$$

which gives  $H = 100 U_b / U_a$

However the open-loop gain is frequency dependent — the relevant response for the TL082 device from Texas Instruments is shown in **Figure 3**. Below a relatively low frequency (here, about 30 Hz) the opamp exhibits constant high gain ( $H$  approaching 200,000) without phase shift. Above this frequency,  $H$  drops at a rate of 10 (20 dB) per decade at an almost constant phase shift of 90 degrees. This range extends almost to 3 MHz, with the product of frequency and gain remaining virtually constant. This parameter is called the Gain/Bandwidth product (GBP) of the opamp. For a TL082, GBP is typically 3 MHz. Consequently, the open-loop gain  $H$  will be about 3,000 at 90 degrees phase shift (see also Fig-

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**The closing date is**  
**31 December 2005**

(solution published in the December 2005 issue). The outcome of the quiz is final. The quiz is not open to employees of Segment b.v., its business partners and/or associated publishing houses.

This 15<sup>th</sup> instalment marks the end of the Quizz'away series in Elektor Electronics. The problems to solve were supplied by Professor Martin Ohsmann of Aachen Technical University.

**Table 1.** Next, we use a laser pointer for the light source and a red LED as the sensor. As you can see from the table, this combination generates a relatively high current, providing proof of the laser power. The table has two missing values for you to supply.

LED	bulb 6 V/0.1 A	laser- pointer
red	100 nA	500 nA
yellow	150 nA	??
green	30 nA	??

### This month's question is:

How much current can be expected when aiming the laser pointer at the green and yellow LED respectively?

### Plus an additional question:

For what achievement was Albert Einstein awarded the Nobel Prize?

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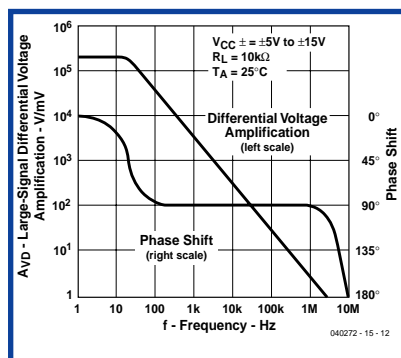
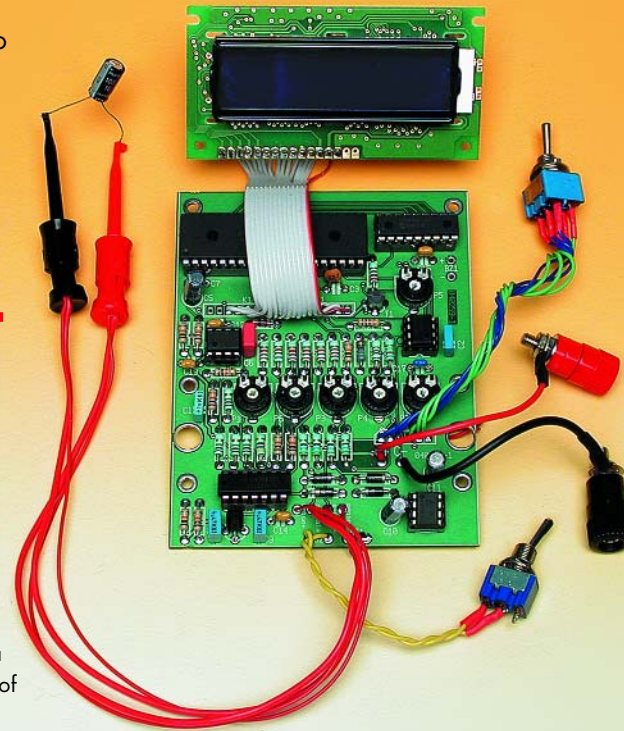


Figure 3. Frequency and phase response for TL082 open-loop gain.

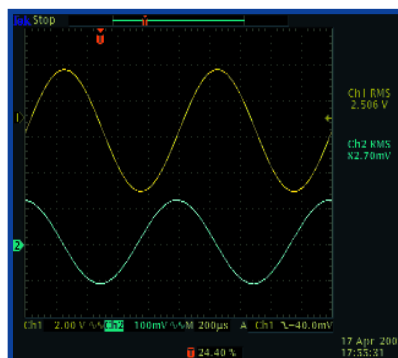


Figure 4. Upper trace;  $U_e$ ; lower trace:  $U_a$ .

ure 3). This allows us to calculate the results: at  $U_e = 250 \text{ mV}_{\text{eff}}$  we get

$$U_b \approx 10 U_e = 2.5 \text{ V}_{\text{eff}}$$

Hence we have  $U_m \approx U_b / 3,000$  and we can write

$$U_a \approx 100 \times 2.5 \text{ V}_{\text{eff}} / 3,000$$

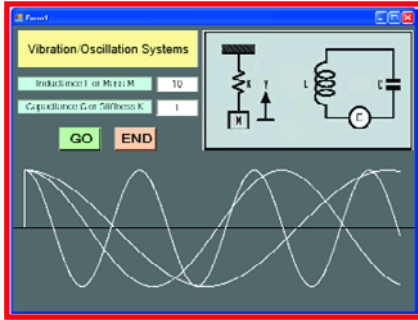
$$U_a \approx 83 \text{ mV}_{\text{eff}}$$

The actually measured value of 80 mV seems to agree well with the theoretical result.  $U_a$  will lead  $U_b$  by 90 degrees.

The two output voltages are shown in **Figure 4**, which proves their phase difference. The levels of  $U_a$  and  $U_b$  may be verified using the scaling factors. The same experiment was repeated using other opamps. The results appear in **Table 2**.

opamp	$U_a$	GBP (calculated)	GBP (typ.) (datasheet)
TL082	80 mV	3.1 MHz	3 MHz
TL062	250 mV	1 MHz	1 MHz
TLC272	100 mV	2.5 MHz	2 MHz
MC1458	200 mV	1.2 MHz	1 MHz
NE5532	8 mV	31 MHz	10 MHz

# Free Visual Basic 2005 booklet with the January 2006 issue



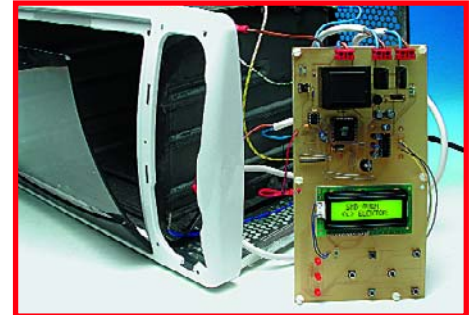
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