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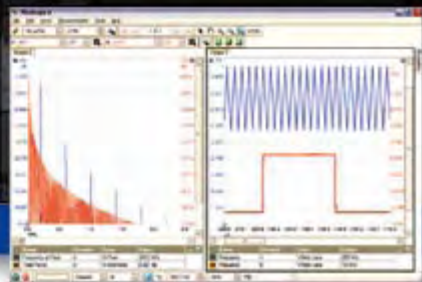
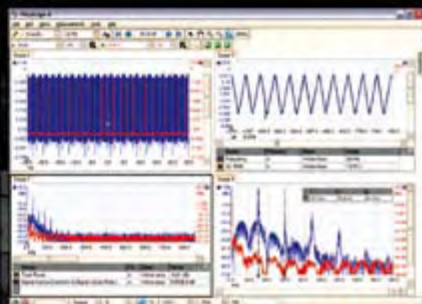
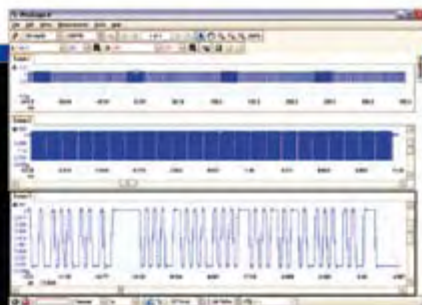
Homebrew E-bike



Motorised Audio Volume Pot



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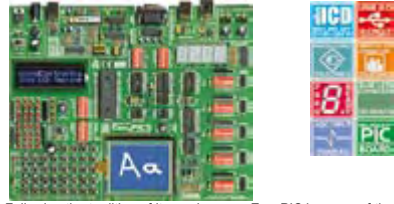
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EasyPIC5 Development Board

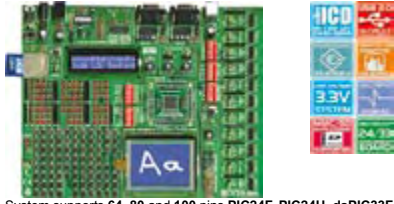
Complete Hardware and Software solution with on-board USB 2.0 programmer and mikroICD



Following the tradition of its predecessor EasyPIC4 as one of the best PIC development systems on the market, the EasyPIC5 provides newly revised features for the same price. System supports 8-, 14-, 18-, 20-, 28- and 40 pin PIC microcontrollers (supplied with a PIC16F887). USB 2.0 on-board programmer with mikroICD (In-Circuit Debugger) enables very efficient debugging and very fast prototype development. Examples in C, BASIC and Pascal language are provided with the board. Touch screen controller with connector is available on-board.

LV24-33A Development Board

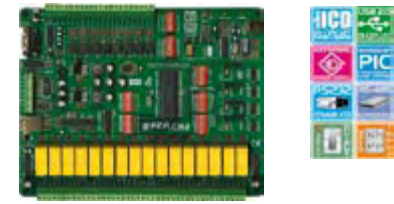
Complete Hardware and Software solution with on-board USB 2.0 programmer and mikroICD



System supports 64, 80 and 100 pins PIC24F, PIC24H, dsPIC33F microcontrollers (supplied with PIC24FJ96GA010 - PIC24 16-bit Microcontroller, 96 KB Flash Memory, 8 KB RAM in 100 Pin Package). Examples in BASIC, PASCAL and C are provided with the board. You can choose between USB and external power supply. LV 24-33A has many features making your prototype development easy. USB 2.0 on-board programmer with mikroICD (In-Circuit Debugger) enables very efficient debugging and very fast prototype development. Touch screen controller with connector is available on-board.

PICPLC16B Development Board

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



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

EasyAVR5 Development Board

with on-board USB 2.0 programmer



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

EasyPSoc3 Development Board

with on-board USB 2.0 programmer



System supports 8, 20, 28 and 48 pin microcontrollers (supplied with CY8C27843). Every jumper, element and pin is clearly marked on the board. EasyPSoc3 is an easy-to-use PSoC development system. On-board USB 2.0 programmer provides fast and easy in-system programming.

Uni-DS 3 Development Board

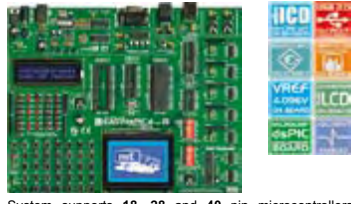
Complete Hardware and Software solution with on-board USB 2.0 programmer



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

EasysPIC4 Development Board

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



System supports 18, 28 and 40 pin microcontrollers (supplied with dsPIC30F4013 general purpose microcontroller with internal 12-bit ADC). EasysPIC4 has many features that making your prototype development easy. Many of these ready-to-go examples in C, BASIC and PASCAL language guarantee successful use of the system. Ultra fast on-board USB 2.0 programmer and mikroICD (In-circuit Debugger) enable very efficient debugging and fast prototype development.

EasyARM Development Board

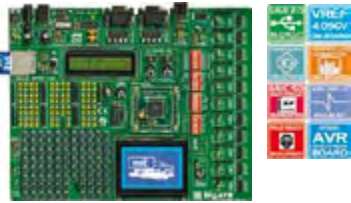
Complete Hardware and Software solution with on-board USB 2.0 programmer



EasyARM board comes with Philips LPC2148 microcontroller. Each jumper, element and pin is clearly marked on the board. It is possible to test most of industrial needs on the system: temperature controllers, counters, timers etc. EasyARM has many features making your prototype development easy. There is an on-board USB 2.0 programmer with automatic switch between 'run' and 'programming' mode. Examples in C language are provided with the board.

BIGAVR Development Board

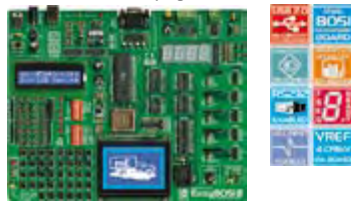
with on-board USB 2.0 programmer



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

Easy8051B Development Board

with on-board USB 2.0 programmer



System is compatible with 14, 16, 20, 28 and 40 pin microcontrollers (supplied with AT89S8253). There are also PLCC44 and PLCC32 sockets for 32 and 44 pin microcontrollers. USB 2.0 Programmer is provided with the system and programming can be done without removing the microcontroller out.

LV 18FJ Development Board

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



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

dsPICPRO 4 Development Board

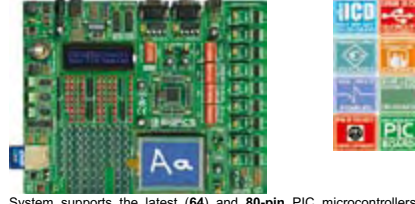
Complete Hardware and Software solution with on-board USB 2.0 programmer and mikroICD



System supports dsPIC microcontrollers in 64 and 80 pins packages. It is delivered with dsPIC30F6014A microcontroller. dsPICPRO4 development system is a full-featured development board for the Microchip dsPIC MCU. This development board has an on-board USB 2.0 programmer and integrated connectors for MMC/SD memory cards, 2 x RS232 port, RS485, CAN, on-board ENC28J60 Ethernet Controller, DAC etc. Touch screen controller with connector is available on-board. Examples in C, BASIC and Pascal language are provided with the board.

BIGPIC5 Development Board

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



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

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

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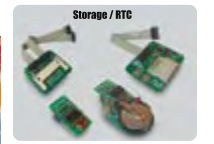
CAN-1 Board - Interfaces CAN via MCP2551.

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RS485 Board - Connects devices into RS-485 network.

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IrDA2 Board - Irda2 serves as wireless RS232 communication between two MCUs.



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RTC Board - Is PCF8583 RTC with battery backup.



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

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

Keypad 4x4 Board - Adds keypad to your application.

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

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mikroICD debugger enables you to execute mikroC, mikroPascal or mikroBasic programs on the host PIC microcontroller and view variable values, Special Function Registers (SFR), memory and EEPROM while the program is running.

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Small things & great editors

You only have to read a few of Umberto Eco's books to be reassured that in mediaeval times 'things invisible' like vacuum, gravity, time, the plague and static electricity were awe inspiring if not a cause of great fear to the uninitiated. I wonder if the same applies to such seemingly unrelated stuff we struggle with in today's electronics, like surface mount components, electromagnetic radiation, microcontroller firmware and buried vias. Invisibility and tiny dimensions both cause the same feeling of unrest. When the transistor took over from the valve, a frequently heard complaint was that 'it sure is much more efficient but you can't see if the thing is alive or not' and 'these things die with not so much as a whisper'. Reportedly some radio & TV servicemen actually opened up faulty transistors to see if they could be fixed.

Although far from being invisible, in the case of SMD components we heard reports like "more ended up in mum's vacuum cleaner than on my printed circuit board". Being able to view SMD parts is the first requirement to using them — next come handling, positioning them on a board, and only then, soldering. The soldering having been covered in great detail in last month's issue on the Elektor SMD Reflow Oven, we figured a magnifying glass might open up a world to you if you still feel those minuscule parts are encroaching upon the hobby. The card-shaped flexible lens attached to this month's front cover is a free gift included with the full 125k print run of Elektor in all language editions — newsstands sales and subscriptions. Personally, I am near-sighted to the degree of being able to scrutinize SMD solder joints with my nose almost on the board surface, so the magnifier saves me the trouble of raising my expensive glasses to an insecure position on my forehead.

On 18 September 2008, Guy Raedersdorf, editor of the French edition Elektor, officially retired. Guy was 'Monsieur Elektor' for 27 years, not just to his French readership but also to all Elektor staff struggling with the fine points of the French language. Guy's helpful attitude, sheer speed, inventiveness and accuracy down to the last comma made him an exemplary editor totally dedicated to his audience whilst exerting 'precision in expression' (now a fast disappearing skill it seems). Merci Guy and *bonne chance* from all of us.

Jan Buiting
Editor

Speed Camera Warning Device

The little module developed using e-Blocks lets you detect geographical points of interest (POIs) using the frames output from a GPS receiver module. These POIs might be restaurants, petrol stations, or —why not? — the positions of fixed speed cameras!

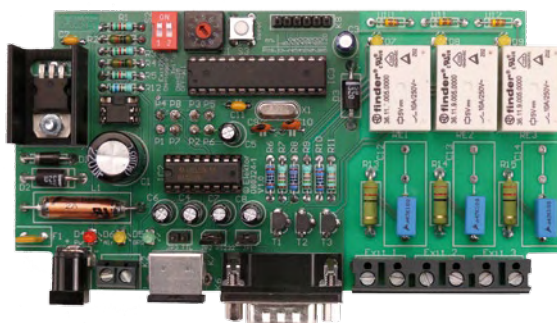
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- **Embedded Systems** — Boston, USA, October 27-30.
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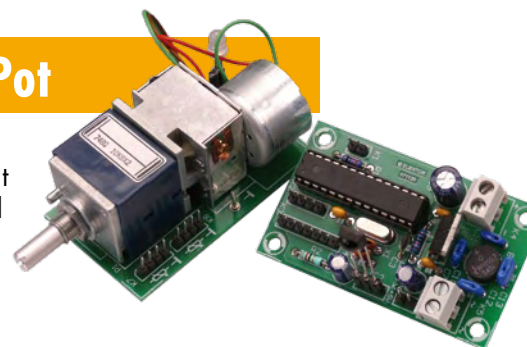
30 Remote Control by Mobile Phone



This ingenious new design combines powerful capabilities with low technical overheads. It has programmable AC mains switching outlets plus status reports by text message and alarm-activated delivery of GPS data. Remote control by mobile was never easier, cheaper or more reliable!

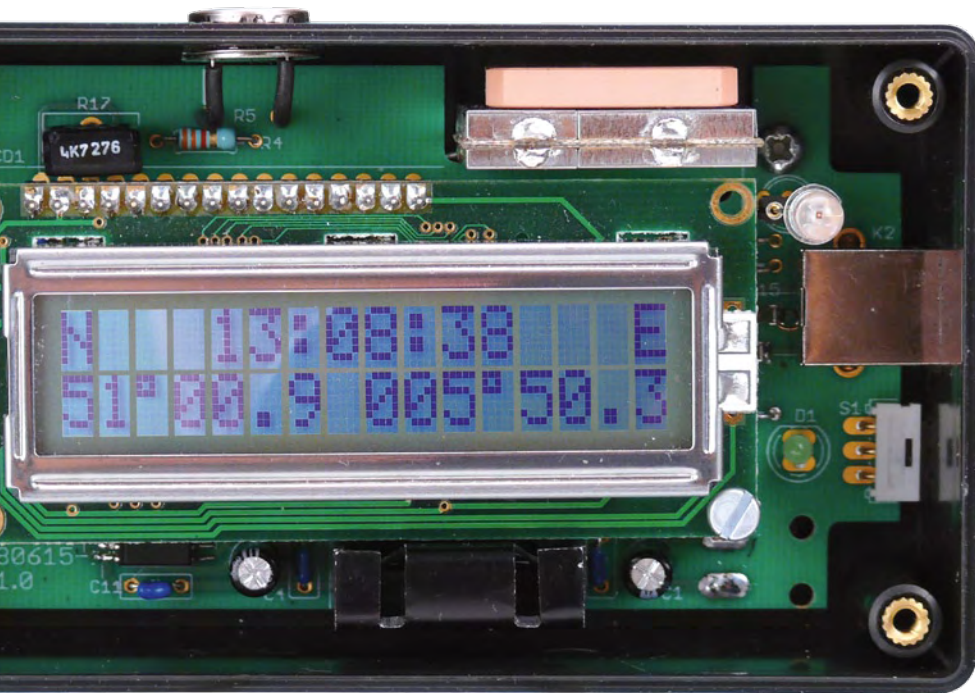
38 Motorised Volume Pot

Many audio enthusiasts still prefer a good potentiometer for adjusting the audio volume. It would be even nicer if this potentiometer could also be controlled remotely. This is possible with a high-quality motorised potentiometer from Alps and a handful of electronics, as is described in this article.



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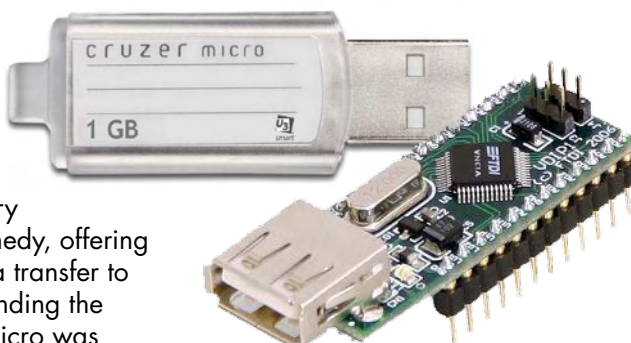


48 Lazy on the Bike

Electric bikes have become popular in recent times. But an off the shelf contraption is not nearly as much fun as one which we have to build ourselves. So, on the look-out for DIY kits!

52 ATmega meets Vinculum

When it comes to matters of memory, microcontrollers tend to be rather poorly endowed. An external USB memory stick is the ideal remedy, offering straightforward data transfer to your PC. Now if bonding the memory stick to a micro was somewhat problematic until recently, it's now totally stress-free with the Vinculum chip from FTDI!



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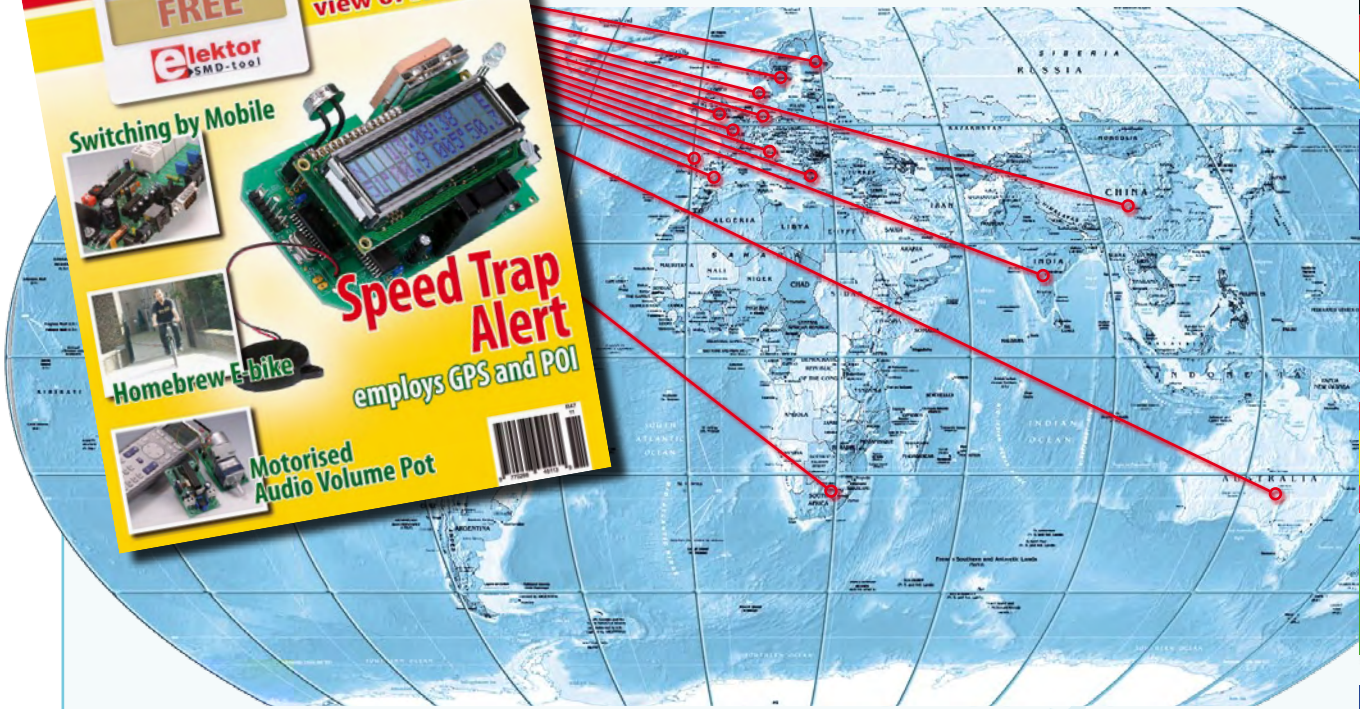
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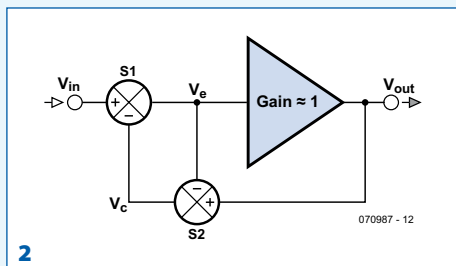
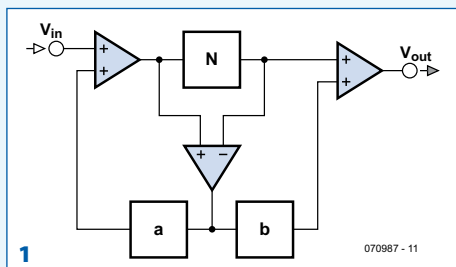
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PaX amplifier stability

Dear Jan — I would like to comment on the article on the paX Amplifier by Jan Didden in the April 2008 issue of *Elektron*.



Error correction

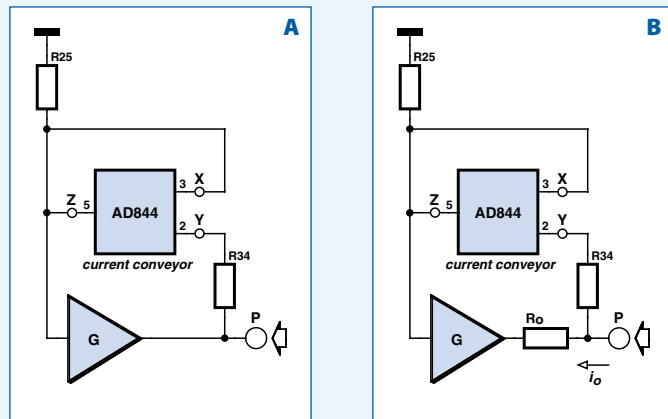
Around 80 years ago already, before feedback was commonly used, Black obtained a patent on feedforward error correction. Due to the limited availability of suitable components at that time, this principle was not used on a large scale until much later. The

basic scheme of Hawksford [1], as shown in **Figure 1** of Didden's article, is often used as the starting point. If $a = 0$ and $b = 1$, feedforward error correction is present. If $a = 1$ and $b = 0$, there is feedback error correction. Accurate addition of the correction signal at the output is difficult with a power amplifier, which is why the feedback approach is often used. In **Figure 2** of the article, S1 and S2 are idealised functions whose purpose is to add the error correction signal to V_{in} at the input. However, the problem here is that a replica of the error signal must be generated. As a result, conversion stages are necessary to transform current into voltage and voltage into current. This means that the accuracy of the replication process is dependent on the matching of pairs of transistors and/or resistors. As a result, the replication factor K can be less than or greater than 1. This inaccuracy influences distortion reduction, and possibly other characteristics of the circuit as well. It is thus desirable to analyse the stability of the amplifier as a function of K .

Feedback error correction

The basic circuit shown in Figure 2 of Didden's article is based on a form of feedback. My version of a simple equivalent circuit of the feedback loop is shown in **Figure A**. As far as I know, this is the first time that the use of a current conveyor for this purpose has been described in a published article. If Z is connected to X , the current conveyor acts as a current mirror with 100% voltage feedback. In order to analyse the feedback loop, the input terminal is connected to ground. The behaviour of the current conveyor is idealised in order to avoid complex formulae: $V_x = V_y$, $A_i = 1$ (where A_i is the current gain of the current mirrors in the current conveyor). The error signal V_e , which in this case is the signal between the Z and P terminals, is converted to a current by $R34$. As a result

of the current mirroring action of the current conveyor, a current with the same value flows in $R25$ if $A_i = 1$. This current produces a replica of the error signal across $R25$ if $R25 = R34$. Now it is extremely important for the loop gain H_{loop} to be less than 1. If H_{loop} is equal to or greater than 1, latch-up will occur with a DC-coupled circuit such as the one shown in the figure.



This means that depending on the polarity of the DC offset, the output level will gradually increase until it reaches the positive or negative supply voltage. With the previously mentioned simplifications, the loop gain H_{loop} is given by:

$$H_{loop} = (1 - G) \times R25/R34 = (1 - G) \times K \quad [1]$$

Here the replication factor K is equal to $R25/R34$ and G is the combined voltage gain of the buffer and the output stage. This is a special form of feedback, since feedback is present if G is greater than 1, the loop gain is zero if G is 1, and feedforward is present if G is less than 1 (as in the paX amplifier). If G is 0.95 (which is a reasonable estimate of the transfer function of the buffer plus the output stage) and K is 1, the loop gain is 0.05. This is well below the critical limit ($G = 1$). This means that the feedback loop is sufficiently stable with regard to latch-up risk.

Output impedance

The open-loop output impedance of the buffer plus the output stage is shown in **Figure B**. As R_o has a large influence on the non-ideal behaviour of the buffer and output stage, a value of 1 for G can reasonably be assumed for the purpose of calculating the output impedance. The current source i_o (shown here for the sake of the analysis) connected to the output produces a voltage across R_o . A replica of this voltage (just as with the error correction feedback loop) is generated at the Z terminal. This can be expressed by the following formula:

$$Z_{out} = R_o \times (1 - R25/R34) = R_o \times (1 - K) \quad [2]$$

The output impedance Z_{out} is positive if K is less than 1, zero if K is 1, and negative if K is greater than 1. A positive output impedance causes overdamping of the loudspeaker, while a negative

Panorama (virtual) CAD DVD

Dear Editor — regarding your topic in the September 2008 issue on CAD.

You did not include DIPTRACE (<http://www.diptrace.com>). As a non-electronics amateur but one who has used AUTO-CAD for many years in civil

engineering, I found DIPTRACE was by far the most intuitive CAD package I tested. DIPTRACE is free for smaller projects (up to 250 pins).

Please include this software in your next review.

David (G3ZOI) (United Kingdom)

output impedance causes underdamping. As a result, an amplifier with a negative output impedance and a mediocre impulse response will cause overshooting if it is loaded with an LCR network (i.e. a loudspeaker), and in the worst case it can oscillate.

Conclusions and recommendations

From the above, it can be seen that the error correction feedback loop is stable, but the output impedance is negative in the presence of overcompensation. This is undesirable, especially with a problematic speaker load (such as an electrostatic speaker). The output impedance can easily be checked by connecting an audio signal generator to the input of the amplifier. When a load is connected to the amplifier, the amplitude of the output signal will decrease if the output impedance is positive or increase if the output impedance is negative. If the output impedance is found to be negative, the cure is to reduce the value of K by decreasing the value of $R25$ or increasing the value of $R34$.

Wim de Jager (The Netherlands)

Response from Jan Didden, the designer of the paX amplifier:

Dear Wim,

Your reasoning with regard to the output impedance is correct. However, if you attach a few values from actual practice to it, it turns out to not be a real problem.

You raise two issues with regard to the stability of the error-correction amplifier implemented in my design.

The error correction resistors ($R24$ and $R25$) should be matched as closely as possible for maximum error correction. In practice, 1% matching can be achieved without having to use adjustable resistors or trim pots. This yields an error correction of 40 dB. Furthermore, the loop gain of 0.05 that you mention (with an open-loop output stage gain of 0.95) means that the values of these resistors can differ by up to a factor of 20, or 2000%, with regard to stability considerations. Consequently, latch-up is not an issue.

Your reasoning with regard to the output impedance is also correct. Here again, it is enlightening to consider a few practical figures. A quick simulation shows that the open-loop output impedance of the circuit shown in Figure B is approximately 0.4 ohm (at 10 kHz). If the value of $R25$ is 1% larger than it should be (relative to $R34$), this yields a negative output impedance of 4 milliohms. For comparison, the resistance of 1 metre of speaker cable with a 2-mm wire diameter is approximately 10 milliohms. Here you could say that the negative output impedance offsets the resistance of the first half metre of the speaker cable. If it has any effect at all, it is to improve the damping.

In summary, it appears that a mismatch of the error correction resistors by a few percent does not create any problem at all with regard to latch-up or output impedance. A matching level of 1% can be achieved by a 'clever' choice of standard resistance values.

All of this is confirmed by the trouble-free operation of several dozen amplifiers that have been built according to this design.

Jan Didden

Thanks for that David — will do! By the way, for those keen on statistics: the chunks to compile the ISO file and from there burn your own DVD were down-

loaded 2,880 times and almost bowled over our web servers.

Multiple DigiButlers on the same network

Dear Editor — in part 2 of the DigiButler article (*Elektor* May 2008), it says that you can have only one DigiButler (or more generally, only one server) on your network. However, this is not strictly true — it is actually possible to connect several butlers, and possibly other servers as well, if you use a trick. This is based on the fact that an IP address and port can be accessed from any desired web browser. As noted in the article, to do this you have to enter the IP address assigned by your provider and instruct your router to remap port 80 to port 80 of the IP address of your DigiButler. However, a specific IP address and port can be accessed from any web browser, and you can take advantage of this to allow several butlers to operate on a single network. An example of how this works may help clarify this.

The normal situation when only one DigiButler is connected is as follows:

IP address assigned by provider: 86.131.222.120

DigiButler IP address:

192.168.0.2

Access address in the web browser: 86.131.222.120

Resulting remapping in the router: external port 80 to internal IP 192.168.0.2 with internal port 80

However, it is possible to run two DigiButlers on the same network, and in particular on two ports of your ISP, such as ports 1024 and 27888. The first DigiButler sits on port 1024, and the second one on port 27888. In this case you have:

IP address assigned by provider: 86.131.222.120

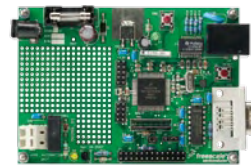
DigiButler 1 IP address: 192.168.0.2

DigiButler 2 IP address: 192.168.0.3

DigiButler 1 access address from the browser: 86.131.222.120:1024

DigiButler 2 access address from the browser: 86.131.222.120:27888

Resulting remapping in the



router:

- for DigiButler

1: external port 1024 to internal IP 192.168.0.2 with internal port 80

- for DigiButler 2: external port 2788 to internal IP 192.168.0.3 with internal port 80

Now you can log in to two DigiButlers from any desired location. Naturally, this scheme can also be expanded if your router allows it.

Tim Geerts (The Netherlands)

A really handy trick! It's certainly worth mentioning here. The DigiButler project seems to have gone down well witness the flurry of activity in our forum where you can read how readers got DigiButler to be less hot around the collar (one heatsink) and better prepared to relocate to other IP addresses (DHCP compatibility)! It's exactly the objective we had in mind for these articles: cheap hardware and fun in programming. At the time of writing, about 750 units have been sold. Thanks all for making this a success.

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Complete IEEE802.15.4 solution for wireless networking

Microchip announces the MRF24J40MA FCC-certified Radio-Frequency (RF) transceiver module and the MiWi™ Peer-to-Peer (P2P) Wireless Protocol Stack, based upon the IEEE 802.15.4™ specification. Together the MRF24J40MA module and MiWi (P2P) stack can target a variety of wireless networking applications, such as industrial monitoring and control, home and building automation, remote control, low-power wireless sensor networks, lighting control and automated meter reading.

The MRF24J40MA transceiver module is surface mountable and can be used with hundreds of 8-bit, 16-bit, or 32-bit PIC® microcontrollers (MCUs). It includes discrete biasing components and an integrated PCB antenna to be used in sensor and control network environments. The module is fully regulatory-agency certified for the US (FCC), Canada (IC) and Europe (ETSI), and is expected to save designers time and money by eliminating the need to receive FCC certification for their wireless products.

The MiWi P2P protocol stack sup-



ports star and peer-to-peer wireless-network topologies with an ultra-small code implementation of 3K bytes for Microchip's PIC microcontrollers (MCUs). As a result, the stack provides short-range wireless customers with hundreds of possible MCU implementations for applications that require simple node-to-node communication. Additionally, the new MiWi P2P stack provides sleeping-node, The MiWi P2P protocol stack supports star and peer-to-peer wireless-network topologies with an ultra-small code implementation of 3K bytes for Microchip's PIC microcontrollers (MCUs). As a result, the stack

provides short-range wireless customers with hundreds of possible MCU implementations for applications that require simple node-to-node communication. Additionally, the new MiWi P2P stack provides sleeping-node, active-scan, and energy-detect features that enable robust operation while supporting the low-power requirements of battery-operated devices.

Available as a free download from Microchip's new online Wireless Design Centre at www.microchip.com/wireless, the small-footprint, proprietary stack complements the new MRF24J40MA 2.4 GHz FCC-certified transceiver mod-

ule. It represents Microchip's third free software protocol stack for IEEE802.15.4 transceivers, joining its ZigBee stack and existing MiWi stack.

As well as Microchip's free ZigBee, MiWi and new MiWi P2P software-protocol stacks, the module is supported by Microchip's PICDEM™ Z Demo Kit and the ZENA™ Wireless Network Analyser. When combined with these development tools, the module enables designers with little or no RF design experience to design low-power wireless networking products quickly and inexpensively. Designers can also use Microchip's PICDEM Z Demonstration Kit (DM163027) with all of the company's free stacks and MRF24J40MA module. The kit includes a pair of development boards with a PIC18LF4620 MCU, along with the ZENA Network Analyser and wireless network configuration utility (DM183023). The kit and the ZENA Network Analyser are available today at the website below.

www.microchipdirect.com

LED constant current demo board

V.I Chip, Inc., a subsidiary of Vicor Corporation has announced a constant current (CC) PRM™ regulator demonstration board for LED applications such as street & stadium lighting, high-end projectors, active outdoor advertising and architectural installations.

The board provides a precisely regulated current as required for direct-drive multi-LED applications where the intensity and bright-

ness are controlled by regulating the current through the LEDs. The board can be used to provide adjustable current up to 240 W (5 A at 48 V) when employed as an standalone non-isolated source or can be combined with the range of VTM™ transformers to provide an adjustable isolated current up to 100 A.

A PRM+VTM pair uses less than 1 watt for every 1,000 Lumens

generated by the LEDs for high performance applications. This solution is a perfect complement to using BCM™ bus converters with low voltage driver ICs for lower power applications such as LED TV backlighting.

The constant current board demonstrates the high power density of the PRM with current accuracy of 99.7% across the load range. The board has Kelvin connections

for measuring the efficiency of the V.I Chip™ components independent of load connect losses. Oscilloscope probe jacks are available for measuring output voltage, including output voltage ripple. The board has fused PRM inputs, provision for mounting an optional V.I Chip pushpin heat sink, and system enable and disable.

www.vicorpower.com/ccdemo/

(080624-IX)

World's highest integration single chip GPS receiver

SkyTraq recently introduced their Venus634LP GPS receiver, reportedly the world's highest integration single-chip GPS receiver using its low-power Venus6T GPS architecture. Measuring 10x10mmx1.2 mm, the Venus634LP integrates LNA, SAW filter, RF front-end, GPS baseband, 0.5 ppm TCXO, RTC crystal, LDO regulator, and passive components. A complete GPS receiver requires only an antenna and

Venus634LP. Featuring highest integration, 1 centimetre squared footprint, ultra fast TTFB, high sensitivity, and low current consumption, the Venus634LP GPS receiver enables lowest cost of embedding location awareness into portable applications without compromising size, performance, and battery life. It is compatible with both active and passive antennas. The receiver consumes 50 mA during signal acqui-

sition and 30 mA during full power continuous tracking. The dedicated signal parameter search engine within the Venus634LP is capable of performing 8 million time-frequency hypothesis testing per second, offering ultra-fast 1-second hot start and 29-second cold start under open sky. The advanced track engine allows tracking sensitivity of -158 dBm, enabling continuous navigation in harsh environments such as urban, canyon



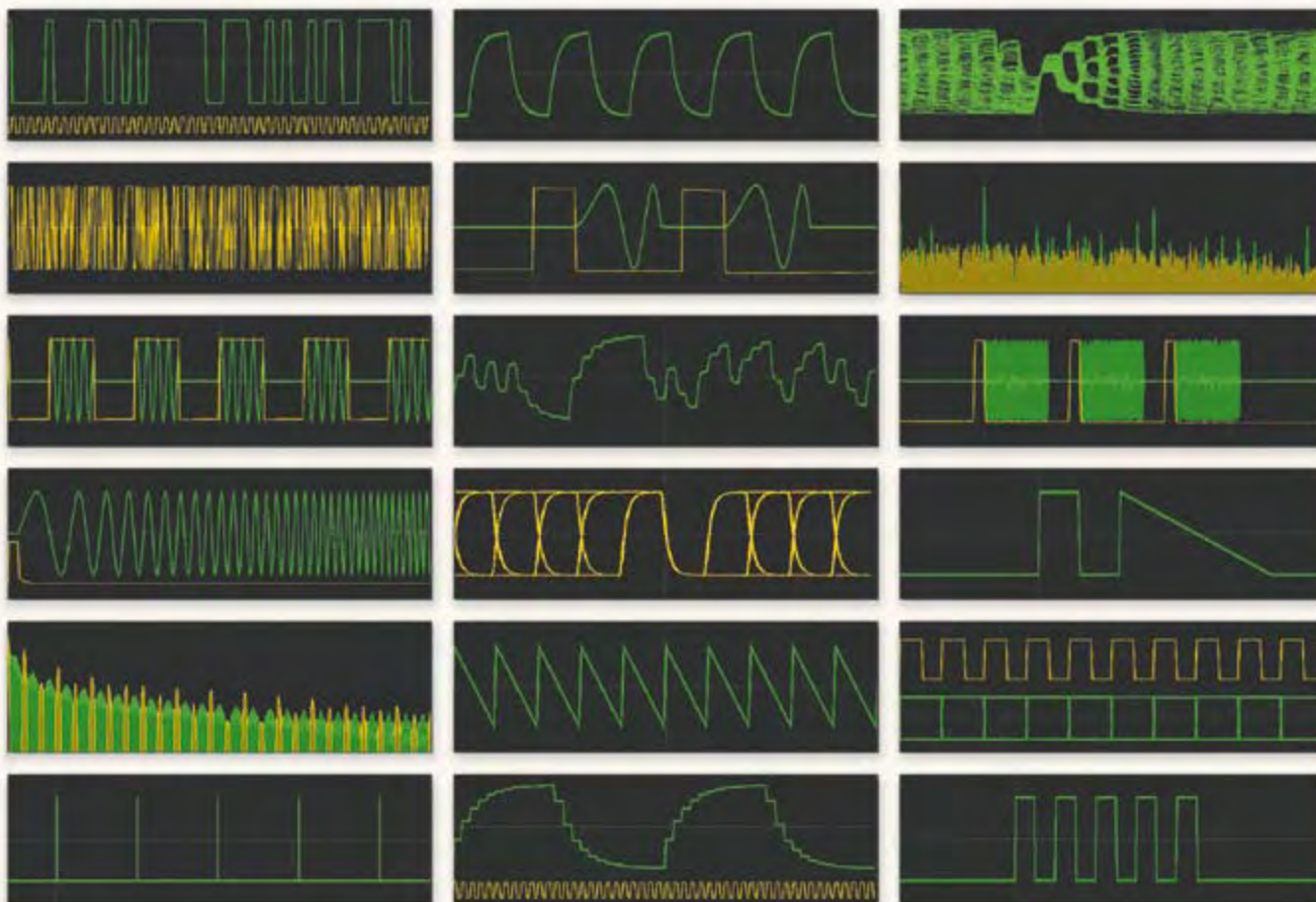
and under deep foliage.

www.skytraq.com.tw

(080624-XI)

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Multi-Band Spectrum Analyzer

- ✓ Display analog waveforms and their spectra simultaneously. Base-band or RF displays with variable bandwidth control.

Direct Digital Synthesis Generator

- ✓ Arbitrary waveform crystal referenced DDS frequency synthesis. Microsecond one-shot timing precision and burst generation. Independent but sample synchronized with BitScope capture.

Noise, Dither and Entropy Generator

- ✓ Pseudo-Random Number noise, dither and entropy generation. White, pink or binary with programmable or random seed.

Voltage, Clock and Logic Generator

- ✓ Programmable voltage, clock and serial logic generation. Adjustable DC reference and mark/space clocks to 5MHz. Logic level shifting and probe calibration signals.



BitGen is a comprehensive DSP based waveform and timing generation solution available as standard in BS100M or an option for BS100U. From clocks, sine, square or triangle waves to sophisticated bursts, chirps, noise or user programmable signals, BitGen supports them all.



www.bitscope.com

Electronworks electronic kits



You don't have to be mad in life... Second thoughts, yes you do. Electronworks have taken some of life's insanity (and lots of their own) and put it into electronic kits. Electronworks' aim is to make learning electronics fun and to bring you a range of kits that are both practical and educational. A whole tonne of kits and ideas is available for unleashing in the

coming months, so if you are young or old, new to electronics or a seasoned veteran you will find something to suit your needs. For example, Electronworks' MP3 booster amplifies the output of your MP3 player, so you can fill the room with music via your PC speakers. Also available are a random number generator that generates a completely random number



from 0-99 and an in car power supply, so you can power all your battery powered electronics from a

12V input and many more.

www.electronworks.co.uk

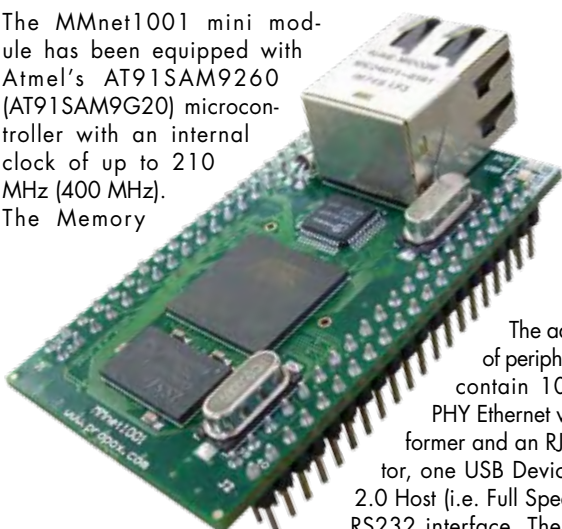


Ethernet mini module with ARM9 400 MHz microcontroller and Linux

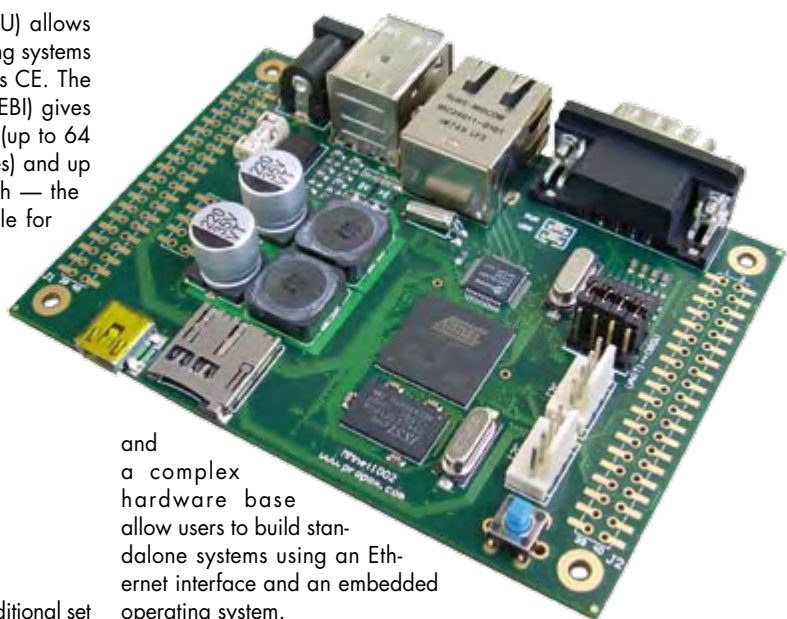
PROPOX from Poland introduce a new family of modules based on microcontrollers with the ARM9 core. The modules were designed to achieve 100% compatibility with the mmTm socket already used and promoted by PROPOX for few months in their EVBmmTm boards.

Management Unit (MMU) allows the micro to run operating systems like Linux and Windows CE. The External Bus Interface (EBI) gives connectivity to SDRAM (up to 64 MB on board of modules) and up to 4 GB of NAND Flash — the largest amount available for now.

The MMnet1001 mini module has been equipped with Atmel's AT91SAM9260 (AT91SAM9G20) microcontroller with an internal clock of up to 210 MHz (400 MHz). The Memory



The additional set of peripheral devices contain 10/100Mbit PHY Ethernet with a transformer and an RJ45 connector, one USB Device, 2x USB 2.0 Host (i.e. Full Speed) and 5x RS232 interface. These features



and a complex hardware base allow users to build standalone systems using an Ethernet interface and an embedded operating system.

PROPOX went one step further by offering the 'Linux on board' solution to customers: all modules are available with running Linux and come with a DVD containing source codes, compilers and sample software.

A complete eLinux solution called the MMnet1002 module will be available soon.

www.propox.com

(080793-1)

EasyPIC5 C Starter Pack—everything needed to start developing PIC projects in C for just £189



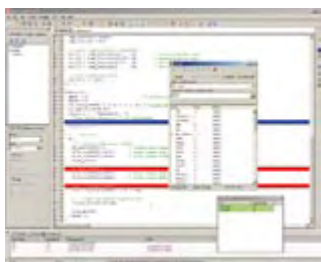
The EasyPIC5 C Starter Pack contains everything needed to start learning about and developing with PIC microcontrollers using the C programming language. The package contains the popular EasyPIC5 development board, a full version of MikroElektronika's powerful mikroC compiler, USB and serial cables, blue backlit 16x2 character and 128x64 graphic LCDs, touch-screen overlay for graphic LCD, DS1820 temperature sensor and a 40-pin enhanced Flash PIC16F887 microcontroller—all for just £189.

The EasyPIC5 C Starter Pack is well-suited to beginners and experienced developers alike and comes with high-quality printed documentation and a large number of easy-to-understand example programs for a number of PIC microcontrollers.

The **EasyPIC5** supplied in the starter pack is a full-featured development board for PIC10F, 12F, 16F and 18F microcontrollers in 8, 14, 18, 20, 28 and 40-pin packages. The EasyPIC5 incorporates an on-board USB-based PIC programmer and in-circuit debugger as well as a useful selection of built-in I/O devices such as LEDs, switches, 7-segment displays, potentiometers, RS-232 interface, PS/2 and USB connectors and provision for fitting of the included LCD displays, touch-screen and DS1820 temperature sensor. What's more, all of the PIC's input/output lines are available for connection to your own circuits or to any of our huge range of low-cost optional add-on boards such as Ethernet, RS-485, CAN, LIN, IrDA and RFID communications, EEPROM, SD/MMC and Compact Flash storage, 12-bit A/D and D/A, and many useful interfacing and prototyping boards.



Supplied in the EasyPIC5 C Starter Pack is a full version of MikroElektronika's **mikroC**, a powerful integrated development environment and C compiler for PIC12, PIC16 and PIC18 microcontrollers. With its built-in user-friendly features, mikroC makes developing code for PICs easier than ever. When used in conjunction with the EasyPIC5 development board, mikroC provides full in-circuit debugging capabilities. mikroC also provides a library of ready-written routines that provide support for all of the EasyPIC5's on-board I/O devices and optional add-on boards. This enables programs to be quickly constructed even when working with advanced features such as CAN, Ethernet and USB communications, character and graphic LCDs and touch-screen, and EEPROM, MMC/SD and Compact Flash data storage. mikroC also incorporates useful tools such as LCD custom character generator, GLCD bitmap generator, USART, HID and UDP terminals and 7-segment display decoder.



EasyPIC5 BASIC Starter Pack and **EasyPIC5 Pascal Starter Pack** also available at £149 each. Similar starter packs also available for 8051, AVR and dsPIC—please see our website at www.paltronix.com for prices and full details.

Get an oscilloscope, logic analyser and much more with the PoScope USB-based Instrument for only £79



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- Dual-channel chart recorder
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- 8-channel pattern generator
- Square-wave/PWM generator

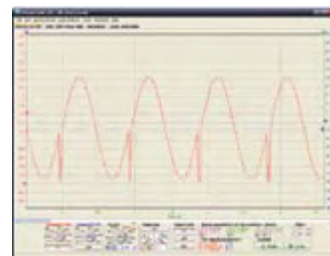
This latest version of the popular PoScope is a must-have tool for those developing microcontroller-based projects or with a general electronics interest and provides the features of six instruments in one compact PC-based unit at an incredibly low price.

The PoScope connects to one of your desktop or laptop PC's USB interfaces (USB 1.1 or USB 2.0), is Windows XP and Vista compatible and comes with easy-to-use software.

The PoScope provides two BNC connectors for oscilloscope, spectrum analyser and chart recorder inputs and a 25-way female D-connector for logic analyser and pattern generator input/outputs. Supplied with USB connecting cable and software and manual on CD-ROM.

A PoScope Bundle is also available for £119, which additionally includes two high-quality oscilloscope probes and a logic analyser test lead and clip set.

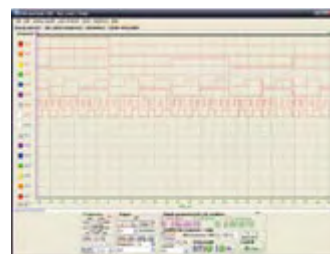
The **dual-channel oscilloscope** provides voltage and frequency measurement, absolute, differential and external triggering, adjustable pre-trigger, marker measurements and filtering. Specifications include a 100Hz - 200kHz sampling rate, 1126 samples/channel (1 channel) or 563 samples/channel (2-channel) memory depth with pipe reading of 64k samples per channel, 10-bit resolution A/D and input voltages from -20 ~ +20V.



Dual-channel oscilloscope view

The **spectrum analyser** provides Hamming, Hanning, Blackman and Blackman-Harris window functions.

The **chart recorder** provides dual-channel recording at sampling rates from 0.01Hz ~ 200kHz with a maximum record time of 24 hours at Fs < 100Hz. A/D resolution and input voltage range are again 10-bit and -20 ~ +20V respectively.



Sixteen-channel logic analyser view

The **logic analyser** provides 16 channels (eight when pattern generator in use) with a sampling rate of 1kHz ~ 8MHz, internal and external clocking, versatile triggering and an input range of 0 ~ +5V. Memory depth ranges from 1544 bits/channel (Fs <= 1MHz) to 128 bits/channel (Fs <= 8MHz). Built-in **serial bus protocol decoding** facilitates the decoding of UART, SPI, I2C and 1-wire serial buses.

The **pattern generator** allows eight of the logic analyser's channels to be used to provide output waveforms from 1kHz ~ 1MHz with a memory depth of 1544 bits/channel and an output voltage of 0V for logic "0" and 3.3V for logic "1".



UART, SPI, I2C and 1-wire decoding view

The **PWM generator** provides a 7.8125kHz output with a 1 ~ 100% adjustable duty cycle. Square waves can also be output with a 50% duty cycle and an adjustable frequency ranging from 3.91kHz to 1MHz.

Please see our website at www.paltronix.com for further products including components, microcontroller development tools, prototyping aids, educational robot kits, test equipment and wireless communications products.

Pix-Cell GSM Controller

New product—the Pix-Cell is a stand-alone controller offering GSM/GPRS communications, three digital inputs, three 10-bit analogue inputs, SPDT relay output and RS-232 interface priced at £129.



ZeroPlus Logic Analysers

A range of powerful 16 and 32-channel logic analysers with advanced serial bus protocol decoding including CAN, LIN, USB, UART, SPI, I2C, 1-wire and more. With prices from only £125, there's a logic analyser in this range to suit all needs and budgets.



Universal Development System

The UNI-DS3 is a versatile microcontroller development system supporting PIC, dsPIC, 8051, AVR, ARM and PSoC devices with an extensive range of built-in I/O features and on-board USB programmer priced from £109.



New Capacitive Touch Demo Board

Microchip announces the PICDEM™ Touch Sense 2 Demo Board (Part # DM164128) for capacitive touch-sensing applications. The easy-to-use board comes with the royalty-free mTouch™ Sensing Solution Software Development Kit (SDK) and is populated with a 16-bit PIC24FJ256GB110 microcontroller (MCU), which features an integrated Charge Time Measurement Unit (CTMU) peripheral



for fast capacitive touch sensing. This is also the world's first

16-bit MCU family with USB On-The-Go (OTG). The board and supporting materials provide a complete platform for implementing capacitive touch-sensing interfaces, without the need for external components. Additionally, with the PIC24FJ256GB110 family's rich peripheral integration and 256 kBytes of Flash memory, and Microchip's broad portfolio of free

and low-cost software libraries, embedded designers can use a single MCU to cost effectively implement a wide variety of additional user-interface functions, including QVGA touch-screen displays, speech-based audio prompts and USB connectivity. The PICDEM Touch Sense 2 demo board (Part # DM164128) can be purchased for \$ 99.99 from Microchip. This price includes the mTouch Sensing Solution SDK and a USB cable.

www.microchip.com/mtouch
www.microchipdirect.com

(080793-II)

New industry alliance promotes use of IP in networks of 'smart objects'

A group of leading technology vendors and users have formed the IP for Smart Objects (IPSO) Alliance, whose goal is promoting the Internet Protocol (IP) as the networking technology best suited for connecting sensor- and actuator-equipped or 'smart' objects and delivering information gathered by those objects.

Smart objects are objects in the physical world that – typically with the help of embedded devices – transmit information about their condition or environment (e.g., temperature, light, motion, health status) to locations where the information can be analyzed, correlated with other data and acted upon. Applications range from

automated and energy-efficient homes and office buildings, factory equipment maintenance and asset tracking to hospital patient monitoring and safety and compliance assurance.



Intended to complement the efforts of entities such as the Internet Engineering Task Force (IETF) and the Institute of Electrical and Electron-

ics Engineers (IEEE), which develop and ratify technical standards in the Internet community, the IPSO Alliance will perform interoperability tests, document the use of new IP-based technologies, conduct

marketing activities and serve as an information repository for users seeking to understand the role of IP in networks of physical objects.

The alliance seeks to advocate how networks of objects of all types have the potential to be converged onto IP. Founding members of the IPSO Alliance are Arch Rock, Atmel, Cimetrix, Cisco, Duke Energy, Dust Networks, eka systems, EDF (Électricité de France) R&D, Emerson, Freescale, IP Infusion, Jennic, Kinney Consulting, Nivis, PicosNet, Proto6, ROAM, SAP, Sensinode, SICS, Silver Spring Networks, Sun Microsystems, Tampere University, Watteco and Zensys. IPSO Alliance membership is open to any organisation advocating an IP-based approach to connecting smart objects.

www.ipso-alliance.org

(080793-VI)

MLX90614 Infrared Thermometer Module

The MLX90614 Infrared Thermometer Module from Parallax is an intelligent non-contact temperature sensor with a single pin serial interface for connection to most microcontrollers. The MLX90614 sensor is designed for non-contact temperature measurements of objects placed within the sensor's cone of detection. The sensor is comprised of an integrated ASIC and infrared sensitive thermopile detector. The sensor communicates with an SX20AC/SS-G coprocessor over a digital SMBus, which Parallax has programmed

to simplify an otherwise fairly complex communication protocol. With a temperature range of -70°C to 380°C, auto-baud detection and a programmable alarm setting, this module becomes very useful in many applications such as surface temperature measurement, human/animal presence detection or HVAC. Up to 100 modules can be connected on the same bus making multi-zone temperature measurement easy.

www.parallax.com (search '28040')

(080793-IX)



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A large range of replacement tips are available for most irons, and technical help is on hand from our offices in Devon UK.

Buy Online

Our new website has all of our irons, and soldering spares and accessories available 24hrs a day. Most items are shipped next day, and we offer free carriage throughout Europe. Why not give antex.co.uk a try!

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Thermostats for UPS Battery Back-Up Systems

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UPS system installers a simpler and more cost-effective solution. Matsuo thermostats have a unique twin-bimetal system that creates a control which is capable of switching over 1 million cycles. Accuracies of ± 1.5 K and differentials down to $3\text{ K} \pm 1\text{ K}$ are readily available, with repeatability as

small as ± 0.2 K. Basically they function on a par with electronic controllers. The thermostat's IP64 plastic housing can be readily fixed to the side of a battery and so each one can be safely monitored. www.atcsemitec.co.uk

(080793-V)

ULP wireless SoC solution

The nRF24LE1 from Nordic Semiconductor integrates a fully-featured nRF24L01+ 2.4GHz transceiver core including Nordic's proven Enhanced ShockBurst™ hardware link layer. It delivers true ULP operation with peak currents low enough to run on coin cell batteries.

The nRF24LE1 also integrates an enhanced 8051 mixed signal MCU core featuring fewer clock cycles per instruction than legacy 8051 devices. Most instructions need just one or two clock cycles leading to an average performance improvement of 8x using the MIPS (Million Instructions Per Sec-

ond) benchmark. This high performance combined with 16 kBytes of on-chip flash plus 1 kByte of SRAM ensures the processing platform is powerful enough to run both the RF protocol stack and application layer with ease.

A wide range of peripherals and power saving modes support the RF protocol stack. A ULP 32 kHz crystal oscillator provides high accuracy timing for low report rate synchronous protocols and a 16 MHz RC oscillator provides fast start-up times from idle. The 32 kHz oscillator can provide timing accurate enough for

higher report rate protocols without requiring an external crystal. A security co-processor supports AES encrypted wireless communication. The nRF24LE1 provides a range of nanoamp and microamp idle modes specifically designed for ULP RF protocol stacks. Further benefits include higher precision protocol timing, lower power consumption, and improved co-existence performance.

For the application layer the nRF24LE1 offers a rich set of interfaces and peripherals including an SPI, 2-wire, UART, 12-bit ADC, PWM and an analogue comparator. As such, the nRF24LE1 is the



ideal single chip solution for wireless applications including mice, keyboards, remote controls, game controllers, sports/healthcare sensors, toys, and active RFID tags. Engineering samples of the nRF24LE1 and development tools are widely available today. www.nordicsemi.com

(080793-III)

6-channel touch controller with integral LED driver

Atmel® Corporation's AT42QT1060 is a touch control chip that integrates 6 channels of touch sensing with the ability to drive up to seven low current LEDs directly through a pulse width modulated (PWM) output function. The device operates from 5.5 V down to 1.8 V and consumes less than 1 μA in standby mode to give long battery life; it comes in a tiny 4x4 mm MLF28 package, making it ideal for use in mobile phones and other handheld devices. The AT42QT1060 is the latest addition to Atmel's comprehensive range of capacitive touch controllers based on Quantum Research Group's charge-transfer technology. These include QTouch™ and QMatrix™ based controllers for single and multiple touch buttons, touch sliders and touch wheels.

The AT42QT1060 is designed for use in portable electronics products. An inbuilt capacitive guard channel feature helps prevent false



triggering, for example, where moisture is an issue. This feature also prevents against erroneous commands that can occur when devices such as MP3 players are carried in a pocket, or in the case of a cellular phone, when it is held against the ear. The highly integrated AT42QT1060 reduces component count, cutting design complexity and cost, and enabling faster product development.

The AT42QT1060 functions through any insulating panel including glass or plastic up to 3 mm thick. Electrodes can be made from copper, silver, carbon, indium tin oxide (ITO) or Orgacon conductive ink and must be 6x6mm or larger. Widely different electrode sizes and shapes are possible, giving the product designer great flexibility in tailoring the user interface.

www.qprox.com

(080793-VII)

An Introduction to SMD

Thijs Beckers (Elektor Netherlands)

The first step is always the hardest, so we're providing a brief introduction to SMT to help you out. Here we introduce you to some of the jargon, pitfalls and packaging so you can hold your own in discussions of this technology, which has become indispensable in the production of modern electronic equipment.

If you want to work with surface-mount technology (SMT), you need to have a bit of basic knowledge. This article explains several terms, discusses some of the things to watch out for, and gives you some pointers for finding more information so you can learn to loosely mention the terms like a pro.

What does it mean?

To start off, let's take two terms that many people tend to mix up: 'surface mount device' (SMD) and 'surface mount technology' (SMT). SMT refers to the technology, which means using components (usually small) that do not have leads designed to pass through holes in the circuit board, while SMD refers to the actual component.

Another term you will see is 'SMA'. This stands for 'surface mount assembly', which indicates that a component is designed for mounting **on** the circuit board, rather than with pins that pass **through** the circuit board. The same term can also be used as an abbreviation of 'surface mount adhesive', which is the glue used to attach SMDs to the circuit board so they don't slide around during soldering.

Jargon

Nowadays SMDs are used in almost all electronic equipment. In fact, there are probably more components available now in SMD form than in 'through-hole' form (with individual pins or leads). Naturally, the reason for this is the extensive miniaturisation of electronic circuitry. SMDs are also appearing increasingly often in the DIY world.

When you use SMDs, you run into a considerable amount of insider terms. In order to get your bearings in the SMD world, you need to know these terms and understand what they mean. Most likely you have already heard the term 'ball grid array', but 'flip chip' is probably less familiar. With the latter technology, the chip is mounted with its active surface facing downward (**Figure 1**), which means that the active surface of the chip can be used directly for the connections. This makes it possible to make a large number of connections to the chip, and they have much lower inductance than with wire bonds due to the shorter distance.

Another recent development is called 'package on package' (PoP). This consists of stacking one chip on top of another one (usually discrete logic and memory), which saves space and keeps the connections short to minimise inductance problems.

When boards are assembled automatically, they must have fiducial marks. A fiducial mark (or simply 'fiducial') is a symbol that is placed on the circuit board. It can be used to determine the position of the board with high accuracy, so that the solder paste can be applied correctly or a pick-and-place machine can place the components in exactly the right positions before the board goes into the oven for soldering.

Incidentally, two standard methods have been developed for applying solder paste: silk-screening (also called screening or stencil printing) and direct printing. In the silk-screening process, a stencil is created with openings exactly aligned to the copper track layout. A rubber squeegee spreads the paste over this stencil, with the result that it ends up exactly where it should be on the circuit board. This method is feasible for series production, but producing a stencil of this sort is far too expensive for making a single PCB. The direct printing method is more suitable in the latter case. This involves using a special 'printer' (similar to an ink-jet printer) to deposit the solder paste directly on the PCB. However, these printers are rather costly.

Reflow problems

There are several common problems with soldering SMDs (including reflow soldering). One of them is called the 'tombstone effect', or 'tombstoning'. **Figure 2** shows the forces acting on an SMD component during soldering. They can cause the component to stand upright on the circuit board instead of remaining flat on the board when it is soldered. Upright SMD resistors resemble miniature tombstones, which is where the term comes from.

The component will rise up if the sum of F_1 and F_2 is less than F_3 , or in mathematical terms:

$$M \cdot g \cdot [(D^2 + L^2) / 2] \cdot \cos(\alpha + \beta) + \gamma \cdot W \cdot \cos(\alpha / 2) < \gamma \cdot D \cdot \sin(\alpha + \Phi)$$

where M is the mass of the component and g is the force of gravity.

Terminology

What does all that jargon mean?

There are several causes of tombstoning. For instance, lightweight components are more susceptible to this effect. Relatively long solder pads can also cause this undesired effect, because the portion of the pad that extends beyond the component causes an increased torque (larger value of Φ in **Figure 2**).

Tombstoning can also occur if temperature does not rise uniformly at both ends of the component. If one end is warmer than the other one, the solder will melt first at this end, leading to an undesired upright component. This problem usually does not occur in modern convection ovens, but design-related factors such as screening and cooling surfaces can lead to temperature differences.

Incorrect component placement can also lead to tombstoning, but the main cause is a temperature difference between the two ends of the component, which causes the solder to melt earlier at one end than at the other end.

'Popcorning' is another example of what can go wrong during the soldering process. This refers to a condition that can occur if moisture-sensitive components remain outside a moisture-proof package too long before they are soldered in a reflow oven. The component package can absorb moisture due to its hygroscopic properties. If such a component is heated relatively quickly, the moisture turns into steam, which may create so much internal pressure that the package will crack or burst open.

Another problem is that the component may float on the molten solder and tip over along its long axis as a result. This is particularly annoying with LEDs, since it causes the light to be emitted toward the side instead of straight up.

Standards

Since the 1st of July 2006, electronic equipment marketed inside the EU is not allowed to contain certain substances. This is stipulated by the 'Restriction of Hazardous Substances' directive, usually abbreviated as 'RoHS'. In colloquial language, this is also described by saying that the equipment and components must be 'lead-free'. The fact that a component is 'lead-free' or fulfils the RoHS standard does not necessarily mean that it is suitable for lead-free processing. It only says something about the chemical composition of the product, but not that it can withstand the relatively high temperatures used in lead-free soldering. Consider yourself warned.

A good reference source for industrial standards related to components is the Institute for Interconnecting and Packaging Electronic Circuits (IPC) – see the web link at the end of this article. The standards in the IPC-7351 to IPC-7359 series are especially important for PCB design. They provide information about suitable dimensions, shapes and

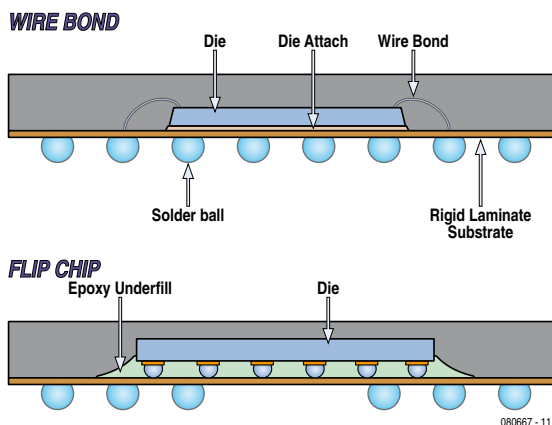


Figure 1. Wire-bond or flip-chip? Flip-chip technology is often used in processors due to high clock rates.

tolerances of pads for SMDs, so that they provide enough surface area for soldering but not too much (which would create a risk of tombstoning).

Packages and packaging

We could fill dozens of pages with information about SMD packages – it's an almost endless subject. Here we recommend that you read through the overview of the most common SMD codes and pin layouts prepared by R. P. Blackwell [1].

With regard to packaging, we can keep our remarks quite short: as SMDs are usually processed by automated machines, it is essential to standardise the containers used

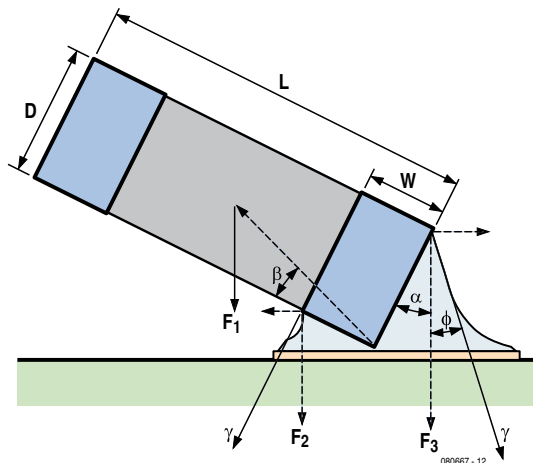


Figure 2. The tombstone effect is caused by unbalanced forces.

to supply the components to the machines. There are four common types:

- **Tape or reel:** the components are located on a tape that is wound on a reel, just like the tape of an (old-fashioned) tape recorder.
- **Tray or pallet:** components with a small pin spacing or BGA are usually packaged in this sort of container.
- **Stick or tube:** IC with edge-mounted pins are often supplied in a plastic tube to prevent accidental bending of the pins.
- **Bulk:** a large number of the same type of component, which are not packaged in an orderly manner. Often used in the past with large quantities.

Requisites

In the old days, enthusiasts went to an electronics shop to purchase their components. As there are often a large number of package options available now for components, it is simply impossible for an average shop to keep all types of components in stock. Fortunately they can usually supply the desired version on request.

Online shops often have a larger selection, but there is a chance that they do not have the part in inventory and will have to order it from a distributor. In addition,

there are usually shipping charges. The really big players, such as Farnell and Conrad Electronics, can usually deliver from stock.

Finally, you need solder paste if you want to solder PCBs with a reflow oven. There is large selection of various pastes, each with its specific properties. The one may have a higher melting temperature, while the other may have smaller solder particles, and so on. See reference [2] for more information on solder pastes.

You can also consult the web links listed below under 'Background information' to learn more about the topics discussed in this article. Once you've digested all this information, you'll be a lot more knowledgeable, and you won't be at a loss for words when the subject turns to SMT, SMD or SMA.

(080667-1)

Internet Links

[1] www.marsport.org.uk/smd/mainframe.htm

[2] www.siliconfareast.com/solder-paste.htm

Background information

www.answers.com/topic/flip-chip

www.ipc.org

www.ami.ac.uk/courses/topics/0229_place/index.html

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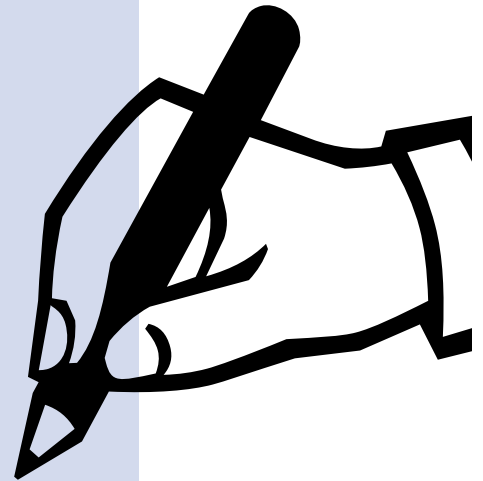
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Speed Camera W

Drive wisely!

Gilles Le Maillot (France)

The little module described here lets you detect geographical points of interest (POIs) using the frames output from a GPS receiver module. These POIs might be restaurants, petrol stations, or —why not? — the positions of fixed speed cameras!

Having found it hard to find fully-developed, ambitious projects every year, the circuit published online by Christophe Le Lann [1] seemed to me a good starting point. So we adapted this Electronics Design project for the course taught at our College (*ENSIETA* [2]). We've used a PIC microcontroller and added several new options like a bigger memory, the possibility to update the memory via USB, speed display, etc. In addition, we produced the program under Flowcode using E-blocks [3].

Flowcode is a high-performance graphical development environment for microcontrollers (PIC and AVR) that makes it possible to swiftly create quite complex electronics systems, and above all, to simulate them. The program description is in the form of a standardized (ISO5807) flowchart using macros that make it easier to control complex peripherals, like 7-segment displays, motor controllers, LCD displays, Bluetooth, TCP/IP, etc. Elektor has already published numerous articles about this product. For myself, I was quite surprised by how power-

ful, user-friendly, and easy to learn this software is. Of course, it's not a magic tool, it does have its limitations — for example, the PIC interrupt library is not comprehensive enough, and it only recognizes whole number values to a maximum of 16 bits — but these are fairly easy to work around.

It's up to you...

The project described in this article may be used as a warning device for fixed speed cameras, which is perfectly legal in France at the time of publication of this article. However, this does not mean to say that the use of this project is legal in other countries, nor that it is going to remain legal for use in France.

In addition, the Flowcode simulation mode allowed us to test the code for this project (except for the serial connection interrupt part) before implementing it.

Thanks to Flowcode, we've been able to produce a quite substantial project in a limited time. The use of a tool like Flowcode (in an educational context)

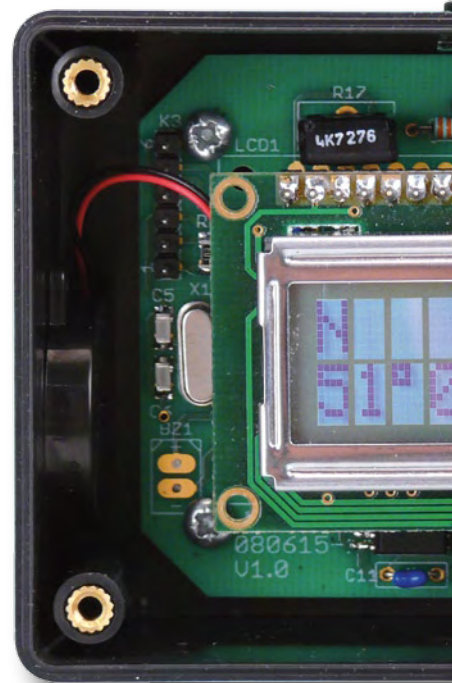
was a first for us — most students appreciated it, and some of them actually managed to see the project right through to the end!

Block diagram

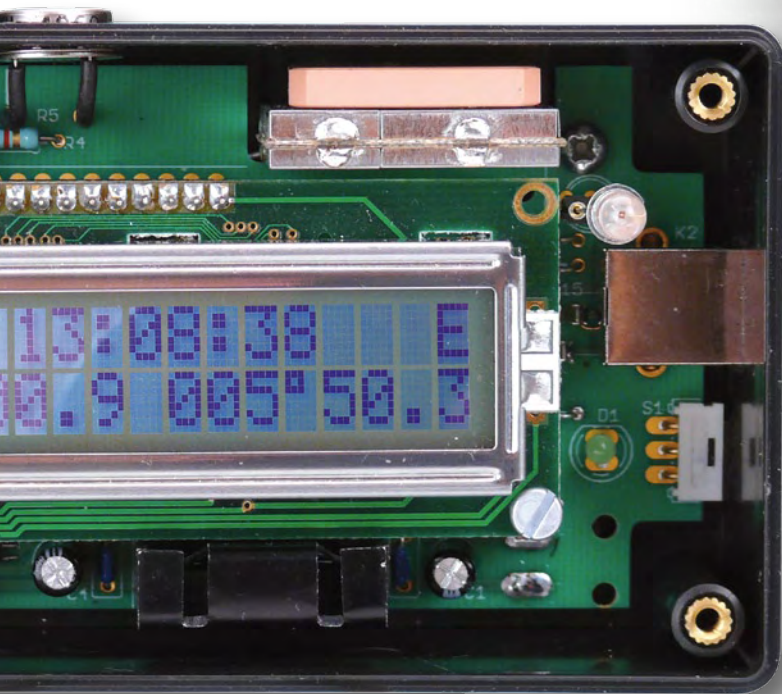
As the block diagram (**Figure 1**) shows, the system is fairly simple: a GPS receiver provides the system's geographical position once a second. This position is then compared to the POI locations stored in a database. If there is a POI within around 500 m of the current position, a visual and audible warning is triggered.

The heart of the system is a 16F876A-I/SO microcontroller from Microchip, which receives the vehicle's positions from the GPS, looks them up in the database, and drives the man/machine interface (MMI).

This MMI consists of an LCD display, a sounder and a bi-colour LED. If there is no POI in the vicinity, the LCD just displays the position and the time or speed. The bi-colour LED flashes green every time a GPS frame is received. In the event of a POI nearby, the sounder



Warning Device



sounds, the bi-colour LED lights up red and steady, and the LCD displays a warning message. The MMI has one little unexpected extra: automatic backlighting that adjusts itself to the ambient light level.

An I²C memory is used to store the geographical position of the POIs. A USB interface is available for loading the POIs into the memory from a computer.

The GPS receiver, which sends its data via a serial link, shares the microcontroller's serial link with the USB interface. A multiplexer allows the serial data source to be selected using a simple switch.

E-blocks

The first platform was achieved using these E-blocks: an **EB006** for the development platform (this is directly usable under Flowcode for programming the PIC and supports many types of PIC) and an **EB005** for the LCD. For the rest of the project's components, we've created our own E-block, connected to the PIC PORT C. In this DIY E-block (**Figure 2**) we find the I²C memory, the FT232BL USB/RS-232 interface, the bi-colour LED, the sounder, and a

MAX232 to allow us to dispense with the USB port in the first instance and be able to simulate the GPS frames on a PC. **Figure 3** shows the prototype in all its splendour.

The program

The program, developed under Flowcode, comprises two distinct sections. The first and most important section handles the dialogue with the GPS module, compares the data from the GPS with the locations stored in the

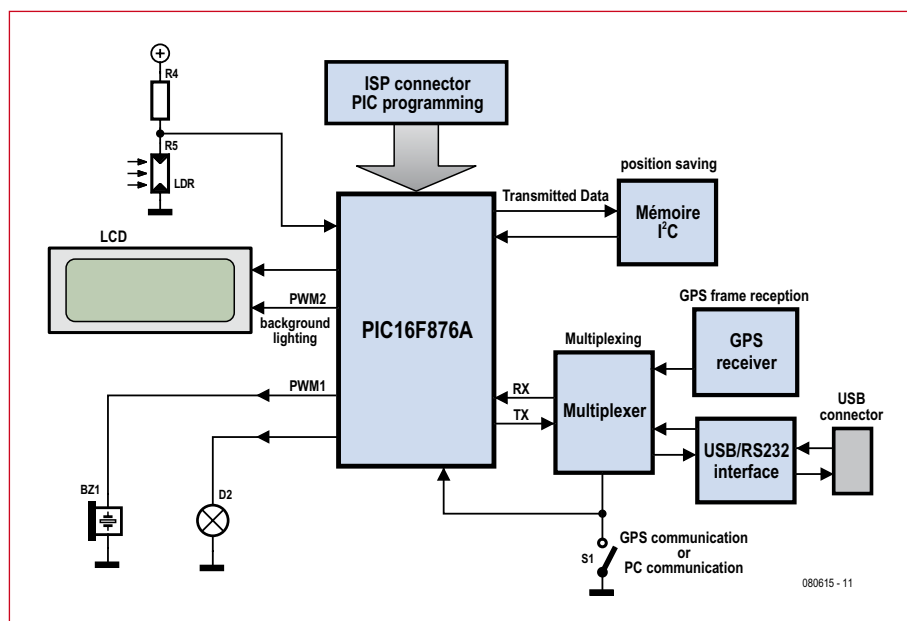


Figure 1. Block diagram of POI warning device.

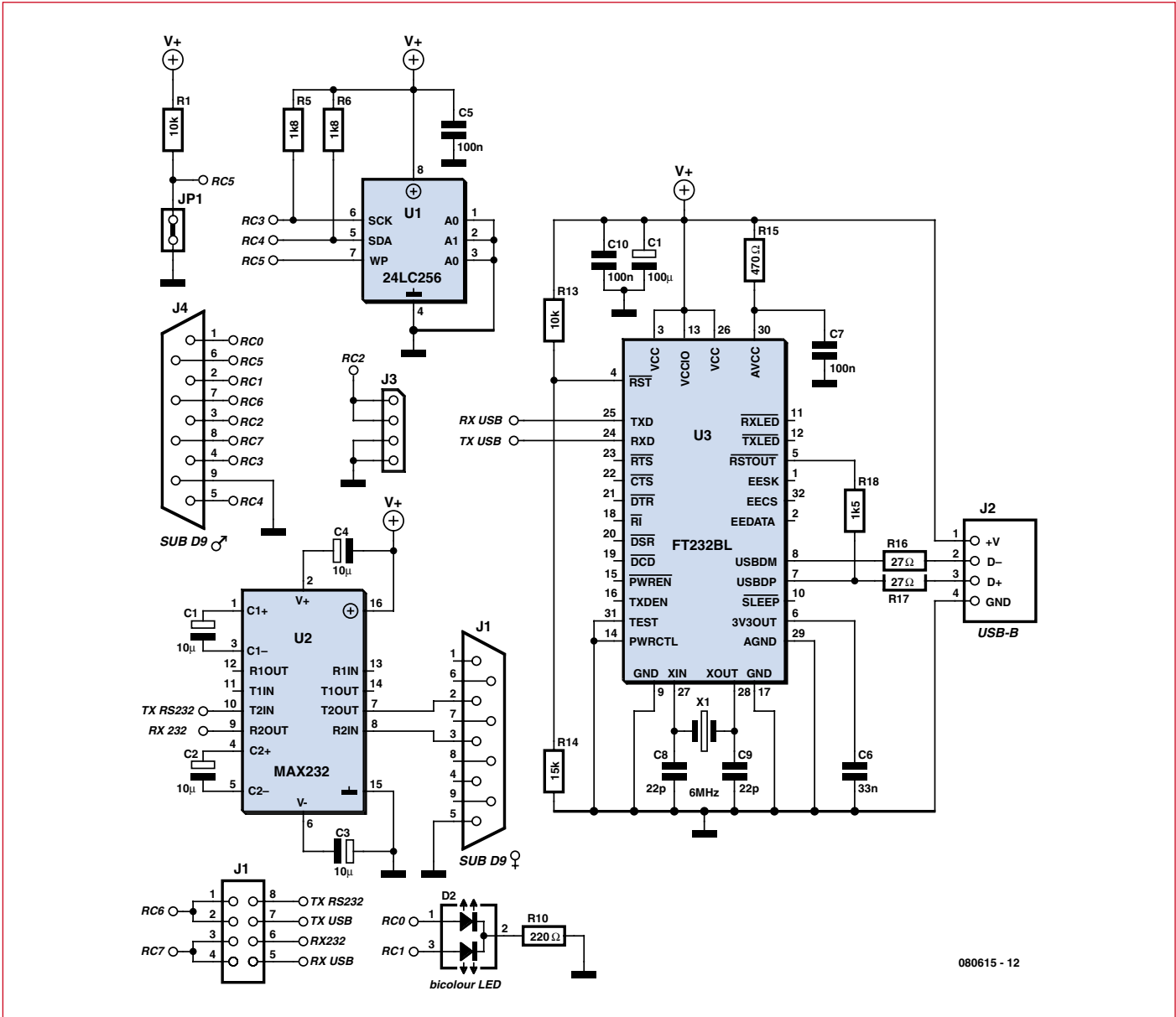


Figure 2. Circuit diagram of the home-made E-block. The serial data input is selected manually by the position of the jumpers on J1.

POI files

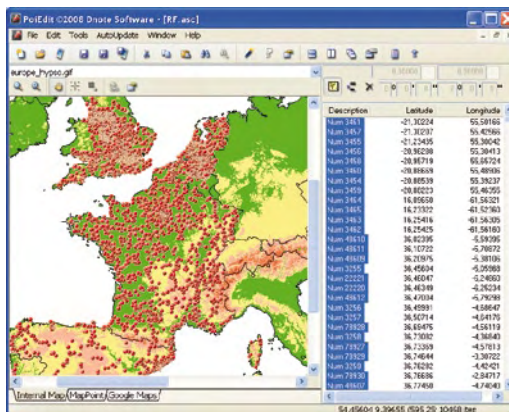
There are lots of different types of POI files, but the ones we're using contain nothing more than a list of geographical positions in ASCII, hence their .ASC extension. On one line of this list we find three comma-separated fields: longitude, latitude, and a name, often a number:

2.68111, 44.43686, "Num 40235"

The longitude and latitude are in decimal degrees.

The simplest way to obtain a POI file that can be used by our project is to pay a visit to the PoiEdit website [5]. PoiEdit is a shareware application that lets you display and edit the contents of a POI file.

This website also has lots of links to other sites where you can get hold



of POI files (for free). To display a POI file, all you have to do is load it into PoiEdit and pick 'Select All' in the 'Edit' menu. Don't forget to load, and if necessary calibrate, a map. Some maps are also available on the PoiEdit website.

To sort a POI file by longitude (if you're using the 080615-11_1 program), all you have to do is click on the Longitude bar and save the file in .ASC format.

The POI file thus created or downloaded can be directly read by the transfert.exe update program, as described elsewhere in this article.

I²C memory (**Figure 4**), looks after displaying the data, and drives the sounder and bi-colour LED. The second section is used for updating the I²C memory with the help of a computer. A switch determines which section of the program is run.

Primary loop

Out of the NMEA0183 frames provided by the GPS, we're going to use the RMC frame [4]. This frame contains all the information we need: latitude, longitude, time, date, and speed. After decoding an RMC frame, we then need to read the I²C memory. If we find a location corresponding to our current position – minus a certain margin, of course, otherwise it's too late! – that means we are near a POI. In this event, we leave our read loop and set off the alarms, i.e. the sounder sounds, the bi-colour LED light up red, and a message is displayed on the LCD warning of a POI close by.

Next time a GPS frame is received, we start again and decode, read the I²C memory, compare, etc.

Updating the database

The second section of the program is used for updating the database via a serial link. The transfer is initiated by the PC which sends the character 13h (19 in decimal) to the PIC, and the transfer starts once the PC receives the same character back. The PC then sends the file to the PIC, which acknowledges each character received by sending the character 13h. When 128 characters have been received, the PIC writes them into the I²C memory. To do this, we've used the I²C routine available in Flowcode, which makes it very easy to use the I²C bus. The transfer ends with a special character FFh, which is the signal for the PIC to display on the LCD the number of points stored in memory. This number is also stored in the PIC EEPROM, as we need it to be able to get out of our comparison loop correctly in the other section of the program.

For updating to be as fast as possible, it is done at 115,200 baud. But the component routine is already configured to 4,800 baud for dialogue with the GPS. We have got round this problem by inserting a little bit of assembler code into our program.

Another complication concerned the interrupt used to detect the reception of a character. The Flowcode library does not include this interrupt, so we had to create a user source for it.

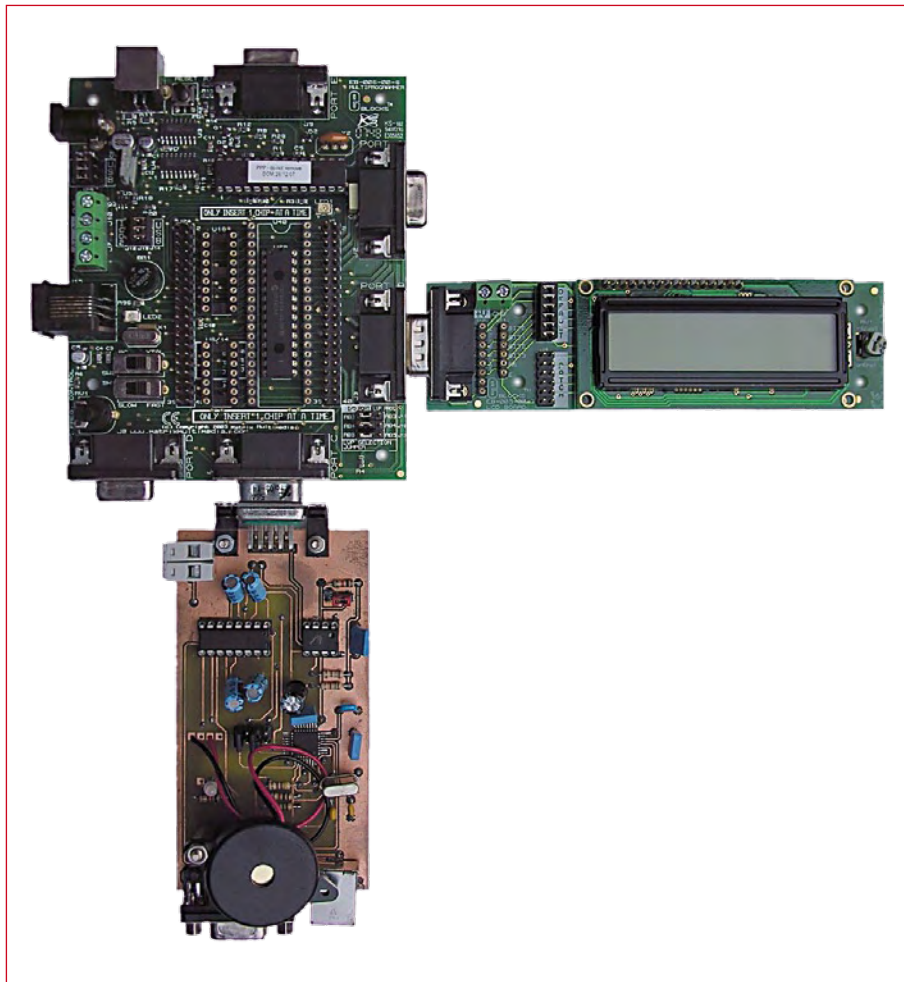


Figure 3. The speed camera warning device built using E-blocks. Our own E-block is the one with the sounder.

Automatic backlight

One option that deserves to be mentioned here is the automatic adjustment of the display backlight depending on the ambient light level. This was easily achieved using the PIC's ADC, which measures the voltage at the terminals of the light dependent resistor (LDR), and a PWM (pulse width modulation) output to control the backlighting via a transistor. The ADC and PWM are component routines included within Flowcode.

Simulation

Virtually the whole of the program can be simulated in the Flowcode environment, except for the reception of the characters during transfer of the file containing the POIs, where we have used some assembler code. Each component of the project can be simulated: the LCD, the PWM output, reading the I²C memory, GPS frame reception, and even the ADC for use with the LDR.

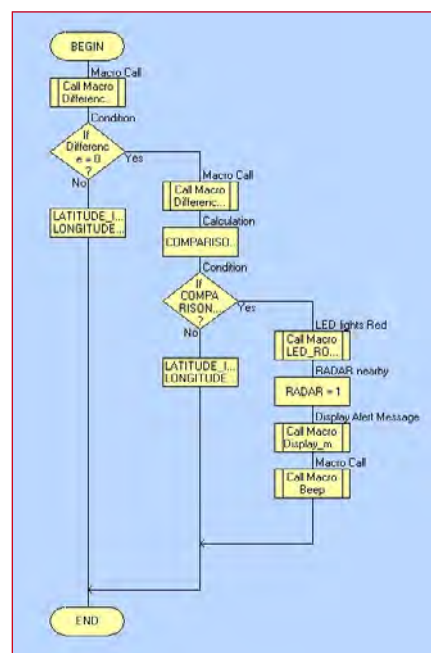


Figure 4. The full program is much too long to be shown complete. So we'll just give the most interesting part: the detection algorithm.

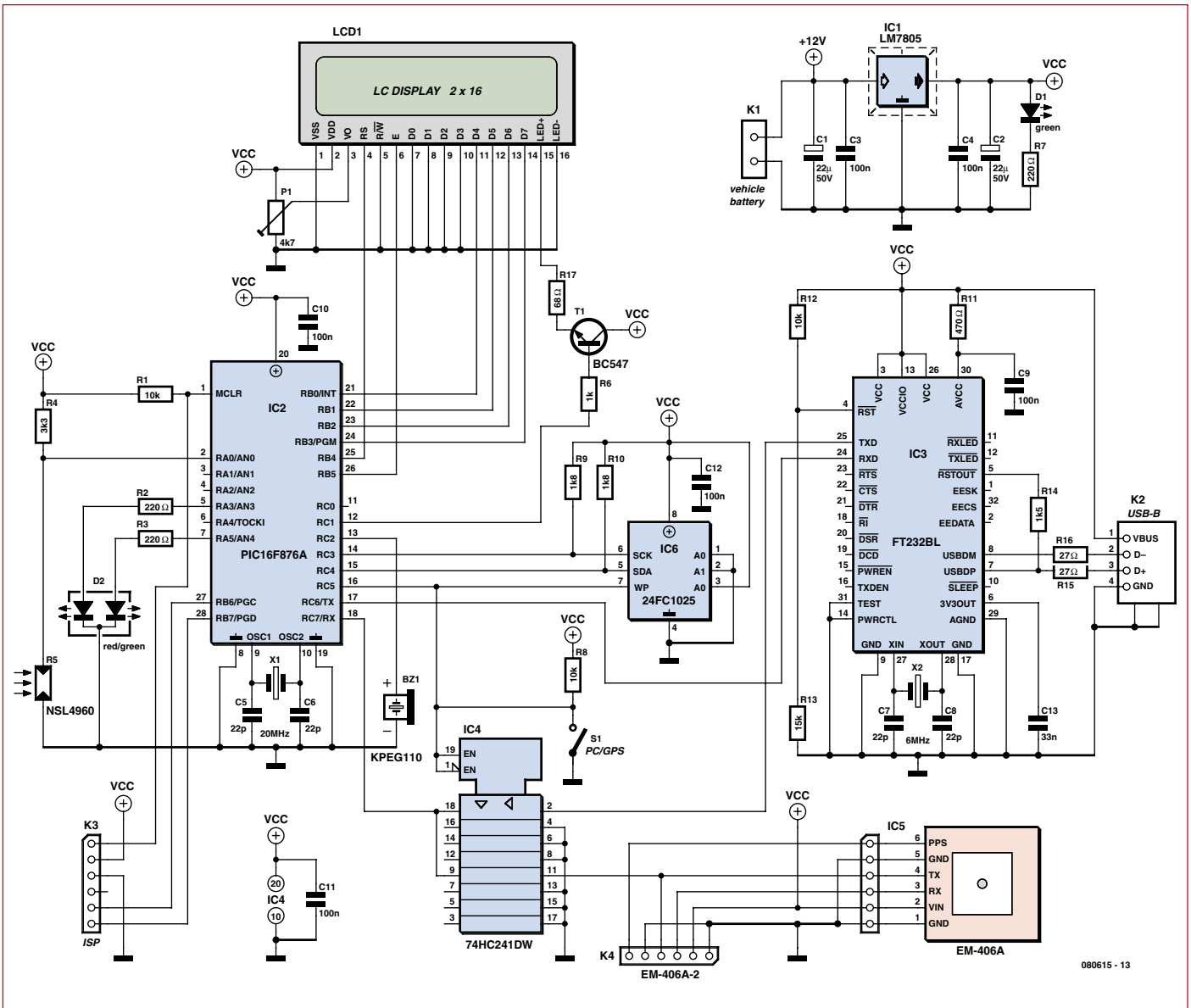


Figure 5. The full circuit diagram of the speed camera warning device.

To simulate decoding a GPS frame, we need to input a GPS frame to the RS-232 component module. We can then see the reading of the memory in the I²C routine, byte by byte. The values of the variables can be displayed (or changed), and simulation can be performed in step-through mode.

Circuit

Once our E-block prototype was operational, we redesigned the circuit without the actual E-blocks (**Figure 5**) – the EB006 E-block has been replaced by a 16F876A PIC (IC2) running at 20 MHz and the EB005 E-block by a standard alphanumeric LCD with backlight (LCD1) – the contrast can be

adjusted with potentiometer R17. We have eliminated the components that are no longer needed, like the MAX232, replaced the manual multiplexer by a 74HC241, and added photoresistor R5.

The PIC connects to the I²C EEPROM via its special I²C bus inputs SCL and SDA. The GPS receiver and the USB/RS-232 interface (IC3) are connected to the PIC USART by way of the multiplexer IC4. In normal mode, the multiplexer connects the PIC RX input to the GPS TX output to receive the GPS frames. In I²C memory update mode, the RX input is connected by the multiplexer to the TX output of the USB/RS-232 converter. The PIC TX output is directly connected to the RX input of the convertor IC3. Switch S1 lets you

choose between normal and update mode, and at the same time controls the EEPROM write protection at the same time.

The display is connected to PORT B of the PIC in 4-bit mode. Input AN0 of the ADC is connected to a potential divider made up of R4 and the photoresistor R5, which enables us to vary the display backlighting depending on the ambient light level. The backlight is adjusted by means of the signal on one of the PIC's two PWM outputs. The other output is used to drive the sounder. The bi-colour LED D2 uses another two outputs of PORT A, RA3 and RA5.

EEPROM chip IC6 contains the position of the POIs, each listed by latitude and longitude to 6 bits. For our

project, we've chosen the 24FC1025 from Microchip, a 1,024 kbit memory that allows us to store the position of 21,845 POIs.

The most expensive part in the whole project is the EM406-A GPS receiver module with built-in antenna from GlobalSat, already familiar to regular Elektor readers [4]. It interfaces directly to a microcontroller via its 'almost' TTL-level serial port.

The USB/RS-232 interface is taken care of by an FT232BL IC from FTDI (IC3). This forms the interface between the PIC and the PC and requires a driver to be installed on the PC in order to be used as a virtual COM port.

And lastly, the project is powered via a 7805 regulator.

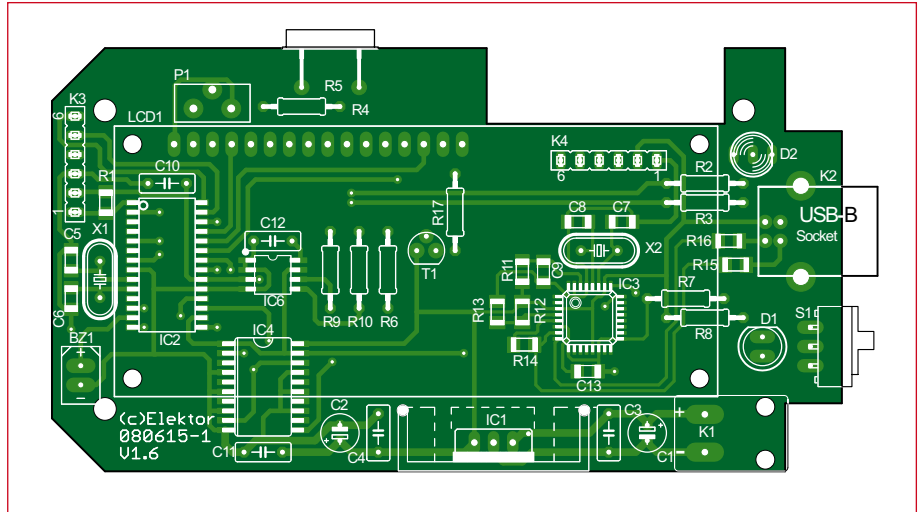


Figure 6. Board component layout.

Construction

It'll take you just a few hours to build this project. Refer to **Figure 6** for the board component layout. Note the use of a 'wire-wrap' socket to bring the display up to the height of the housing, and the same for the bi-colour LED.

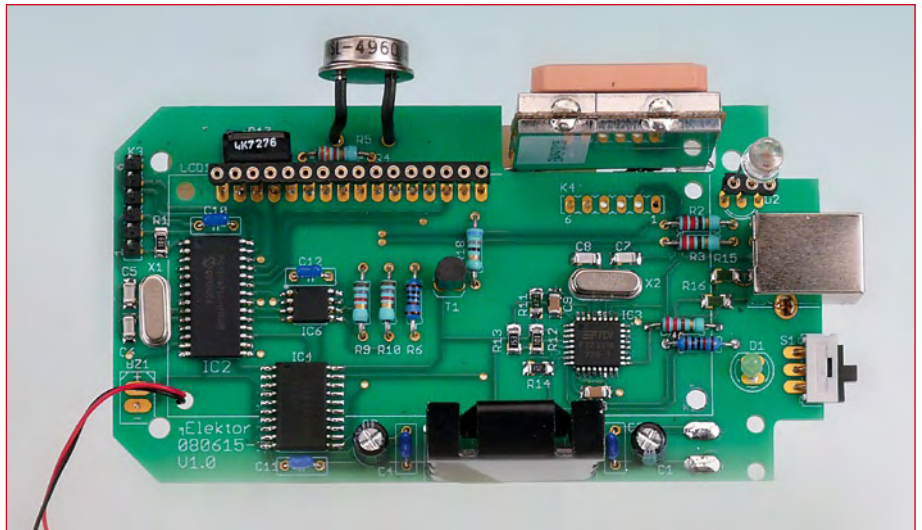
The first step is to solder the SMD components. The FT232BL IC is the trickiest, but with a very fine tip and a bit of patience, it can be done (you can use solder flux to help). The other SMD components ought not to present any real problem. Next, solder the discrete resistors, non-polarised capacitors, and then the electrolytic ones (observing the correct polarity carefully). After soldering all these components, check that the supply voltage is reaching the ICs on the appointed pins.

Two .HEX files are available for programming the PIC (see components list). The executable called 080615-11_2 can be used with downloaded POI files directly. The 080615-11_1 file requires a POI file sorted by increasing longitude, which speeds up the POI detection algorithm.

With the circuit powered and the PIC programmed, the green LED D1 lights and the display shows a start-up message (depending on the position of S1). If the display appears blank, adjust the contrast using R17.

First steps

The first time the circuit is powered up, the EEPROM has to be programmed with a POI database. Close S1 and connect the circuit to your computer's USB port. **Never connect the USB cable and the cigarette lighter plug at the same time!** Now's the



COMPONENTS LIST

Resistors

- (0.25W 5%)
- R1,R8,R12 = 10kΩ
- R2,R3,R7 = 220Ω
- R4 = 3kΩ
- R5 = NSL4960 (LDR)
- R6 = 1kΩ
- R9, R10 = 1kΩ
- R11 = 470Ω
- R13 = 15kΩ
- R14 = 1kΩ
- R15, R16 = 25Ω
- R17 = 4kΩ 7preset, vertical mounting
- R18 = 68Ω

Capacitors

- C5,C6,C7,C8 = 22pF
- C1,C2 = 22μF 50V
- C3,C4,C8-C12 = 100nF
- C13 = 33nF

Semiconductors

- D1 = LED, 3mm, green
- D2 = LED, 3mm, bi-colour
- T1 = BC547
- IC1 = 7805

- IC2 = PIC16F876A-I/SO, programmed, Elektor SHOP # **080615-41**
- IC3 = FT232BL
- IC4 = 74HC241DW
- IC5 = EM406A GPS receiver (Sparkfun, Lextronic)
- IC6 = 24FC1025

Miscellaneous

- X1 = 20MHz quartz crystal
- X2 = 6MHz quartz crystal
- LCD1 = LCD, general purpose, 2 lines, 16 characters, with backlight
- BZ1 = KPEG110 buzzer (Farnell)
- K1 = cigarette lighter plug
- K2 = USB-B socket
- K3,K4 = 6-way SIL socket strip
- S1 = switch, 1 pole, 2 positions
- Enclosure, Hammond type 1591XXCBK (Farnell)
- PCB, Elektor SHOP # **080615-1**
- Project software: free download from www.elektor.com/080615

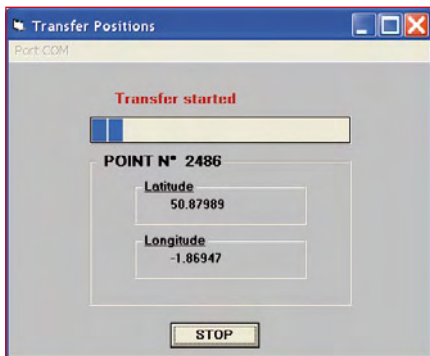


Figure 7. The database is updated using the Transfer.exe program.

moment to install the FTDI drivers, if needed. Then, in the Windows 'Device manager', set the speed of the virtual COM port to 115,200 bits/s and, under 'advanced' settings, change the latency to 1 ms, then click OK.

Now run the Transfer.exe program (Figure 7), available on the web page for this project. When the program starts, you need to select the serial port used by the FTDI IC driver (double-click on the port, the window should close). Click the 'Run' button, then select the file to be loaded into the EEPROM. Click 'Open' to start the transfer. You can follow its progress on the PC screen. At the end of the update, the circuit beeps and the display shows the number of POIs in memory.

You can now go over to GPS mode: open S1 and reset the circuit by briefly interrupting the power supply. As soon as a GPS frame

About the author

Gilles Le Maillot is an electronics design engineer in the **DTN** department at the **ENSIETA**. He is passionate about electronics and computers.

The **ENSIETA** (Higher National Engineering College) is a multi-disciplinary engineering college based in Brest, France. It trains mechanical, electrical, and IT engineers for all sectors of industry (automotive, naval, aeronautics, and so on). The **ENSIETA** runs numerous research and development programs within its four laboratories (**DTN, E3I2, MSN, SHI**).

is received, the bi-colour LED will flash green and the display will show the position, alternating with the time and speed. It may take a while to receive the first frame from the GPS; the EM406 module has a red LED that flashes each time the GPS receives a frame. And there you have your POI warning device finished — safe journey, and above all, remember to obey the speed limits!

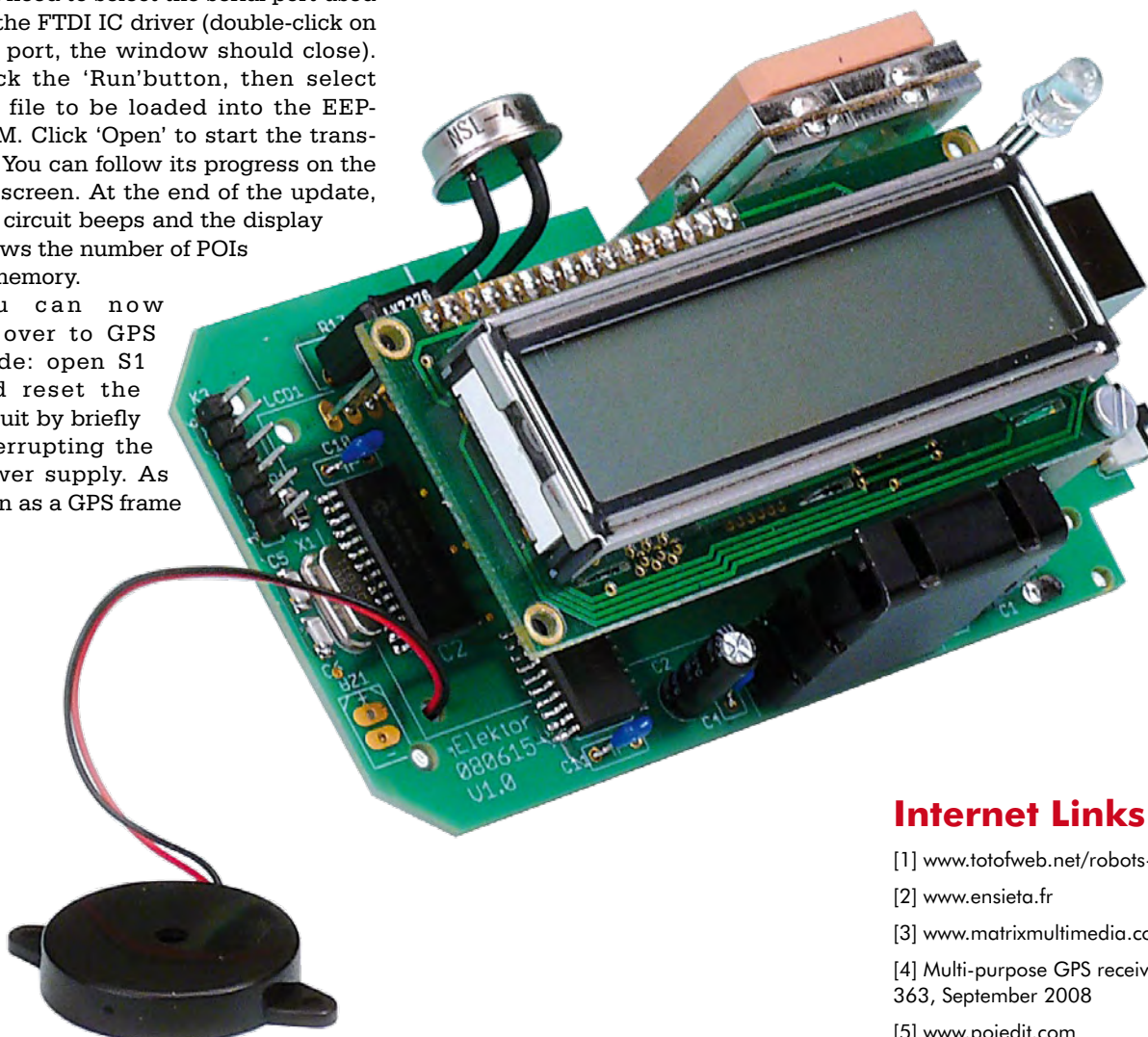
(080615-1)

Acknowledgements

Dominique Kerjean: design engineer at ENSIETA.

Pierre Cambon: research lecturer at ENSIETA.

André Mininno: design engineer with Multipower.



Internet Links

- [1] www.totofweb.net/robots-projet-53.html
- [2] www.ensieta.fr
- [3] www.matrixmultimedia.com
- [4] Multi-purpose GPS receiver, p.34, Elektor 363, September 2008
- [5] www.poiedit.com

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Remote Control by Mobile Phone

Receive back: confirmation and GPS position data



Florian Schäffer (Germany)

Remote control using mobile phones and SMS (Text Messaging) is in great demand but many systems on sale suffer from imperfections. The ingenious new design combines powerful capabilities with low technical overheads. It has programmable AC mains switching outlets plus status reports by text message and alarm-activated delivery of GPS data.

Mobile phone (GSM/Cellphone) controlled switching devices have been around for a while now, without earn-

ing a reputation for reliability or affordability. The project featured here corrects this impression, making use of

readily available mobile phones for the GSM receiver and data output function (at no cost at all if you use

discarded handsets). Its many capabilities are listed opposite in the inset under the headings **Characteristics** and **Applications**.

Principles

The criterion for activating and controlling this remote switch is the number of incoming calls (not the number of individual ringing sounds heard!) received within 90 seconds. One call within this 90-second time window switches Output 1, two calls enable Output 2, three calls operate Output 3, whilst four calls trigger a status alert by SMS text.

Since nobody actually answers the calls, there are no telephone charges for receiving these control commands. The only costs are for sending the status alert text messages, which are charged according to the tariff relating to the SIM card of the mobile used.

Characteristics

- Worldwide remote control from a mobile phone (GSM/Cellphone) without incurring call charges
- Three switched outputs with on-off switching, changeover switching and timed switching, max. 230 VAC, 6 A
- GPS data transfer indicates location (GPS tracker function)
- Status-SMS reports indicate state of device outputs plus optionally GPS coordinates
- Alarm function by SMS Text alert in case of alarm (optionally with GPS coordinates)
- Filtering of unauthorised callers prevents false operation

Sample applications

- Control of engine-independent air heating system in cars
- Activation of garden watering systems
- Remote control of domestic apparatus (lighting, roller blinds, etc.)
- Heating control in holiday cottage
- Opening garage doors and driveway gates
- Building protection (break-in surveillance)
- Locating stolen objects of value (cars, boats, etc.)
- Tracking (following route taken by vehicle)

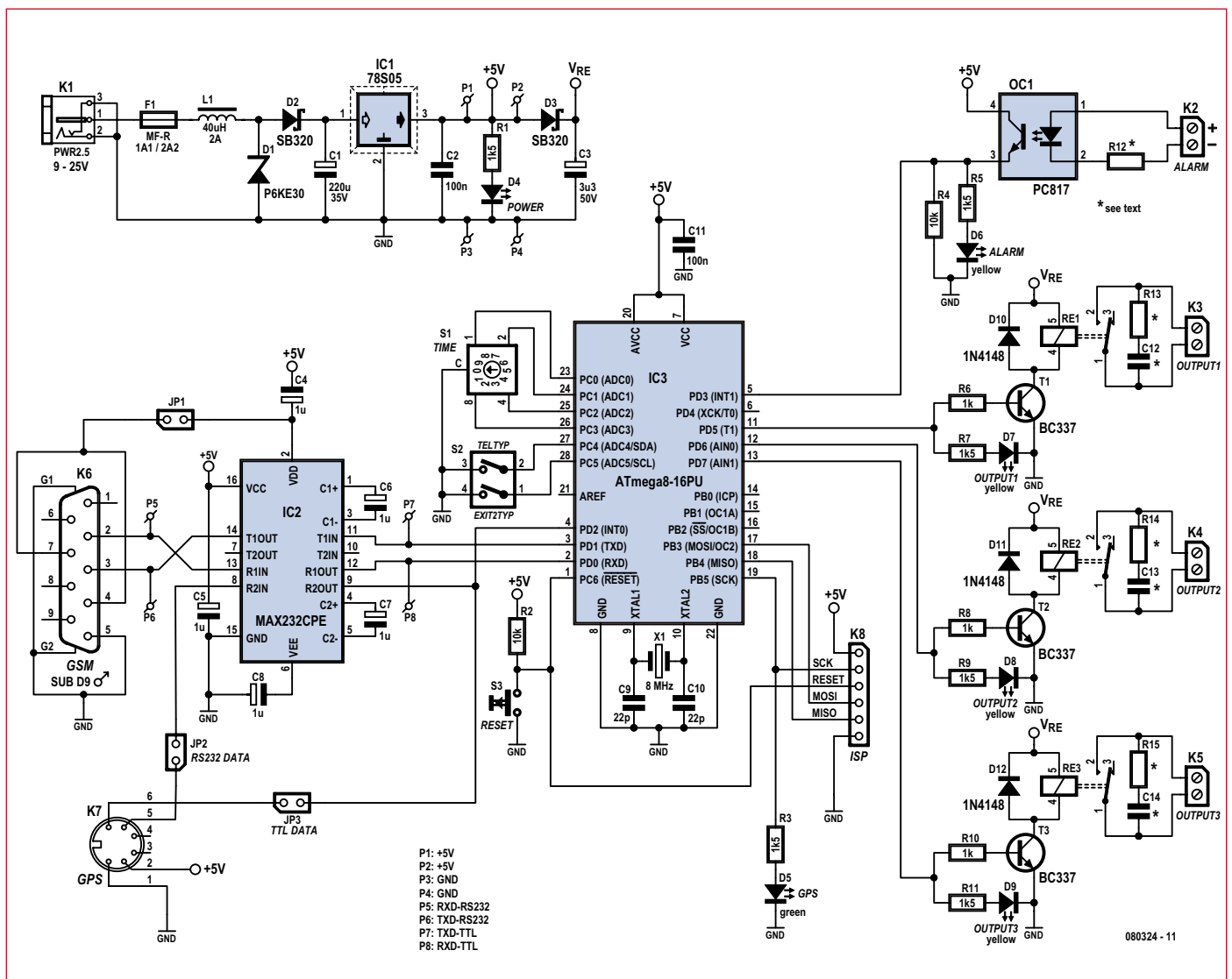


Figure 1. The circuit diagram is remarkably simple since most functions are handled by software in the ATmega8.

If this technique has any shortcoming, then it is the time involved; between the first call and switching an output or sending an SMS alert a delay of between 90 and 180 seconds can occur.

Call recognition

To avoid possible operation caused by ‘false’ calls (wrong numbers, unwanted sales calls, etc.) we use two different operating modes for evaluating calls received (indicated as ‘TelTyp’ in the software). The choice of Teltyp mode is set using the switch S2-2, seen on circuit diagram **Figure 1** next to pin 27 (PC4) of the ATmega8, as follows:

1. TelTyp = On (S2-2 closed)

The calling mobile must have caller ID enabled (in other words the call must not come up as ‘Number Withheld’). The remote switch reacts only to calls from mobiles whose numbers are stored on the SIM card of the mobile associated with the remote switch. Calls from unrecognised numbers are ignored. The SMS status alert is sent back to the number that called.

2. TelTyp = Off (S2-2 open)

Every call received in the 90-second time window is counted. For extra security, however, the device must be called one time more often than when TelTyp=On for the same function. This is because it’s unlikely that an invalid caller would ring more than once within 90 seconds. So to switch Output 1 two calls are required (and so on). The SMS status alert is sent to the first number appearing in the phone book on the SIM card of the mobile attached to the remote switch device.

Control functions

As already mentioned the switched outputs (**Outputs 1-3** on the schematic in **Figure 1**) are controlled by the number of telephone calls received. The switching functions for the three outputs are not the same, however:

1 call: Output1 is on each occasion switched only briefly (relay RE1 operates for just one second).

2 calls: Output2 can be controlled in one of two different ways, depending on how switch S2-1 on Pin 28/PC5 of the ATmega8 is set. If the switch denoted in the software as ‘Exit2Typ’ is closed (**Exit2Typ = On**), the output

Table 1. Typical Status-SMS with a GPS module connected	
Status: TelTyp:1 Exit2Typ:0 Time:15mn Exit1:0 Exit2:1 Exit3:1 *GPS OK* 15:50:23 N52°58.0674 E012°48.3217	
Message	Meaning
TelTyp:1	Switch TelTyp is On
Exit2Typ:0	Switch Output2Typ is Off
Time:15mn	On Output 3 a switching time of 15 minutes has been set
Exit1:0	Output 1 is enabled
Exit2:1	Output 2 is enabled
Exit3:1	Output 3 is enabled
GPS OK	GPS reception is operational. Data valid (“*GPS INVALID*” if reception is disturbed)
15:50:23	UTC time
N52°58.0674	GPS coordinates: 52° 58.0674’ Northerly latitude (“52 Degrees 58,0674 Minutes”)
E012°48.3217	GPS coordinates: 12° 48.3217’ Easterly longitude

toggles or changes state on each activation. If switch S2-1 is open (**Exit2Typ = Off**) then Exit2 behaves like Output1 (RE2 then operates for one second).

3 calls: Output3 is switched on and then off for the period set by the rotary switch (S1). The following on periods can be selected: 1, 5, 10, 15, 20, 30, 45, 60, 90 and 120 minutes.

4 calls: SMS status alert is generated and sent.

Status and alarm reports

The status alert message provides information about the switching state of Output1, 2 and 3 and the setting of S2-1 and S2-2 (Exit2Typ and TelTyp). Optionally the report can include information about GPS coordinates. The setting of TelTyp also determines to whom the text message is sent (see paragraph above on call recognition). Connection of a GPS receiver module is entirely optional. If you decide to do this, the data sent from the GPS-module is examined and if reception is good enough to decode the geographical coordinates, these are included in the text message. If the status of the GPS module means the coordinates are inexact but available, then these are sent in the text along with details on the quality of the coordinates. There are various ways of converting the GPS coordinates (see penultimate Web link at end of article) or else you can enter them direct into Google Maps to find their position on the map (for example, N51 00.9892 E005 50.3189 gives the location of Elektor House).

A typical status text including GPS data is shown and explained in **Table 1**.

Sending an SMS text can also be triggered via the alarm input at K2 in **Figure 1**. This input is protected by an optoisolator and reacts to changes in signal. Every change in signal level during operation sets of an alarm. In this situation an alarm alert is sent by SMS to the first phonebook entry on the SIM card of the mobile connected to the remote switch. The text notifies the alarm and if a GPS module is connected, the location coordinates as well.

Circuit and printed circuit board

The schematic (**Figure 1**) is extremely straightforward since most functions are handled in software within the ATmega8. All the same the PCB itself (**Figure 2**) is not exactly compact, partly because we have not used surface-mounted devices (SMDs) and also because the AC mains (110 V/230 V) section of the circuitry needs adequate room for the relatively large relay and interference-suppression components.

Switches S1 and S2 have already been described. The reset switch S3 plays a relatively crucial role here; as far as the microcontroller is concerned, the settings of switches S1 and S2 become valid only following the reset operation or applying power. **Every change to the settings of S1 and S2 requires a fresh reset to take effect!** LED D5 indicates reception of GPS data (if a GPS module is connected to

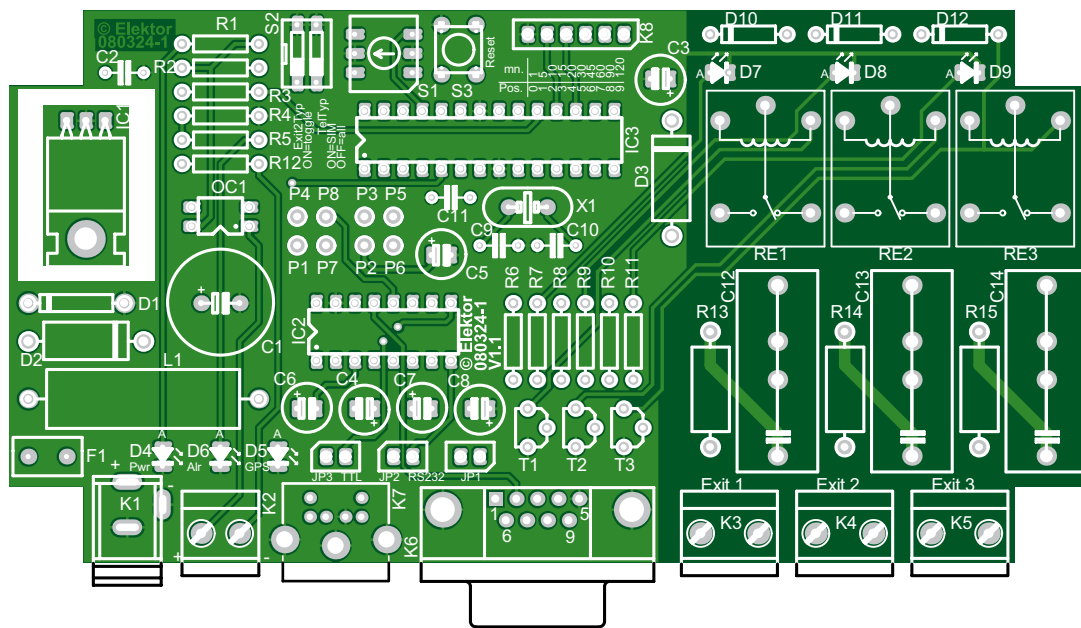


Figure 2. The printed circuit board manages without SMDs. Almost half the surface area is taken up by the mains-voltage section with the relatively large relay and interference suppression components.

Mini-DIN connector K7): flashing light denotes poor reception (inadequate signal or interference) but continuous illumination signals valid coordinates. After switching-on or reset the LED flashes rapidly for about two seconds to indicate that the mobile be connected is making a connection (which can take up to 30 seconds or so). If the LED remains unlit, the mobile is not responding and the remote switch is not working properly. Sub-D connector K6 is provided for

making a serial connection to the mobile, and since we are dealing with RS-232 signals, the level changer MAX232 (IC2) must not be omitted. Test points are provided for the signals and operating voltages around the serial interface in the form of solder pins P1 to P8. The programming interface (ISP interface) for the microcontroller is taken out to connector pins K8, although this will be needed only if you choose to load different firmware into the microcontroller.

The power supply for the circuitry can be fed either to connector K1 or from an external mains plug-in PSU (what our American friends call a wall wart) or else you can use the on-board battery supply of the car, boat, caravan, etc. Any mains PSU will do (an unregulated one is fine) so long as it delivers at least 9 V. Make sure there is sufficient power for other devices connected (mobile and GPS); this means you must have at least 1 A available. Voltage regulation is handled by the

COMPONENTS LIST

Resistors

R1, R3, R5, R7, R9, R11 = 1kΩ
R2, R4 = 10kΩ
R6, R8, R10 = 1kΩ
R12 = see text
R13, R14, R15 = 1Ω/volt, 2W (see text)

Capacitors

C1 = 220μF 35V
C2, C11 = 100nF
C3 = 3μF 50V
C4, C5, C6, C7, C8 = 1μF 16V
C9, C10 = 22pF
C12, C13, C14 = 0.1μF/ampère (see text)

Semiconductors

D1 = P6KE30A, TVS (30V / 600W)
D2, D3 = SB320 or 1N5820 (Schottky; 3A / 20V)
D4 = LED, red, low current, 3mm
D5 = LED, green, low current, 3mm
D6-D9 = LED, yellow, low current, 3mm
D10, D11, D12 = 1N4148

T1, T2, T3 = BC337 (TO92 case)
IC1 = L78S05CV (TO220 case)
IC2 = MAX232CPE+ (DIP16 case)
IC3 = ATMEGA8-16PU, DIP28 case, programmed, Elektor SHOP # **080324-41**
OC1 = PC817X2J000F, optocoupler, DIP4 case

Inductor

L1 = 40μH 2A (e.g. EPCOS)

Miscellaneous

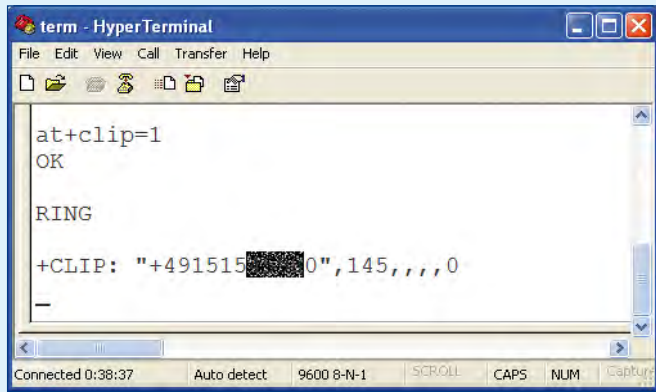
X1 = 8-MHz quartz crystal (HC49 case)
RE1, RE2, RE3 = HRS4E-S (DC 5V)
K1 = DC adapter socket, PCB mounting
K2 = 2-way PCB screw terminal block, lead pitch 5mm
K3-K5 = 2-way pinheader, lead pitch 2.54mm
K6 = 9-way sub-D plug (male), PCB mount
K7 = 6-way mini-DIN socket, PCB mount
K8 = 6-way SIL pinheader, lead pitch 2.54mm
JP1, JP2, JP3 = 2-way SIL pinheader, lead pitch 2.54mm

S1 = MCRH2AF-10R 10-way DIP rotary encoder
S2 = MCDS02 2-way DIL switch
S3 = F5M4JH single-pole pushbutton, PCB mount
F1 = auto-resetting PTC fuse, 30V, sustain current 1.1A, activation current 2.2A, e.g. Multifuse MF-R110-0-99 (Bourns) or Polyfuse 30R110 (Littlefuse) or Polyswitch RUEF110 (Tyco), ES-LP30-110 (ESKA) = PFRA 110 (Reichelt.de)
P1-P8 = 1mm dia. solder pin
IC sockets for IC2 (DIL16), IC3 (DIL28), OC1 (DIL6 used as DIL4)
Heatsink for IC1 (U profile, 25x15x20 mm, 17K/W, slotted hole)
M3 screw, 10 mm, with nut (for securing heatsink)
Blue transparent enclosure, 150x80x50 mm (LxWxH), e.g. Conrad Electronics # 522498
PCB, Elektor Shop # **080324-1** or kit incl. PCB, # **080324-71**

Firmware for hardware

The software for the GSM remote-controlled switch was written in C, for which the free development environment WinAVR (release 20060125) was used (this includes AVR-GCC, a version specially optimised for Atmel-AVRs). The main task of the processor is to communicate using a serial interface with the modem in the mobile handset connected. Basic functions such as recognising incoming calls, managing the address book, etc. make use of a Hayes-compatible command set composed of AT commands that were formerly used widely in PC modems. After connecting your mobile phone to the PC using a serial data cable, controlling the mobile requires only a simple terminal program — something that later on the microcontroller can take care of.

Individual models of mobile phone may be programmed to recognise additional commands outside the standard set. However, these are deliberately not included here, as they are not usable with the majority of handsets. While we were developing this project we became aware that telephone manufacturers do not always stick to the rules laid down. An example is the format in which a caller's telephone number is displayed (CLIP): the Siemens C55 presents the data in inverted commas.



Activating the telephone number display by terminal program and signalling a call

Understandably it's impossible to look into every possible detail but during the development process we did manage to verify the software against several different models of phone.

Another consideration arises if a GPS module is to be connected: current AVRs provide only a USART, making it necessary to control an additional serial interface in software. In this case it's advantageous that the GPS module transmits only data and also at a slow rate of 4,800 baud. As the data from the GPS module is repeated continuously there is no need to buffer the characters received. It suffices to simply wait until the required data set occurs, as and when it is required. In this way the code for data reception is much simplified.

Sending an SMS text

A fair amount of effort is involved in sending a text message by mobile telephone. Before the message can be passed to the mobile for transmission it needs to be coded with the destination telephone

number and various other details as a PDU (Protocol Data Unit). It's true that a few models of mobile can also accept the information in plain text format but these are few and far between and their number is dwindling. Once you have got to grips with PDUs, you can then send SMS texts with every type of mobile without further restrictions.

To demonstrate how a PDU is formed we shall send the classic message "Hello World" to the German telephone number +441231234567890. The telephone number is given in international notation like this: +<country code><area code without leading zero><destination number>. For normal text messages (maximum 160 characters) only 7-bit ASCII characters can be used. You can find details of the character set in the official publication GSM 03.38, which describes how a PDU is made up. It is assumed that the number of the messaging centre for texts is already programmed into the mobile. This is the case if you currently can enter texts into your mobile and send them without any other formalities. We will now use our terminal program and enter two lines in order to send our SMS text message:

```
AT+CMGW=26
```

```
0011000F9194211332547698F00000AA0BC8329BFD065DDF723619
```

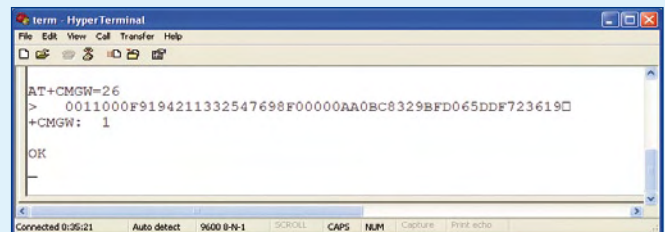
PDU for an SMS message

The first line is completed by pressing Return (CR+LF). The telephone now responds with the symbol ">" to indicate that it is standing by. You can now send the second line, which is ended with the control code Ctrl-Z. The telephone then confirms receipt and tells you the automatically generated reference number of the message if correctly transmitted. This number would enable you to search the telephone's memory for the notification, although generally this is not of any interest.

Note that with this control sequence the mobile does not actually transmit the text message but merely stores it. This is an advantage during the test phase, since the order of events is fundamentally identical to actually transmitting, **except** that there is no cost involved and you can read and check the messages on the mobile's display. Only when you replace the AT command CMGW with CMGS is the message sent to the phone immediately upon data entry.

Creating a PDU message

The digit following an AT command indicates the total number of bytes in the line following. Here the first byte is always 00 if no text



exchange (SMSC: Short Message Service Centre) is indicated (and is then not counted). The 26 bytes following afterwards are arranged as follows:

5-V regulator IC1, which can take care of higher surges from external battery supplies. Fuse F1 protects the circuitry, assisted by suppressor coil L1, protection diode D1 and the two Schottky diodes D2 and D3. F1 is a self-healing PTC fuse that resets itself on power-down or when the fault is cleared (manufacturer names: Multifuse, Poly-

fuse, Polyswitch etc.). D1 is a transient voltage suppressor diode (TVS). The model used (PK6E30) behaves like a 30-V zener diode and has the ability to react extremely rapidly to high-voltage peaks of short duration. The two Schottky diodes prevent the flow of reverse currents either side of the voltage regulator. The 5 V oper-

ating voltage VRE 'decoupled' by D3 supplies the three relay stages. If you don't require all three outputs, the corresponding components can simply be omitted from the PCB. The outputs function like a switch. When the relay contacts are closed, the two terminal connections are linked straight through and make a circuit for the connected

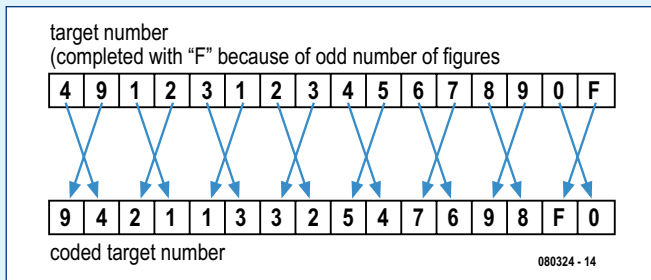
Byte (Hex) Meaning

11	Message Flags; contains details of how the message is coded and how the telephone should react.
00	Reference number. Upon 00 the telephone naturally appoints a number for referencing the message and to be able to respond to this particular number.
0F	Number of digits in the target telephone number. "491231234567890" consists of 15 (0Fh) digits.
91	Telephone number, arranged in international notation.
94 21 13 32 54 76 98 F0	coded telephone number.
00	Protocol Identifier; always 00
00	Data Coding Scheme; always 00
AA	Expiry time; message is valid for four days
0B	Number of septets (not bytes) following with the actual message text. The number corresponds to the total text characters of the SMS text message. "Hello World" consists of 11 (0Bh) characters.
C8 32 9B FD 06 5D DF 72 36 19	Method of writing the bytes of a message coded in septets.

Particular attention must be paid to the coding of the telephone number and the actual text message. The telephone number is coded relatively simply: first check whether the number of digits is even. If not, an "F" is appended to the end of the digit sequence. Following this every two pairs of digits are switched with one another.

See also <http://www.gsm-modem.de/sms-pdu-mode.html> and <http://www.developershome.com/sms/operatingMode.asp>

Coding a text message involves more effort. In contrast to normal practice elsewhere only seven (instead of eight) bits are used per character. The seven bits used for each character are known as a septet. However, the telephone always expects a byte (8 bits) to be



sent. To achieve this, the eighth bit (HSB) of the first byte is filled with the LSB of the following byte. In the second byte there are now two bits free, which are filled with bits from the third byte. This process of transformation is carried out in a number of steps. These are tedious but simple to understand, like this:

1. First we convert individual symbols into their ASCII hex values.
2. These hex values are then transformed into binary digits, in which the HSB is always 0 and omitted (since only the first 127 charac-

ters of the ASCII set are used).

3. The bits of the binary number are then mirrored, i.e. arranged in reverse order.

Symbol	Hex	Binary (7 Bits)	mirrored
H	48	100 1000	00 01001
e	65	110 0101	10 10011
l	6C	110 1100	00 11011
l	6C	110 1100	00 11011
o	6F	110 1111	11 11011
	20	010 0000	00 00010
W	57	101 0111	11 10101
o	6F	110 1111	11 11011
r	72	111 0010	01 00111
l	6C	110 1100	00 11011
d	64	110 0100	00 10011

4. The mirrored bits are written one after another as a bit sequence:
00010011010011001101100110111111011000010111010
11111011010011100110110010011
5. Onto this chain are added, on the right, as many zeros as necessary to make up the total number of bits that can be divided by 8 without any remainder. For the sample text three filler bits are required:
00010011010011001101100110111111011000010111010
11111011010011100110110010011000
6. The bit sequence is divided into bytes of 8 bits each.
7. Now each byte is mirrored again.
8. Each byte is represented in the hexadecimal system and when written in sequence produces the coded information C8329BFD065DDF723619.

Binary (8 bits)	mirrored	Hex
0001 0011	1100 1000	C8
0100 1100	0011 0010	32
1101 1001	1001 1011	9B
1011 1111	1111 1101	FD
0110 0000	0000 0110	06
1011 1010	0101 1101	5D
1111 1011	1101 1111	DF
0100 1110	0111 0010	72
0110 1100	0011 0110	36
1001 1000	0001 1001	19

DC or AC load. As shown in the component list, the values of the capacitors and resistors used in the R-C networks that protect the relay contacts from arcing must be matched to the voltage and current flowing through the contacts:
For capacitors C12 to C14 you should allow around 0.1 μF per amp of load

current. For example 2 A would require 200 nF. The capacitor should be rated for the maximum voltage to be applied. Mains voltage of 230 VAC would need a capacitor rated at around 630 V DC. If the contacts are to pass 230 V at 2 A we would choose an MKS-4-630 type of 220 nF value, for example. Several solder points are provided for each

capacitor on the printed circuit board, to enable you to use different form factors of capacitors.
For resistors R13 to R15 the best ones to use are 2-watt metal film types with a value of about 1 Ω per V of load voltage. For 230 V we would calculate 230 Ω and actually use 220 Ω/2 W). The alarm input on K2 is isolated elec-

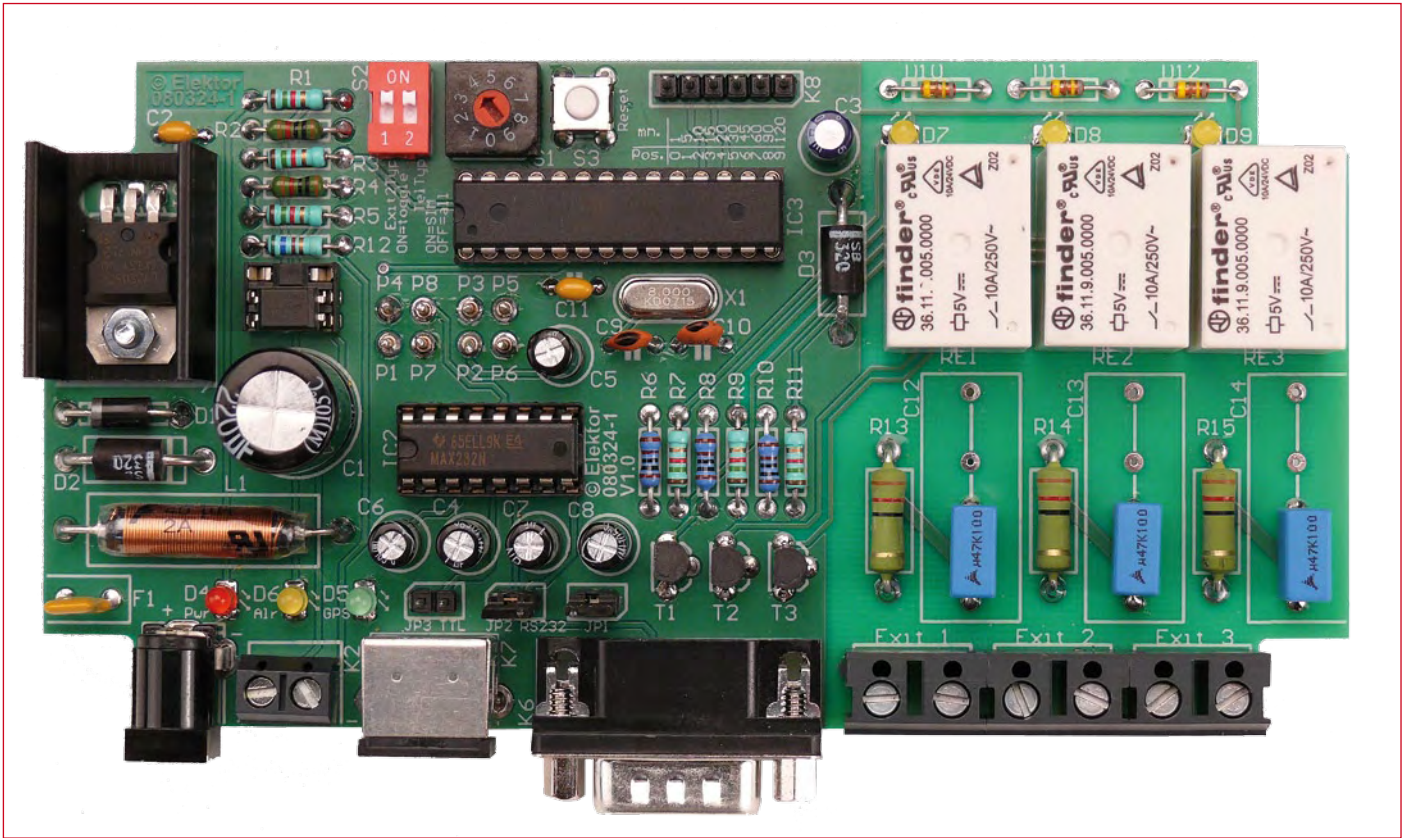


Figure 3. Sample PCB with components inserted, viewed from above.

trically from the alarm circuitry by optocoupler OC1. As the LED inside the optocoupler cannot be seen, we have provided LED D6 to display the logic level on the output of the optocoupler. An alarm is always triggered by a change in logic level. If LED D6 lights after a reset (= quiescent state), the alarm is given until it goes out (and vice versa). The alarm input must be

switched in such a way that a current of around 20 mA flows through the LED in the optocoupler (in either alarm or quiescent state). You need to watch the polarity of the voltage too, since the internal LED of the optocoupler can be damaged otherwise. The LED in OC1 drops around 1.2 V, meaning that resistor R12 is calculated as follows:

$$(U_{K2} - 1.2 V) / 20 \text{ mA}$$

So, if the voltage at K2 is 12 V for example, you need a value for R12 of $10.8 \text{ V} / 20 \text{ mA} = 540 \Omega$ (in fact you would use 560Ω).

When inserting components into the PCB (Figure 2) there are only two details to note. The EPCOS inductor (L1) used on our sample board does not allow the connection leads to be made too close to the end caps of the coil and a minimum distance of 3 mm is indicated. The second detail is the socket for the optocoupler, which is produced as a 4-pin DIL chip. Because 4-hole sockets are not available everywhere, we have used a 6-hole socket. You can see in the photo (Figure 3) how the IC is placed in this socket. Of course you can solder the chip direct into the PCB if you prefer, without using a socket.

Mobiles, Cellphones

The mobile connected to the PCB requires an RS-232 interface. Permissible data rates are 4.8, 9.6, 19.2, 38.4 and

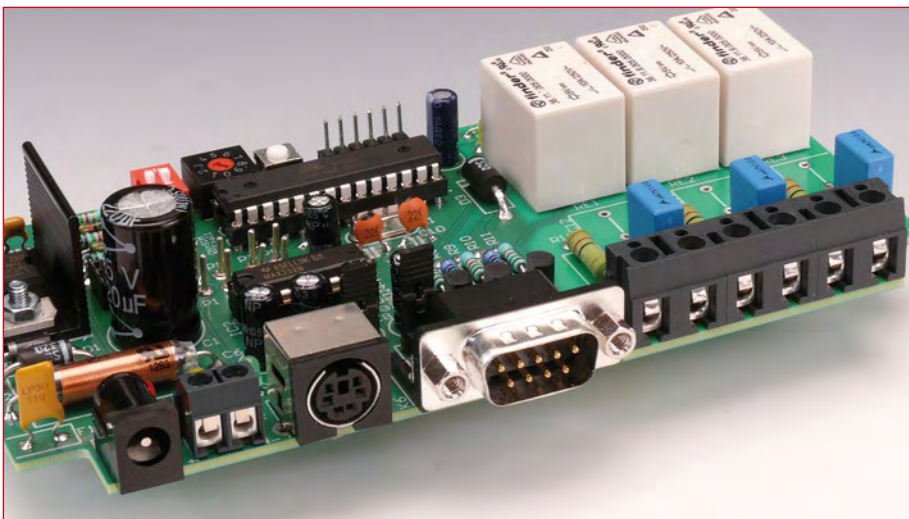


Figure 4. The connections for mobile handset, GPS module and plug-in mains unit are on the forward side of the PCB.

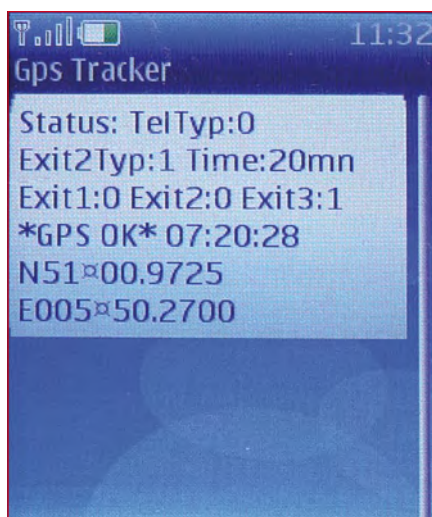


Figure 5. Status acknowledgement by text message looks like this on the mobile's display.

57.6 kilobaud. For the data format of SMS Text messages you require some understanding of the PDU language, which is used on most mobile phones. We tested the circuit with the widely available Siemens models C55 (+ data cable) and S35. Some other models might not work with our remote switch, as inevitably some minor variants occur in control systems.

The mobile needs to be equipped with a SIM card, switched on and subscribed to a network. Ringtones are best dispensed with and the keypad lock activated. It is important to store the telephone numbers used to initiate the switch operation and send a text not in the mobile's memory but on the SIM card itself. These telephone numbers must be entered in the international notation (not in any other format), as shown in the inset on how to create an SMS text message. Furthermore, the telephone numbers must occupy the memory slots on the SIM card in ascending order without any gaps. The first authorised telephone number (to which alarm and status alerts may also be sent as required) is entered in memory slot 1, the next number then in slot 2 and so on. This sequence is not the same as how the numbers are indicated in the mobile's phonebook list (probably sorted in ascending numerical order). The memory slots can be checked and amended either as they are being entered or else subsequently — please check in the mobile's instruction book for details. The mobile is connected using the RS-232 protocol. Older models of

phone generally have this interface, although they do need a suitable data cable for linking the system connector on the mobile to the sub-D9 connector K6 on the remote switch board. If the data cable requires a supply of volts, this can normally be taken from the sub-D connector ('vampire feed') with around 9.5 V on pins 4 and 7 (this will require bridging JP1). Take time to check the connections of the data cable against **Figure 1** to ensure it is correct for you.

In some cases using this vampire feed for the data cable will overload the MAX232, with the mobile unable to 'talk' to the remote switch. You can confirm this by applying a reset to pin 14 of IC2; if the signal level does not reach around ± 10 V but hovers around ± 5 V you have problems. Another indication is if the voltage on pin 2 of IC2 measures less than about 9.5 V. If this is the case you will have to supply volts into the data cable in some other manner. It may also help if you use 10- μ F electrolytics for capacitors C4 to C8. Plenty of solutions can be found on the Web and you may end up making your own data cable.

GPS connection

Including a GPS module is necessary only if you actually require GPS data in the alarm or status alerts (as in **Figures 5 and 6**). The module must provide data in NMEA format at 4,800 baud. The data can be handled at either TTL or RS-232 level (around ± 12 V). Only the data output (TxD) of the module is used. All these requirements are met on most modules. The set-up was tested by the author with a GPS-41MLR module and then in the Elektor labs with a Navilock 303P, with jumper JP2 set for RS-232 level. The GPS module can be connected using the standard Mini-DIN connector on the Navilock to K7 on the switch or else soldered direct onto the PCB. The necessary power supply of 5 V (check the data sheet of your GPS module to see if it uses 5 V too) can be taken from the PCB, for example on solder pins P1 or P2 (ground on pins P3 and P4).

If a module using TTL level is connected to K7 then jumper JP3 must be set (under no circumstances can both JP2 and JP3 be set at the same time!). If connecting TxD from the module direct to the PCB, either TTL or RS-232 level can be fed in (but never

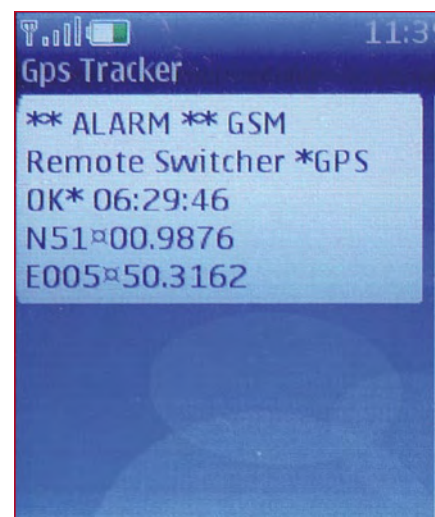


Figure 6. This shows an SMS alarm report being received, with GPS data included.

both simultaneously). The direct connection passes through JP2 (for RS-232 operation) or JP3 (for TTL level), and onwards either JP2 to pin 8 of IC2 (designated 'RS-232') or else from JP3 to pin 4 of IC3 (labelled 'TTL'). In each case the other pin of JP2 or JP3 is then isolated and out of circuit. The heading photo shows the remote switch connected to a Siemens mobile and the Navilock-GPS Mouse. The red wire of the data cable is for charging the mobile's battery (+5 V to pin 1 on the mobile connector).

(080324-1)

Internet Links (Google can translate pages for you)

WinAVR:

<http://sourceforge.net/projects/winavr>

AT command set for GSM/GPRS telephones:

www.communicase.se/multitech/gprs_at.pdf

Technical specification GSM 03.38:

www.mobilecity.cz/doc/GSM_03.38_5.3.0.pdf

Technical data on mobile handset models:

www.mikrocontroller.net/articles/Handy
(Hersteller = manufacturer, Systemstecker = system connector, Ladespannung = charging voltage, nur = only, Schnittstelle = interface, Besonderheit = special feature).

Online PDU Encoder and Decoder:

<http://twit88.com/home/utility/sms-pdu-encode-decode>

Online coordinate conversion:

www.cache-test-dummies.de/tools/koordinatenumrechnung

Author's own project page:

www.blafusel.de/misc/mc_gsm.html

Motorised Volume Pot



High-end with remote control

design: Frank Link (Germany)

Many audio enthusiasts still prefer a good potentiometer for adjusting the audio volume. It would be even nicer if this potentiometer could also be controlled remotely. This is possible with a high-quality motorised potentiometer from Alps and a handful of electronics, as is described here.

Controlling the volume in high-quality audio equipment is always a critical part of the audio path. The potentiometer that is to be used for this has to be first-rate to give excellent matching between the two channels and at the same time it needs to function for a long time without generating any crackling or other noise. These days it is more common that electronic potentiometer-ICs and resistor networks with relays are used, but these solutions are rather involved. Many audio enthusiasts still swear by a good 'old-fashioned' potentiometer. Whenever you start looking for a good specimen you will quickly arrive at the

Alps brand. Alps truly make excellent potentiometers, both without and with motor control. The latter is very nice to enable you to conveniently control the volume remotely from your listening position. In this article we present a small circuit that can control such an Alps motorised potentiometer using a standard RC-5 remote control. In addition to turn the volume up or down the circuit also has 5 outputs for switching between different input channels.

One IC

Not counting the voltage regulator IC, the entire circuit contains only one IC

that takes care of all the operations: an ATmega from Atmel, which is responsible for decoding the RC-5 signals and driving the potentiometer (and the optional input relays). Apart from that, there isn't much to the schematic, shown in **Figure 1**, but we will nevertheless walk through it.

IC1 is the brains in this circuit, an ATmega8L, which is running here at a clock frequency of 4 MHz, thanks to crystal X1. An IR receiver module, type SFH5110-36, is connected to port PD7. This receives the signals from the RC-5 remote control, polishes them into 'clean' digital pulses and then passes

them on to the controller for further processing. The software has been written so that the processor reacts to RC-5 commands from a remote control from a tuner/amplifier (receiver), RC-5 system 17 (decimal).

Port pins PD2 through PD6 are made available externally via connector K3 for switching the pre-amplifier inputs. Driving the motor of the Alps potentiometer is done from ports PB0 through PB5 and PC0 through PC5. Six outputs from each of the ports B and C are connected in parallel to provide sufficient drive current for the motor (this also reduces the number of parts). The maximum current through the motor when it is stalled is 150 mA, according to the Alps data sheet (100 mA when rotating normally). The absolute maximum current per I/O pin is 40 mA, according to Atmel. So by connecting 6 pins in parallel more than 200 mA can be delivered.

To indicate that the motor is turning, a dual-colour LED (D1) is connected in parallel with the motor. Depending on the direction of rotation the LED will illuminate red or green. The current through the LED is about 10 mA, this is therefore not a problem for the driver stage in the microcontroller. You can make an RS232 connection via K2 (which is connected to PD0 and PD1) for debugging or other purposes (however, you will have to write the software routine to do this yourself!). The power supply consists of a bridge rectifier, a 5-V regulator (IC3) and a few capacitors. For the power supply you can use a transformer, a suitable DC voltage already present in the amplifier or a mains adapter.

Practical matters

Figure 2 shows the PCB layout for this circuit. The board is split into two parts, one for the processor section and one for the potentiometer. For the latter, all the connections for the potentiometer are implemented as a row of pins. Separate ground connections have also been added in case you would like to add additional screening (K7/K8, for each channel separately). There is also a separate connection for the screen of the motor section, implemented as a separate PCB pin.

For the motorised potentiometer we assumed the version with the connec-

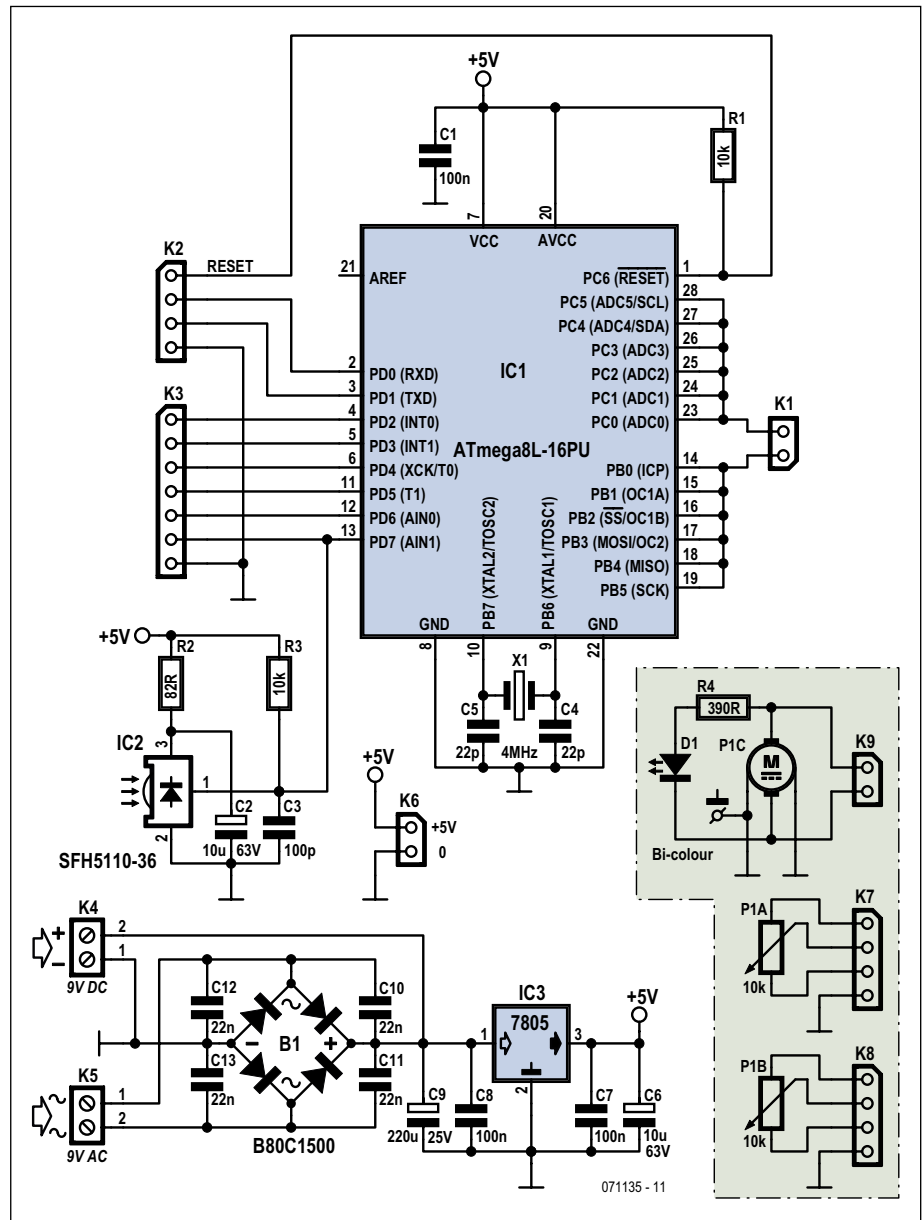


Figure 1. The schematic for the remote volume control. An ATmega8 does all the work here.

tions directly on the motor part (solder eyelets). On the PCB, next to the motor, are two PCB pins to which the motor can be connected with two short wires. Next to that is the actual connection for the motor (K9), which receives the drive signal from the microcontroller on the controller PCB (K1).

Indicator LED D1 is connected next to K9 to a pair of connections. The LED can optionally be connected with two wires if it is to be mounted behind a front panel.

On the controller PCB, K5 is the connection for the power supply voltage. The regulated 5 V is also made avail-

able (K6) as an extra. The five signals for driving, for example input relays of a preamplifier, are available at connector K3. For this purpose the controller decodes buttons 1 through 5 and channel/program up/down (commands 32 and 33 decimal, respectively), so that you can either select an input directly or sequentially step through the inputs in either direction. To make things easy, pins 1 through 5 of K3 correspond to buttons 1 through 5 of the remote control.

The connections for the IR receiver (IC2) that is used here, is via a 3-way row of connections. So you can either

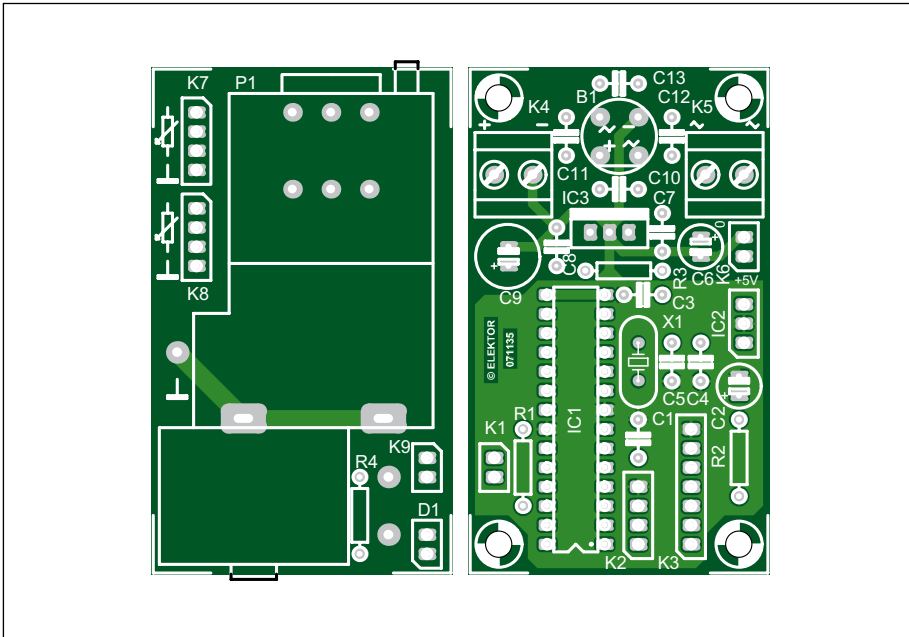


Figure 2. The circuit is built on two printed circuit boards, one for the electronics and one for the potentiometer.

elect to fit IC2 directly on the PCB or connect it with a short length of cable to a connector (but make sure you get the polarity correct!).

Software

The firmware for this circuit is built up in modules. The source code for the various hardware parts can be found in separate files. So, for example, motor.c contains the various functions for switching the motor on and off. In buttons.c are all the definitions and functions for the RC-5 codes from the remote control.

The design of the program is quite simple. An interrupt routine takes care of receiving the RC-5 bits. This routine also checks whether the received code conforms to the RC-5 standard. If this is the case, then the received code is stored so that it can be used for fur-

Code-tangle

Not everyone will have a remote control from a Philips receiver or tuner (or another brand that uses RC-5) handy available to use for this application. Fortunately there are cheap alternatives in the form of a pre-programmed universal remote control. The author had a closer look at a type 'EuroSky 8' which is sold by Conrad, among others, for

about 14 Euro (they call it a 'Universal Remote Control MF-8 Black'). This seems to work well with most devices, although the range could have been a little greater. However, it turned out that the RC-5 system address 17 (dec.), which can be programmed for device AMP (enter code 1112 on the remote control) did not work entirely according to the standard. The volume buttons, channel buttons and stand-by button proved to work correctly. These are very important for us, but the operation of the other functions of an audio device requires the number buttons. Unfortunately the code that is transmitted for these buttons is a complete surprise. While we expected code 1 for button 1, code 2 for button 2, etc. something completely different was transmitted instead (see the following table).

Button	EuroSky 8 (AMP code 1112)		RC5 (Tuner)	
	Address (hex.)	Command	Address (hex.)	Command
1	11	3F	11	01
2	0C	3F	11	02
3	17	3F	11	03
4	12	3F	11	04
5	05	3F	11	05

The author noticed this too and he adapted the software in the controller accordingly. However, this results in problems when we use a remote control which does not transmit the correct codes. This is why the Elektor lab has modified the controller software in such a way that it only reacts to the correct commands of system address 17. For the tests we used a universal remote control from Philips (type SBC RU 865, code 0001 for TUNER). Using this, the circuit works as expected; other universal remote controls should also work well with this circuit. To check whether a remote control transmits the correct codes, you can use the circuit from the Elektor October 2001 issue (IR Code Analyser, article number 010029). If you would like to make your own simple remote control (without microcontroller) you can have a look whether an SAA3010, PT2211 or HT6230 can be obtained from somewhere. One example for such a circuit is in the December 2003 issue (Small RC5 Transmitter, article number 024034).



ther processing by the main program. If the code is incorrect the value '0' is stored. This causes the main program to ignore this code.

After the initialisation of the various peripherals comes the main program loop of the firmware. This loop is repeated indefinitely. Once a valid RC-5 code has been received it is split into device code, key code and the toggle bit. The software subsequently checks, based on a table stored in EEPROM, whether an RC-5 code has been received that is relevant to this circuit.

By the way, these codes can be freely selected. For this you need to change the table in buttons.c and recompile the firmware and program the controller again. For the latter you will need AVR-Studio or WinAVR. When the received code matches one of the codes in the EEPROM, the microcontroller will execute the corresponding command. The software contains also a second

COMPONENTS LIST

Resistors

R1,R3 = 10k Ω
 R2 = 82 Ω
 R4 = 390 Ω
 P1 = Alps 10k Ω logarithmic stereo motor potentiometer (e.g. RK27112MC)

Capacitors

C1,C7,C8 = 100nF ceramic, lead pitch 5mm
 C2,C6 = 10 μ F 63V, radial, lead pitch 2.5mm
 C3 = 100pF, lead pitch 5mm
 C4,C5 = 22pF, lead pitch 5mm
 C9 = 220 μ F 25 V radial, lead pitch 2.5mm
 C10-C13 = 22nF ceramic, lead pitch 5mm

Semiconductors

D1 = 2-pin dual-LED

IC1 = ATMEGA8-16PU, programmed, Elektor SHOP # 071135-41
 IC2 = SFH5110-36 (possibly via 3-way SIL pinheader)
 IC3 = 7805

Miscellaneous

B1 = B80C1500 (80Vpiv, 1.5A) (round case)
 K1,K6,K9 = 2-way SIL pinheader
 K2,K7,K8 = 4- way SIL pinheader
 K3 = 7- way SIL pinheader
 K4,K5 = 2-way PCB screw terminal block, lead pitch 5mm
 X1 = 4MHz quartz crystal
 PCB, ref. 071135-1 from www.thepcbshop.com
 Controller software: free download 071135-11.zip from www.elektor.com

operating mode, where the fifth output is replaced with an on/off function (standby, command 12 decimal).

(071135-1)

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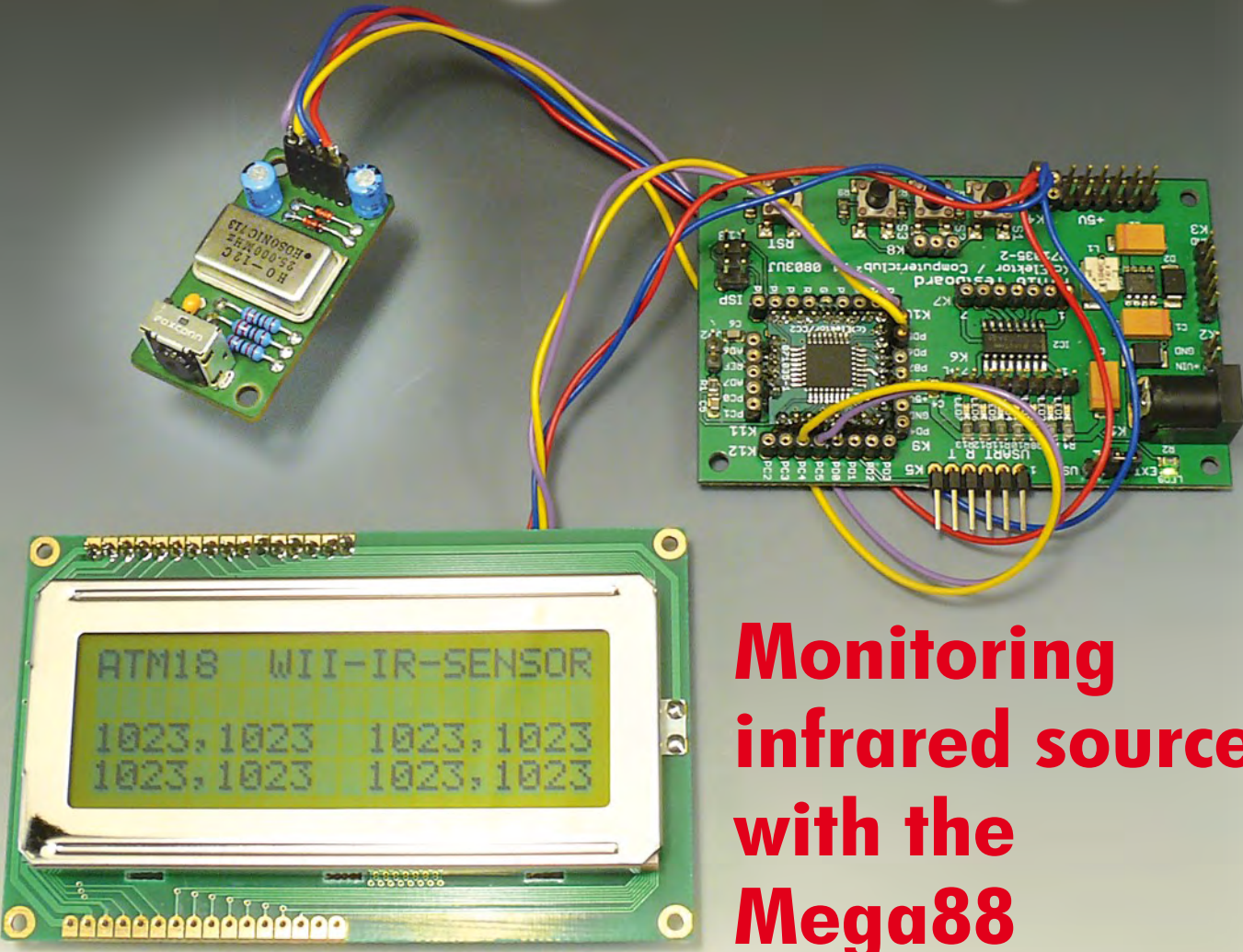
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Tracking Hot Spots



Monitoring infrared sources with the Mega88

Udo Jürsz and Wolfgang Rudolph (Germany)

In this instalment, we add a miniature infrared camera with integrated image processing capability to the ATM18 system. This makes it possible to identify the positions of up to four infrared sources, display the positions on a monitor, and output their coordinates. Assembling a high-tech camera system of this sort is certainly affordable if you take advantage of mass-produced high-tech toys.

When you hear the term 'hot spot', you probably think of a wireless Internet access point, but this term also has other meanings. In a nuclear power plant it means a tiny, highly radioactive particle; in a database it means a data element; and in geology it means a centre of volcanic activity. However, the hot spots we are have in

mind here are literally hot locations. Anything that is hot emits infrared radiation. There are three generally recognised classes of infrared radiation:

- IR-A covers the range from 0.78 μm to 1.4 μm ;
- IR-B covers the range from 1.4 μm to 3 μm ;

- IR-C covers the range from 3 μm to 1 μm .

The terms 'thermal radiation' and 'infrared radiation' are often confused with each other. Thermal radiation is the electromagnetic radiation emitted by a body as a function of its temperature. Infrared radiation occupies



Figure 1. The Nintendo Wii remote control unit.

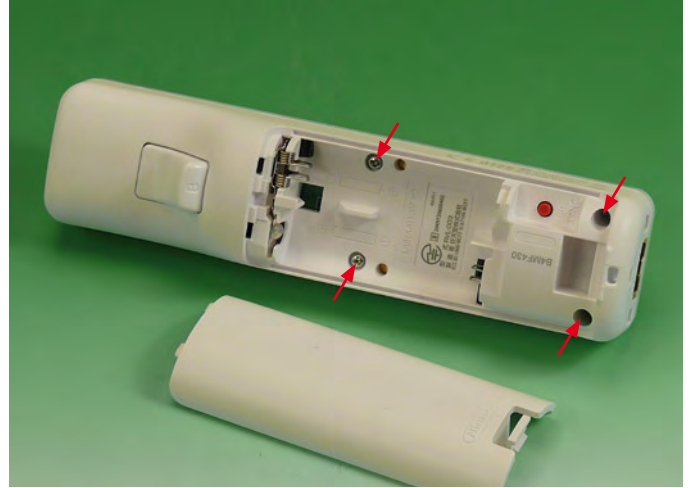


Figure 2. These screws in the battery compartment must be removed.

only a small portion of the total thermal radiation spectrum. For the purposes of the present project, the IR-A range is especially interesting because we intend to use a tiny camera that is fitted with an optical filter so it can only see light in the range of 850 nm to 920 nm, and which has integrated signal processing circuitry. Such a component can provide the basis for innumerable applications, such as a fire alarm, an intrusion alarm, an object tracker, a gesture-controlled input device, an instrument for measuring the speed of objects, and much more. But how can you get your hands on this sort of high-tech camera?

Interesting sensors

By the end of 2007, Nintendo had already sold more than 15 million Wii

game consoles. As a result, the associated remote game controller (Wii Remote), often referred to as 'Wiimote' (Figure 1), has become a very widely used computer input device [1]. Among other things, it includes an infrared camera with a resolution of 1024×768 pixels and built-in hardware blob tracking for up to four objects at the same time. This CMOS camera sensor, which is made by Pix-Art Technologies [2], is in a different league than your average PC-compatible webcam. The Wiimote also contains a three-axis acceleration sensor (Analog Devices ADX330 [3]) with a resolution of 8 bits and a measuring range of $\pm 3 g$. The remote control unit is a fascinating piece of technology, and on top of this it is quite inexpensive. You can pick one up from various

dealers or online auctions for less than £ 20 (€ 25) or at least you could before this article was published!

Before you can start properly dismantling the unit, you have to expose the goodies. Start by removing the two tri-wing screws in the battery compartment (Figure 2). This type of screw head is sometimes called 'Y-shaped', or you may encounter it under its international designation: POO-WC45. You can purchase a suitable screwdriver at your local home improvement shop, or you can buy a full set of bits at a discount supermarket. In the Elektor lab, we discovered that an ordinary cheap screwdriver with a shaft diameter of around 2 mm can also do the job if you file the edges off slightly.

The first two screws are easy to remove, but the two lower screws, which are recessed, are more difficult.



Figure 3. PCB ahoy!

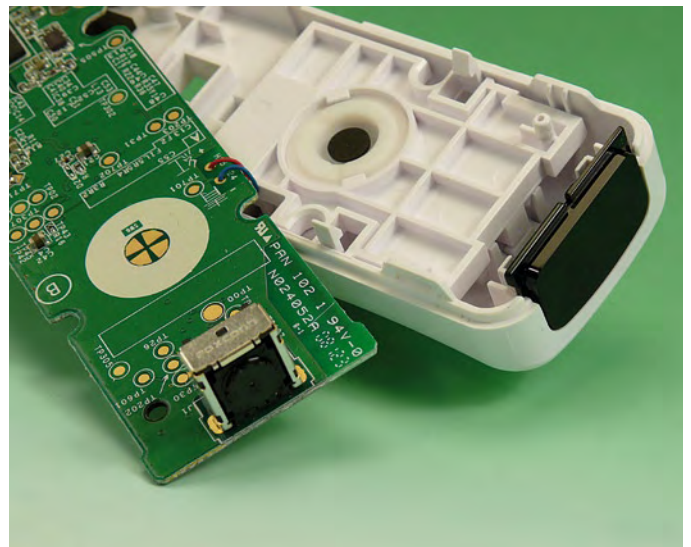


Figure 4. Camera sensor and IR filter.

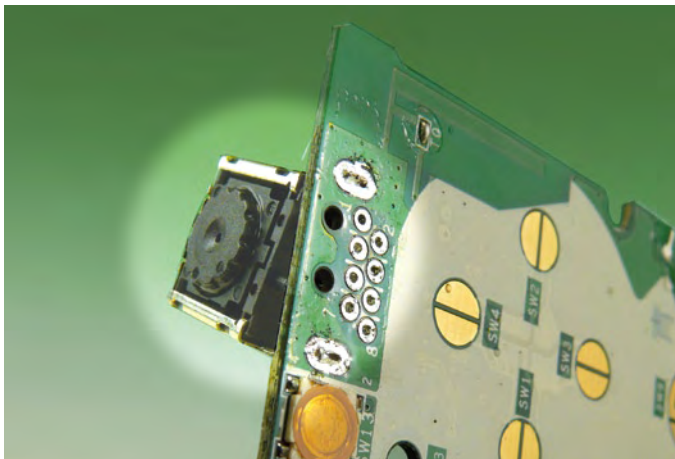


Figure 5. Desoldering the pins is not difficult.

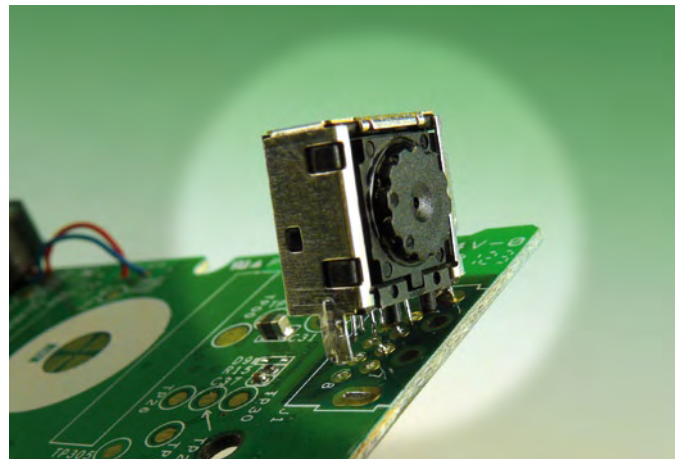


Figure 6. The solder tabs of the sheet-metal screen are a bit more stubborn.

Here it helps to enlarge the holes first with a drill in order to provide better access. You can use a flat-blade screwdriver to release the two plastic locks at the upper end of the remote control, after which the case is open (Figure 3).

After you tip the board out of the case, you will see the infrared sensor at the upper end on the bottom of the board (Figure 4). The case of the remote control unit has a filter insert that screens the sensor against visible light. With the filter, the maximum sensitivity lies in the range of approximately 850–920 nm.

With a bit of caution and careful work, you can unsolder the sensor undamaged. For this purpose, the authors sawed off the end of the PCB before unsoldering the sensor. In the Elektor lab we managed without sawing the board in two, as you can see from the photos. As the Wii PCB is assembled using lead-free solder, you should first apply 'normal'

(lead-based) solder to all of the sensor pins and screen tabs before you start desoldering. Don't be too stingy with the solder, but on the other hand don't 'bake' the solder joints, as otherwise you may overheat the sensor.

After all the pins have been properly treated with solder, you can begin desoldering. Start by using a solder sucker or solder braid to remove the solder from all of the sensor's solder joints. The eight signal and power pins can be freed completely in this way. Now the sensor is only held in place by the two solder tabs of its sheet-metal screen (Figure 5). They can also be desoldered. While heating the solder joint, use a screwdriver to cautiously lever up the sensor on the component side (Figure 6). Then repeat this process with the tab on the other side. With a few back-and-forth repetitions, you can quickly pull the sensor free from the board (Figure 7). The screen (sheet metal enclosure) of the sensor

must be left in place, as otherwise it will quickly and permanently turn into 'dead silicon'.

If you leave the rest of the remote control board undamaged when removing the sensor, the remainder of the circuitry will still function normally. What you have left over then is an interesting Bluetooth device with an acceleration sensor, for which you can probably think of some useful applications.

PCB

In order to use the IR camera sensor with the ATM18 board, you need a bit of simple circuitry (Figure 8), which can be built on a small PCB (Figure 9). A 25-MHz crystal oscillator (CG1) provides the sensor clock signal (CLK). The crystal oscillator can be powered directly from the +5-V supply voltage of the ATM18 board via PCB connector K2 (with the voltage decoupled by C1), but the camera sensor (IR1) requires an

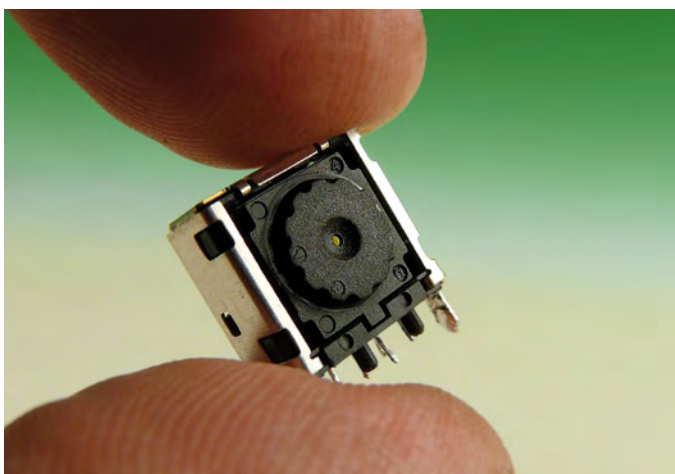


Figure 7. The unsoldered camera sensor.

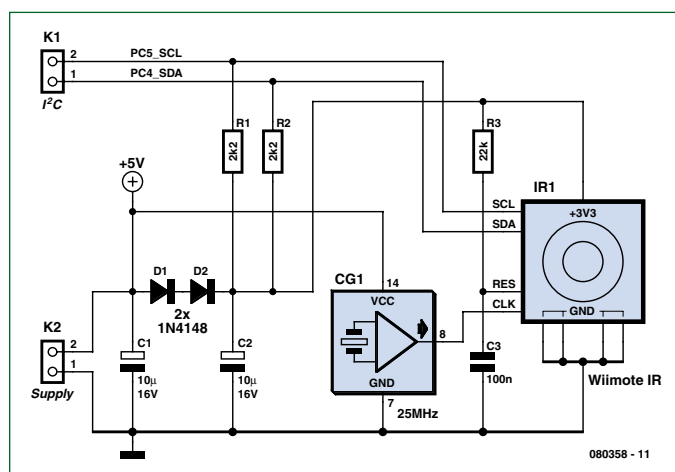


Figure 8. The circuit for connecting the camera sensor.

operating voltage of approximately 3.3 V. This is obtained by wiring two silicon diodes in series (D1 and D2, type 1N4148) to reduce the +5-V level on C1 to around 3.3–3.5 V on C2. The obligatory pull-up resistors for the I²C bus are also located on the PCB. Here this bus operates with 3.3-V signal levels. This is compatible with the 5-V operating voltage of the Mega88 because the active signal level on the bus lines is obtained by pulling them to ground, while the high level is obtained by switching the output pins to the high-impedance state. The 3.3-V level is far enough above the switching threshold voltage

the pins as Ground (two pins), +3.3 V, SCL, SDA, and three other unknown signals. Two of them were quickly identified as the clock input and the Reset signal. The function of the third pin remained unclear. Naturally, after all this research a colleague sent us the address of the website at <http://kako.com/neta/2007-001/2007-001.html>, which describes the pin assignment of the sensor (**Figure 10**). That's how it goes – but at least this information matched our findings. The rest was just a matter of routine effort. After we built a prototype, the ATM18-12C tester (our next project – stay tuned!)

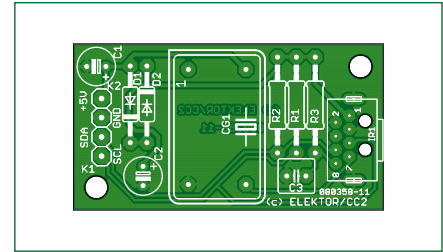


Figure 9. PCB for using the sensor with the ATM18.

I²C

The nature of the I²C bus and how to use will be described in future instalments of the ATM18 series of articles. Here we only want to briefly note that the I²C bus is a serial data transmission bus consisting of two lines: SDA (data) and SCL (clock). Data can be transmitted in both directions: from the microcontroller to the peripheral devices, and from the peripheral devices to the microcontroller. Several devices can be controlled via the bus. For this purpose, each I²C-device has an address that is sent when a link is established.

(2.5 V) for reliable data transfer. The optical sensor from the Wiimote is a 'system on chip' (SOC) device designed by PixArt as an application-specific IC for tracking multiple objects ('multi-object tracking sensor') that includes an integrated signal processor in addition to the CMOS image sensor. The signal processor constantly searches for the brightest spots and determines their coordinates. Up to four bright objects ('blobs') can be recognised and tracked concurrently. The sensor is also sensitive to visible light if the filter is not used, but this capability is not used here.

Communication

The I²C interface makes communication between the sensor and the microcontroller relatively easy. The camera generates an (X,Y) coordinate set for each blob within its field of view of 1024 × 768 pixels and sends this data via the interface for further processing. The only question now is how this works, because Nintendo is totally silent on this subject. We started by using a logic analyser to record the data traffic between the master and slave devices on the I²C bus. After around two hours, we had a clear understanding of how the module is initialised and how to read the data from it. We identified the signals on

once again proved its worth in the first functional tests. The slave address of the Wiimote IR sensors is 0xB0.

Software

The source code of the software in C (Code Vision AVR) and Basic (Bascom AVR) is available on the Elektor website. The C project *ATM18_Wii_Remote_IR_Sensor* demonstrates the use of the sensor with the ATM18. It utilises the internal I²C unit of the Mega88, which means that the pin assignments are fixed: the data line (SDA) is on PC4, while the clock line (SCL) is on PC5. Two additional lines must be connected for the supply voltage. If the LCD module is connected, it will display the blob coordinates detected by the sensor. The ATM18 also outputs the blob positions in the form of four pairs of values (X,Y) on the USART interface, with the format

'X1,Y1,X2,Y2,X3,Y3,X4,Y4<CRLF>'

This string is output repeatedly. The value of X can range from 0 to 1023, while the value of Y can range from 0 to 767. If X = 1023 and Y = 1023, this means that the associated blob is not active. The program 'Wii-Blob-Track', which is also available on the Elektor website,

COMPONENTS LIST

Resistors

R1,R2 = 2kΩ
R3 = 22kΩ

Capacitors

C1,C2 = 10μF 25V
C3 = 100nF

Semiconductors

D1, D2 = 1N4148
CG1 = 25MHz oscillator module
IR1 = Wii Infrared image sensor (see text)

Miscellaneous

K1, K2 = 2-way SIL header
PCB, order code **080358-1** from Elektor SHOP. Free artwork download from www.elektor.com



Figure 10. Lab prototype of the PCB with the camera sensor.

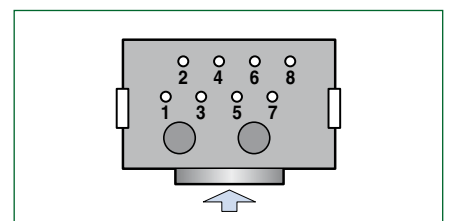


Figure 11. Sensor pin assignment:

- Pin 1 = V_{cc} (+3.3 V)
- Pins 2 and 3 = GND (ground)
- Pin 4 = not used
- Pin 5 = SCL (I²C)
- Pin 6 = SDA (I²C)
- Pin 7 = CLK (25 MHz)
- Pin 8 = Reset

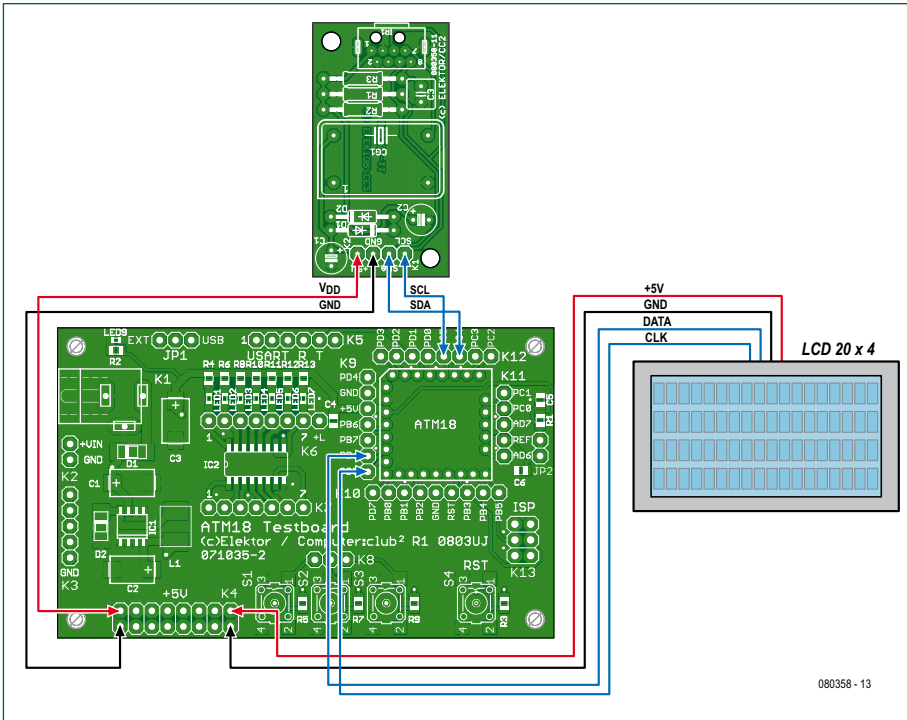


Figure 12. Connecting the sensor and LCD board to the ATM18 board. Here the LCD is connected to PD5 (clock) and PD6 (data).

can be run on a PC under Windows to display the recognised hot spot positions. This program receives the X,Y coordinates from the ATM18 board and

converts them into graphic form. Anyone who has ever tried to determine the position of an object from a camera image can appreciate the clever sim-

licity of this Wiimote-based solution, and especially its excellent cost/performance ratio.

You can test the operation of the unit by wandering around the room with a lit cigarette lighter in your hand while someone logs your travels, or you can fit an IR LED and battery on the back of your pet cat and observe the movements of your experimental feline subject in full darkness.

Bascom example

As usual, we also developed a Bascom application program that provides functions similar to the basic functions of the C program. We also wrote a specific property monitoring application for use with the sample Bascom program.

Unlike the C program, the Bascom program does not use the hardware I²C interface, but instead creates an equivalent function in software. This means that you can use any desired set of pins for the I²C bus. In our case, we use the same pins as for the C program.

The microcontroller sends several bytes to the sensor for initialisation. After this, data is read out at regular intervals in sets of 16 bytes. Each blob requires three bytes. As each coordi-

Listing

Sensor data processing with Bascom

```
'ATM18 CCD sensor
'I2C: SCL = PC5, SDA = PC4

$regfile = "m88def.dat"
$crystal = 16000000
Baud = 38400
```

```
Dim Slave As Byte
Dim Slaverd As Byte
Dim D1 As Byte
Dim D2 As Byte
Dim Din(16) As Byte
Dim N As Byte
Dim X1 As Word
Dim Y1 As Word
Dim X2 As Word
Dim Y2 As Word
Dim X3 As Word
Dim Y3 As Word
Dim X4 As Word
Dim Y4 As Word
Dim Xy1 As Integer
Dim Xy2 As Integer
Dim Xy3 As Integer
```

```
Declare Sub Send2bytes
Declare Sub Sensorinit
Declare Sub Readsensor
Declare Sub Convertdata
Config Portb = Output
```

```
Config Scl = Portc.5
Config Sda = Portc.4
I2cinit
Config I2cdelay = 15
'I2C sensor address
Slave = &HB0
Slaverd = &HB1
Print "ATM18 I2C_Wii_IR_Sensor"
Sensorinit

Do
  Readsensor
  Convertdata
  Print "P1 " + Str(x1) + ", " + Str(y1)
  Print "P2 " + Str(x2) + ", " + Str(y2)
  Print "P3 " + Str(x3) + ", " + Str(y3)
  Print "P4 " + Str(x4) + ", " + Str(y4)
  Xy1 = X1 + Y1
  Xy1 = Xy1 + X2
  Xy1 = Xy1 + Y2
  Xy1 = Xy1 + X3
  Xy1 = Xy1 + Y3
  Xy1 = Xy1 + X4
  Xy1 = Xy1 + Y4
  Print Xy1
  Xy3 = Xy2 - Xy1
  Xy2 = Xy1
  Xy3 = Abs(xy3)
  If Xy3 > 10 Then
    Print "*****"
    Portb.0 = 1
  Else
    Portb.0 = 0
  End If
```

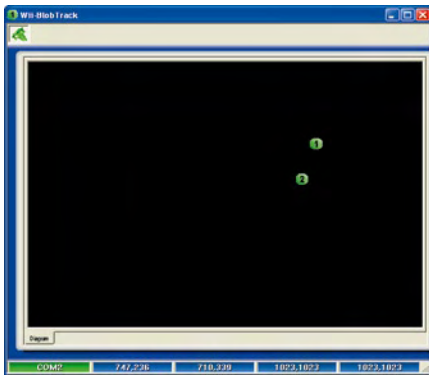


Figure 13. Coordinate processing by the PC program. Up to four 'blobs' can be shown concurrently.

nate is a 10-bit value, the eight lower-order bits of each value are transmitted in one byte, while the two higher-order bits of the X and Y coordinates are stuffed into the third byte. After all the bits have been rearranged properly, you have four sets of (X,Y) coordinates. They are transmitted via the serial interface to a terminal emulator program at a speed of 38,400 baud.

```
ATM18 I2C_Wii_IR_Sensor
P1 66, 67
P2 813, 228
P3 774, 332
P4 722, 113
```

The ATM18 project at Computer:club²

ATM18 is a joint project of Elektor and Computer:club² (www.cczwei.de) in collaboration with Udo Jürsz, the editor in chief of www.microdrones.de. The latest developments and applications of the ATM18 are presented by Computer:club² member Wolfgang Rudolph in the CC²-tv programme broadcast on the German NRW-TV channel. The ATM18-AVR board with the IR camera was described in **Instalment 23** of CC²-tv, which was broadcast on 18 September 2008.

CC²-tv is broadcast live by NRW-TV via the cable television network in North Rhine–Westphalia and as a LiveStream programme via the Internet (www.nrw.tv/home/cc2). CC²-tv is also available as a podcast from www.cczwei.de and – a few days later – from sevenload.de.

The program constantly monitors the 'bright spots' to see whether they change. If they do, an alarm signal is output on PB0, and it can be used to drive the ULN2003. This could be connected to a siren, a fire extinguisher, or some sort of pyrotechnical system. If you want to protect your art collection, for instance, all you need is four infrared LEDs that are constantly observed by the sensor. A checksum is formed from the set of eight coordinates. If it changes from the value of the previous measurement by more than 10, an alarm is generated. This can happen if, for example, a thief passes through one of the invisible infrared beams or uses

a fishing rod to drop a line through a skylight and snag one of your Picassos that is protected by the IR system. Now that we've laid the groundwork, we look forward with considerable anticipation to applications developed by Elektor readers.

(080358-1)

Internet Links

- [1] http://en.wikipedia.org/wiki/Wii_Remote
- [2] www.pixart.com.tw
- [3] www.analog.com/en/mems-and-sensors/imems-accelerometers/adxl330/products/product.html

```

    Waitms 200
    Loop

Sub Send2bytes
    I2cstart
    I2cwbyte Slave
    I2cwbyte D1
    I2cwbyte D2
    I2cstop
End Sub

Sub Sensorinit
    D1 = &H30 : D2 = &H01 : Send2bytes : Waitms 10
    D1 = &H30 : D2 = &H08 : Send2bytes : Waitms 10
    D1 = &H06 : D2 = &H90 : Send2bytes : Waitms 10
    D1 = &H08 : D2 = &HC0 : Send2bytes : Waitms 10
    D1 = &H1A : D2 = &H40 : Send2bytes : Waitms 10
    D1 = &H33 : D2 = &H33 : Send2bytes : Waitms 10
    Waitms 100
End Sub

Sub Readsensor
    I2cstart
    I2cwbyte Slave
    D1 = &H36
    I2cwbyte D1
    I2cstop
    Waitms 1
    I2cstart
    I2cwbyte Slaverd
    For N = 1 To 15
        I2crbyte Din(n) , Ack
    Next N
    I2crbyte Din(16) , Nack
    I2cstop

    Waitms 30
    End Sub

Sub Convertdata
    X1 = Din(4) And &H30
    X1 = X1 * 16
    X1 = X1 + Din(2)
    Y1 = Din(4) And &HC0
    Y1 = Y1 * 4
    Y1 = Y1 + Din(3)

    X2 = Din(7) And &H30
    X2 = X2 * 16
    X2 = X2 + Din(5)
    Y2 = Din(7) And &HC0
    Y2 = Y2 * 4
    Y2 = Y2 + Din(6)

    X3 = Din(10) And &H30
    X3 = X3 * 16
    X3 = X3 + Din(8)
    Y3 = Din(10) And &HC0
    Y3 = Y3 * 4
    Y3 = Y3 + Din(9)

    X4 = Din(13) And &H30
    X4 = X4 * 16
    X4 = X4 + Din(11)
    Y4 = Din(13) And &HC0
    Y4 = Y4 * 4
    Y4 = Y4 + Din(12)
End Sub

End
```

Lazy on the Bike

'DIY' e-bike

Thijs Beckers (Elektor Netherlands)

We wouldn't be Elektor if we didn't do a little experimenting with e-bikes, which have become popular in recent times. But an off the shelf contraption is not nearly as much fun as one which we have to build ourselves. So, on the look-out for DIY kits. And where would you find one of those? Exactly: eBay!

Electronics is still hot! Witness the Segway and the ever increasingly frequent appearance on the street of bicycles with an auxiliary electric motor. A Segway may be a bit difficult to build yourself, but changing a wheel (because it is hardly more than that) is not really a big deal for most people. So, get started with the DIY electric bike kit!

Dear bought and far fetched...

...are dainty for ladies, at least that is how the saying goes. The kit that we ordered for this review is manufactured in China. It is a package containing a motor driver/controller circuit, a set of handbrakes with switch, an accelerator handle, a pedal sensor and a wheel with built-in motor.

The package finally arrived at our lab via a German importer, where, after having travelled half-way around the world it is mounted on a second-hand bicycle that was hurriedly acquired from somewhere for this purpose. The wheel, with regards to its diameter (24 inch), is not quite right for this bike, but that won't spoil the fun.

Technology

From the three power cables that leave the controller box and go to the motor we concluded that we are dealing with a brushless motor. Although the XLR plug for the connection to the batteries is of reasonable quality, the plugs that connect to the motor are unfortunately not the best quality. There is a not inconsiderable chance that these will burn out after a while...

Inside the controller enclosure we find an ATmega48V10, an 8-bit AVR microcontroller with 8 k of in-system-programmable Flash ROM. There is a strong indication the header on the board is suitable for 'updating' (dare we say hacking?) of the controller.

There are also six substantial, N-channel MOSFETs from STMicroelectronics, type P75NF75, which are rated for as much as 80 amps.

The enclosure is made from one piece of extruded aluminium and has a cover at both ends. The power MOSFETs are clamped, with electrical isolation, against one side of the enclosure so that they can dissipate their heat. During our



The kit contains a wheel with built-in motor, two handles with built-in switch, a sensor for the movement of the pedals, an accelerator handle and a controller.





test rides, for which we put the circuit and batteries in panniers to keep things simple, the controller enclosure became quite warm. This is therefore not appropriate as a permanent solution and it would be much better if the controller was exposed to the passing air. We do however question the water-proofing of the enclosure. The connectors aren't really suited for our damp climate either. This could easily become a problem.

Via the phone number on the PCB, we have been able to trace the manufacturer: the Chinese company Jiaxing City. There is a strong suspicion that the circuit has not been extensively tested for use in the EU, evidenced by the absence of RoHS, CE and other approval marks.

The wheel comes from the company Nine Continent in Wenzhou, China and does conform to the RoHS standard.

Practice

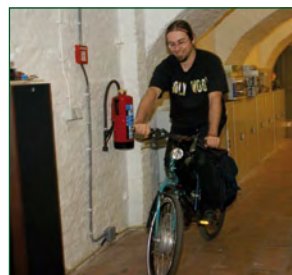
The first problem we encountered was that the wheel was too wide. Carefully(!) we spread the front fork a little so we could fit the wheel in it. And of course, the motor initially

turned the wrong way, so take note which way around the wheel is supposed to be fitted, before you fasten all the cables in place.

The wheel turns with more friction than what we are used to with a normal wheel. When buying the tyre we had to pay close attention. 24 inch is apparently not always 24 inch... These come in different sizes so it is best if you bring the wheel with you. Mounting the accelerator handle was reasonably straightforward. The size of the tubing for the handlebars in China is apparently the same as in Europe.

Once the wheel and the accelerator handle were fitted, and the controller circuit and batteries in the pannier, it was time for a test ride (see photos). The handbrake and pedal sensor should also have been connected (see EU regulations inset), but the motor also works without them. The handbrake contains a switch which turns the motor off the moment you start to brake. An additional 'advantage' of not installing the pedal sensor is that the accelerator handle always works. So you do not need to pedal for the motor to turn on. Note that it is therefore **not** legal to ride on the road this way.





The DIY e-bicycle in action

The advantage of an electric motor over a combustion engine is emphasised once again: an electric motor provides immediate torque, while simple combustion engines first has to get up to speed. The bike soon moved too fast for laps through our lab, so we moved the test outdoors. Even though the batteries were brand new and really should have been 'conditioned' a little, they nevertheless gave very little trouble. The motor was very capable of propelling the test bicycle to a speed of about 25 kilometres per hour, without doing any pedalling at all. We should now try it without the limiter...

Unfortunately our dilapidated mountain bike was not transformed into a barely controllable speed demon, but it did go a little faster nonetheless. We got up to about 30 kilometres per hour, provided there is no wind. The torque of the motor remains the same, so you won't go faster up a steeper hill compared with the limiter enabled.

The other thing we noticed is that once the 30 km/h mark was reached, additional pedalling (to help the motor a little) was pointless. That means, the kilometres in excess of 30 you have to do all yourself. This is nevertheless not a poor performance from a standard bicycle, considering that you do not require a permit, insurance or whatever (at least in The Netherlands), although third-party insurance is recommended, because accidents will happen.

We couldn't find any problems with the front-wheel driven bike. The bike behaves like normal in all other respects.

A few hints for the batteries. For the application in electric bicycles it is best to use batteries with fast charge and discharge curves. The company Huijzer Components recommended us to use the EVZ series made by CSB. The batteries are connected in series to obtain the required 36 V. Note: although this voltage is not lethal, the current that the batteries can supply can be used to weld!

For those among you who are considering obtaining

such a kit directly from China: take into account the shipping and import costs. These will likely increase the price by 30 percent, if not more (depending on the shipping costs). In conclusion we can state that such a kit for about € 200 is a nice 'upgrade' for a bicycle, although the mounting of the control circuit and the batteries will require a bit of thought.

(071128-1)

Our thanks go to Huijzer Components (www.huijzer.com) for making the batteries available.

Internet Links

www.recumbents.com/wisil/e-bent/default.htm

<http://zeep.wordpress.com/>

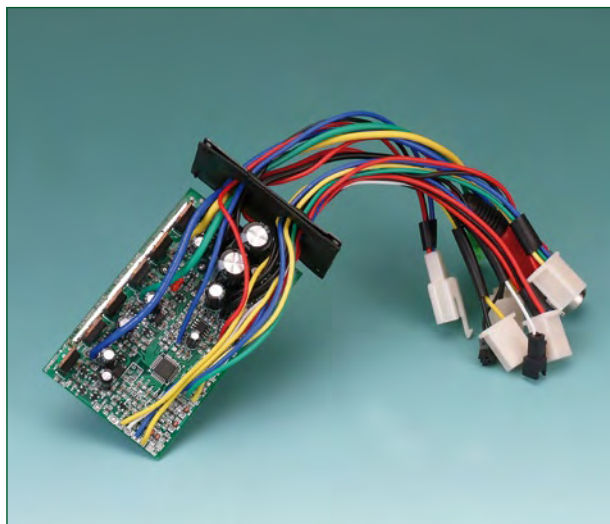
www.elektrischefiets.be/index.html

<http://www.electric-bikes.com/bikes/legal.html>, http://en.wikipedia.org/wiki/Electric_bicycle_laws

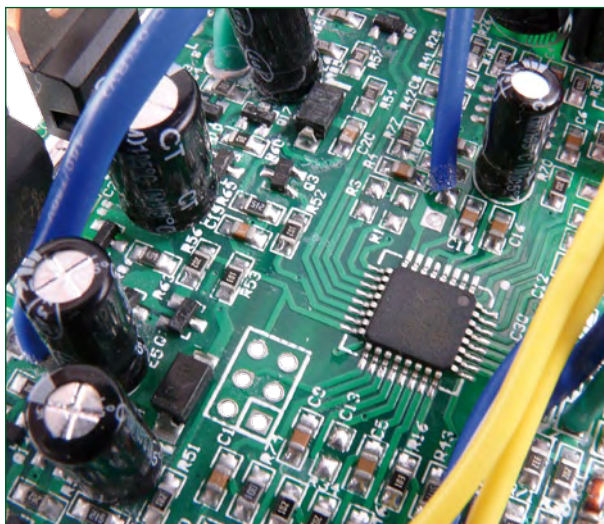
EU regulations

Within the European Union bicycles may be fitted with an auxiliary electric motor. This is subject to the following requirements:

- the electric motor may not propel the vehicle on its own but only assist the pedalling motion
- the maximum power of the motor may not exceed 0.25 kW.
- at a speed of more than 25 km/h the electric motor may not provide any additional power.



The compact controller PCB already comes with a header that can be used to re-program the controller.



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Computer Controlled / Standalone Unipolar Stepper Motor Driver

Drives any 5-35Vdc 5, 6 or 8-lead unipolar stepper motor rated up to 6 Amps. Provides speed and direction control. Operates in stand-alone or PC-controlled mode for CNC use. Connect up to six 3179 driver boards to a single parallel port. Board supply: 9Vdc. PCB: 80x50mm. Kit Order Code: 3179KT - **£12.95**
Assembled Order Code: AS3179 - **£19.95**



Computer Controlled Bi-Polar Stepper Motor Driver

Drive any 5-50Vdc, 5 Amp bi-polar stepper motor using externally supplied 5V levels for STEP and DIRECTION control. Opto-isolated inputs make it ideal for CNC applications using a PC running suitable software. Board supply: 8-30Vdc. PCB: 75x85mm. Kit Order Code: 3158KT - **£17.95**
Assembled Order Code: AS3158 - **£27.95**



Bi-Directional DC Motor Controller (v2)

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



DC Motor Speed Controller (100V/7.5A)

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



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Assembled Order Code: AS3108 - **£64.95**



Computer Temperature Data Logger

4-channel temperature logger for serial port. °C or °F. Continuously logs up to 4 separate sensors located 200m+ from board. Wide range of free software applications for storing/using data. PCB just 45x45mm. Powered by PC. Includes one DS1820 sensor. Kit Order Code: 3145KT - **£17.95**
Assembled Order Code: AS3145 - **£24.95**
Additional DS1820 Sensors - **£3.95 each**



Rolling Code 4-Channel UHF Remote

State-of-the-Art. High security. 4 channels. Momentary or latching relay output. Range up to 40m. Up to 15 Tx's can be learnt by one Rx (kit includes one Tx but more available separately). 4 indicator LED's. Rx: PCB 77x85mm, 12Vdc/6mA (standby). Two and Ten channel versions also available. Kit Order Code: 3180KT - **£44.95**
Assembled Order Code: AS3180 - **£54.95**



DTMF Telephone Relay Switcher

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



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



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



"PICALL" PIC Programmer

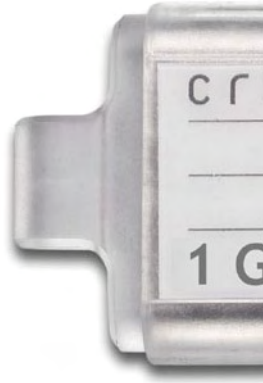
"PICALL" will program virtually all 8 to 40 pin serial-mode AND parallel-mode (PIC16C5x family) programmed PIC micro controllers. Free fully functional software. Blank chip auto detect for super fast bulk programming. Parallel port connection. Supply: 16-18Vdc. Assembled Order Code: AS3117 - **£24.95**



ATMEL 89xxxx Programmer

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





ATmega meets Vinculum

Recording data values with a USB stick

Burkhard Kainka (Germany)

When it comes to matters of memory, microcontrollers tend to be rather poorly endowed. An external USB memory stick is the ideal remedy, offering straightforward data transfer to your PC. Now if bonding the memory stick to a micro was somewhat problematic until recently, it's now totally stress-free with the Vinculum chip from FTDI!

The Vinculum chip has been developed by the FTDI company for adding not merely an uncluttered USB interface but full USB host functionality to all conceivable embedded applications [1]. Boards and devices equipped in this way can be enhanced further, for example with a USB memory stick or 'thumb drive'. The 'Vinculum' controls the FAT file system and relieves devel-

opers of a significant amount of development work.

Experimenter-friendly

The name 'Vinculum' comes from the Latin and has the meaning of bond, fetter, tie or leash. In that same spirit we can use this chip to attach a USB stick to a small 8-bit microcontroller with-

out any problems at all. In this way an Atmel ATmega88 can now enjoy several Gigabytes of external memory. For developing applications of this kind the VDIP1 module [2] is well suited, as all connections from the Vinculum can be taken to a DIP connector (see heading photo and **Figure 1**). You can also carry out initial tests on a breadboard or stripboard (a.k.a. Veroboard, Vector

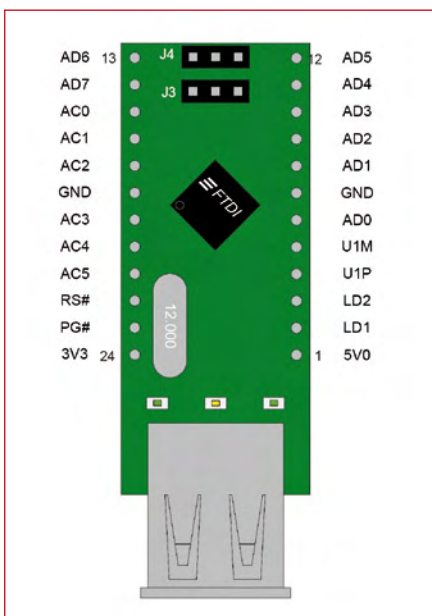


Figure 1. Connections of VDIP1 (Source: Data sheet [2]).

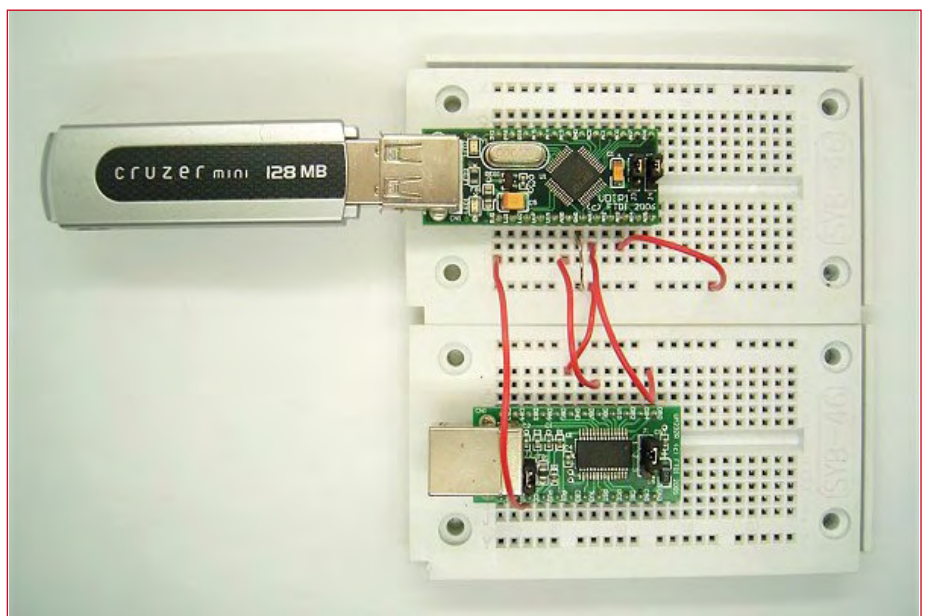
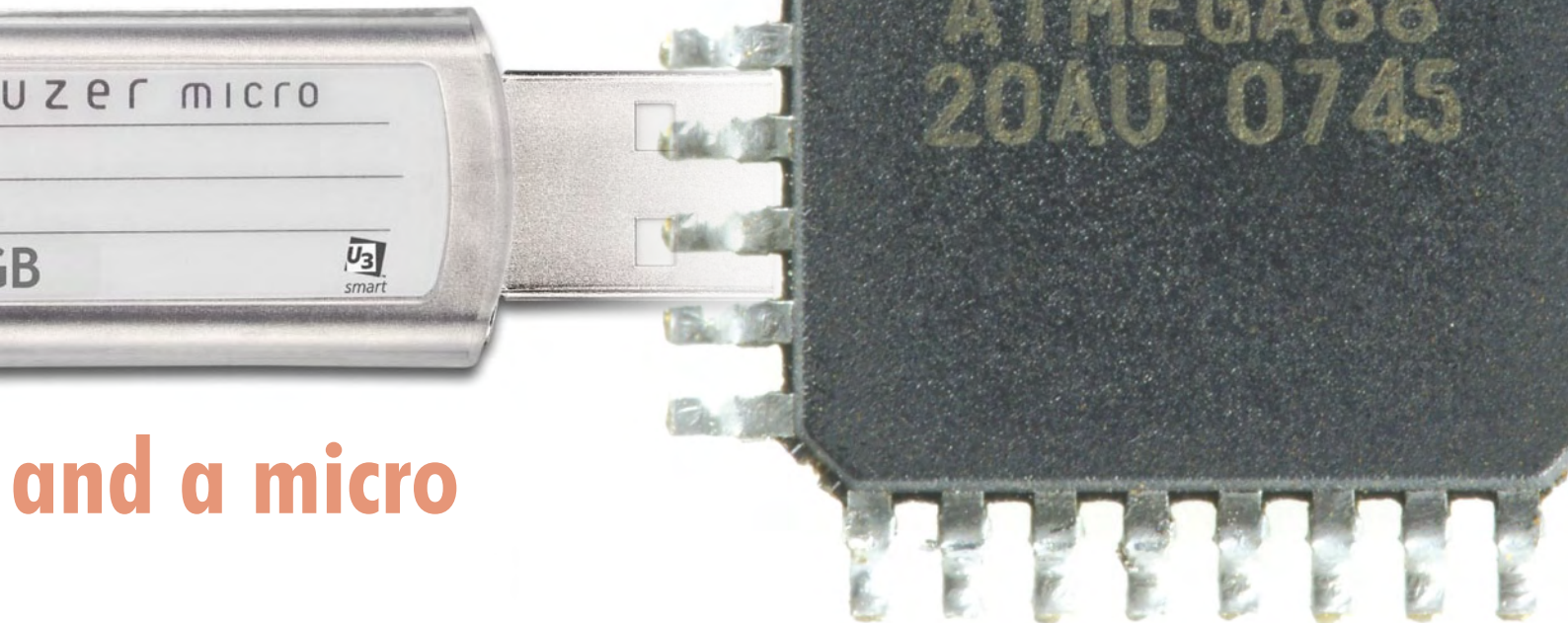


Figure 2. First tests with a USB-serial adapter.



and a micro

Board, perfboard) if you wish. The main connections are set out in **Table 1**. The chip handles a number of serial and parallel operating modes, which are selected using J3 and J4. In our application we need to use the serial interface of the Vinculum, so we must plug J3 and J4 up to Vcc (pins 13/14). Signals are processed at TTL level, meaning that the microcontroller can be operated without the need for a separate interface adapter module. For a first test we need to talk to Vinculum using a PC terminal program Terminal.exe [3]. Since most computers are no longer equipped with a serial interface, a USB-to-serial adapter is used, for example in the form of the DIP module UM232R (as shown in **Figure 2**). An equally good solution is the

Table 1.
Vital Vinculum connections

Pin 1: VCC	to +5V
Pin 6: AD2	data output TXD
Pin 7: GND	to ground
Pin 8: AD1	data input RXD
Pin 10: AD4	Handshake line CTS, to GND

USB-Serial cable supplied by Elektor [4]. The VDIP1 module needs to be fed with a 5 V supply. Internally it is in fact looking for only 3.3 V but it is fully 5 V-tolerant, meaning that it can later be hooked up without modification to a microcontroller running on 5 V. Before we go any further, here's a vital warning: always remember to remove the USB memory stick before

you switch off the Vinculum module. Painful experience indicates that total memory loss may occur otherwise (maybe you need to put some marking on the stick to remind you). As soon as you then connect the stick to a PC, the latter will then attempt to reformat it...

Terminal test

Vinculum recognises two command sets. The Extended Command Set is provided for text-based operations, whilst there are also byte commands (the Short Command Set) that can be used with microcontrollers, for example. At switch-on the text mode is always selected. You can test out both modes using the *Terminal.exe* program very conveniently, as it's easy to switch between byte communication and text.

Open the Terminal with the settings '9600:N,8,1' (see **Figure 3**). Do not connect a USB stick at this stage. Now type DIR <Enter> (it's immaterial whether you use small letters or capitals as they are all treated the same). Vinculum then reports that no data medium has been detected. Now plug in a USB memory stick and 'Vinculum' proudly announces:

```
Device Detected P2
No Upgrade D:\>
```

For a second time type DIR <Enter>, and the directory of contents appears. Just as in DOS, only short filenames are supported in Format 8:3. Long filenames are displayed in an abbreviated format.

```
KAP1 DIR SDR DIR TEXT.TXT D:\>
```

A text file with the content "Hello <CR>" is indicated as follows:

```
RD TEXT.TXT <Enter>
Hello
D:\>
```

As you would expect, the use of subdirectories is equally simple.

Not quite so straightforward is entering data in a file. The key commands are Open, Write and Close:

```
OPW file <Enter>
WRF dword <Enter> data
CLF file <Enter>
```

When writing data you must indicate the number of bytes to be stored accurately. The total is entered as a 32-bit figure (dword). If the file is still open you can repeat the WRF operation if you wish to enter data in blocks. An example is given in our BASCOM application below.

A faster means of entering data is achieved by switching to the Short

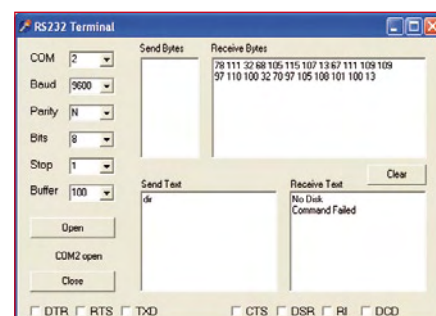


Figure 3. Communication with the Vinculum using Terminal.exe.

Extended Command Set	Short Command Set (Hexadecimal Codes)	Function
DIR↵	01 0D	List files in current directory
DIR·file↵	01 20 file 0D	List specified file and size
CD·file↵	02 20 file 0D	Change current directory
CD·..↵	02 20 2E 2E 0D	Move up one directory level
RD·file↵	04 20 file 0D	Reads a whole file
DLR·file↵	05 20 file 0D	Delete subdirectory from current directory
MKD·file↵	06 20 file 0D	Make a new subdirectory in the current directory
MKD·file·datetime↵	06 20 file 20 datetime 0D	Make a new subdirectory in the current directory Also specify a file date and time
DLF·file↵	07 20 file 0D	Delete a file
WRF·dword↵ data	08 20 dword 0D data	Write the number of bytes specified in the 1 st parameter to the currently open file
OPW·file↵	09 20 file 0D	Open a file for writing or create a new file
OPW·file·datetime↵	09 20 file 20 datetime 0D	Open a file for writing or create a new file Also specify a file date and time
CLF·file↵	0A 20 file 0D	Close the currently open file
RDF·dword↵	0B 20 dword 0D	Read the number of bytes specified in the 1 st parameter from the currently open file
REN·file·file↵	0C 20 file 20 file 0D	Rename a file or directory
OPR·file↵	0E 20 file 0D	Open a file for reading
OPR·file·date↵	0E 20 file 20 date 0D	Open a file for reading Also specify a file access date
SEK·dword↵	28 20 dword 0D	Seek to the byte position specified by the 1 st parameter in the currently open file
FS↵	12 0D	Returns the free space available on disk if less than 4GB is free
FSE↵	93 0D	Returns the free space available on disk
IDD↵	0F 0D	Display information about the disk if disk is less than 4GB

Figure 4. The most important file commands (Source: Firmware manual [5]).

Command Set (SCS):

SCS <Enter>

Vinculum responds in like manner in small Bytes (for example 13 corresponds to CR):

62 13

To return to Extended Command Mode you use the command ECS. Other commands can be found in the *Vinculum Firmware User Manual* [5], as seen in **Figure 4**.

Firmware update

It's always a good idea to use the latest version of the firmware. On the Vinculum download page [6] you can always find the most recent 'VDAP' firmware file (as we went to press this was `ftrfb_main_03_65VDAPF.ftd`). Loading the new firmware is easy with the USB memory stick.

Copy it to the root directory of the medium and rename it as 'ftrfb.ftd' [7]. When you connect the stick the following reports appear:

```
Device Detected P2 Found It
Change MAIN Reflasher Active
.....
.....
.....
Rebooting Ver 03.65VDAPF On-Line:
Device Detected P2 No Upgrade
D:\>
```

Vinculum and ATmega in harmony

That's enough playing around; now it's time for an actual application. A microcontroller, an ATmega88 in this case (for instance on the Elektor ATM18-AVR Board), is connected via its RXD (PD0) and TXD (PD1) lines to the VDIP1. These need to be cross-connected, i.e. TXD to RXD and RXD to TXD (see **Figure 5**).

The microcontroller should read the file 'ToDo.txt' in order to capture the data included as instructions for measurement and to write the test data into a second file 'Log.txt'. The measurement system is an installation that has already been set up somewhere. The user edits a command file on the PC and saves this onto the USB stick. Then he plugs the stick into the microcontroller system and lets the measurement operations take place. At the appointed time the stick is removed along with the data collected. These measurements are then evaluated on the PC.

This is how the Command File is built up:

Total number of measurement operations: (Word) 0 - 65535
 Interval between measurements in ms: (Word) 0 - 65535
 Number of measurement channels: (Word) 1 - 8

For 100 measurements, 1000 ms and two channels, the file `ToDo.txt` will then read:

```
100
1000
2
```

This file can be created in Windows Notepad for instance. It's important to close off the final line with <Return> just like the preceding ones. The end of each line in the file is made up of the special symbol CR and LF, which should be noted when the file is read in the microcontroller.

Listing 1.

Mini data logger

```
'Bascom ATmega88, Vinculum

$regfile = "m88def.dat"
$crystal = 16000000
Baud = 9600
Open "com1:" For Binary As #1

Dim Samples As Word
Dim Delays As Word
Dim Channels As Word
Dim N As Integer
Dim I As Integer
Dim L As Integer
Dim S As String * 20
Dim Ad As Integer

Config Portb = Output
Config Adc = Single , Presca-

ler = Auto , Reference = Off
Start Adc
Echo Off

Do
  Input S
  Loop Until S = "D:\>"
  Portb.0 = 1
  Waitms 1000
  Print "rd todo.txt" + Chr(13);
  Input Samples
  Get #1 , L

  Input Channels
  Get #1 , L
  Input S
  Print "OPW Log.txt" + Chr(13);
  Input S
  For N = 1 To Samples
    S = ""
    For I = 1 To Channels
      Ad = Getadc(i)
      S = S + Str(ad)
      If I < Channels Then
        S = S + Chr(9)
      Next I
      S = S + Chr(13) + Chr(10)
      L = Len(s)
      Print "WRF ";
      Put #1 , 0
      Put #1 , 0
      Put #1 , 0
      Put #1 , L
      Put #1 , 13
      Print S ;
      Input S
      Waitms Delays
    Next N
  Print "CLF log.txt" + Chr(13);
  Input S
  Portb.0 = 0
End
```

Measurement program

Our measurement program is implemented here in Bascom-AVR [8] for an ATmega88. In principle the only com-

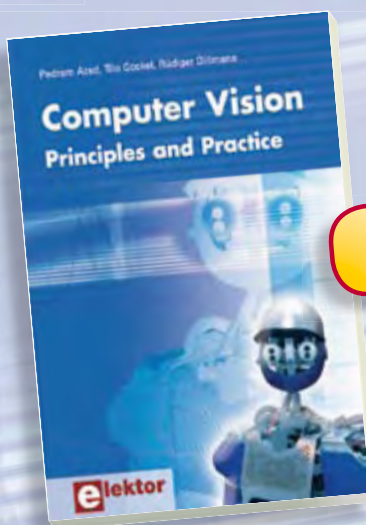
mands necessary to share serial data with Vinculum are Print and Input, also Put and Get, for single bytes. A small devil lies in the detail: in Bascom the Print command (as in the other BASIC

dialects) at the end of a line is inextricably linked with CR (ASCII 13) and LF (ASCII 10). Vinculum does not take kindly to the final LF symbol, however. It is always treated as the first

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symbol of the following line, which is then rejected as a 'Bad Command'. However, you can suppress the two end-of-line symbols by following the Print command with a semicolon (print "dir";). The required CR must be added separately. For example:

```
print "dir" + Chr(13);
The program 'Vinculum.bas' can manage quite well without the Short-Command mode — in other words, using the 'long' text commands.
```

The problem of needing to enter the length of data lines in exactly four bytes (dword) is solved by using the Put command. The length of a data line, even when we are using the maximum possible of eight channels, is clearly less than 255 symbols. In fact we need only one byte, so, for a line length of, for example, 16 symbols, you can send four times Put with the bytes 0, 0, 0 and 16. Why send these bytes with four Put commands and not as a text string? Well, a Null byte in a String indicates its end. For that reason Put is used only when Nulls need to be sent.

Problemette solved

A further small problem arises when reading the Command File. The BASIC indicator Input Samples reads a total value into the variable Samples. The issue is closed out when a CR appears. In the file this is followed with a LF, however. This must now be trapped with a Get to avoid upsetting the entry following. Likewise in the source text we find repeatedly an obviously superfluous 'Input S'. It is entered at locations where Vinculum quits a completed action with D:\>t. In this manner we ensure on the one hand that the ATmega does not new data until the old has first been processed, and on the other hand that no junk is left to remain in the data buffer of the microcontroller. The end result can be seen at the end of Listing 1. Now we shall try out everything

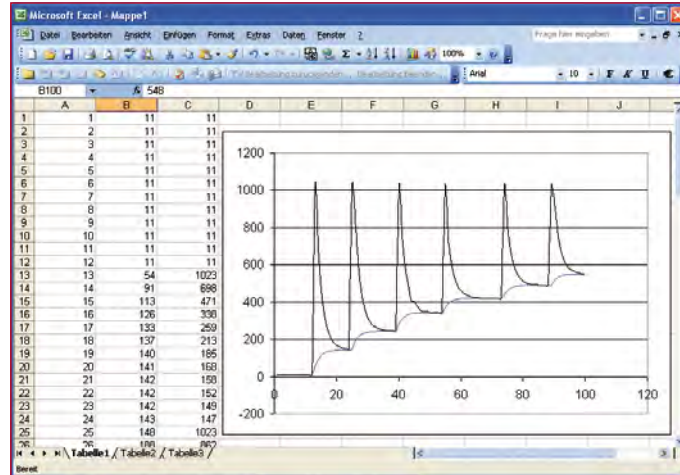


Figure 6. Data evaluation using Excel.

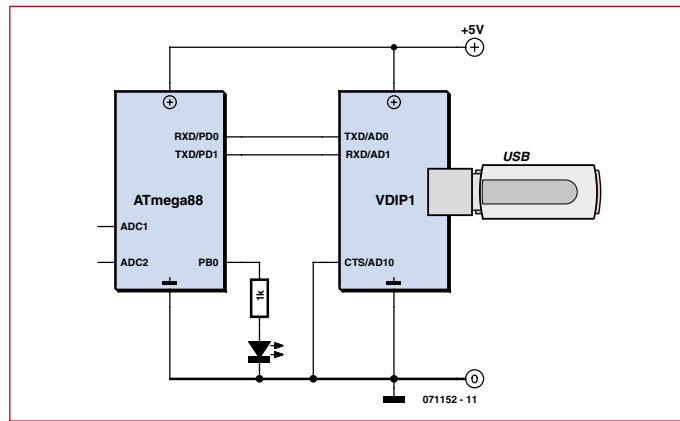


Figure 5. Connections between VDIP1 and ATmega88.

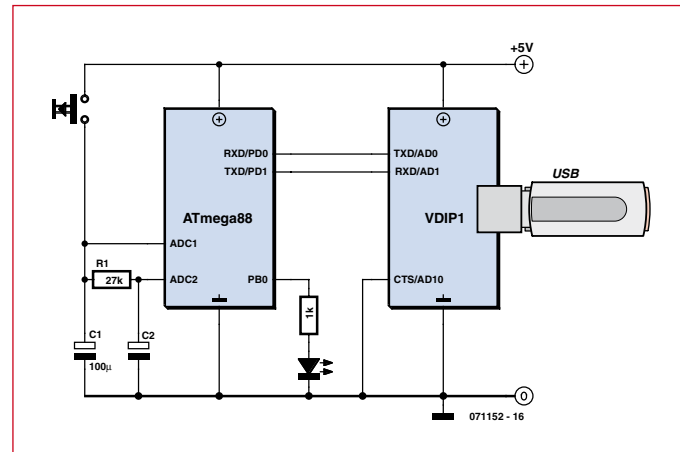


Figure 7. Mini measurement circuit.

stick should not be removed. The LEDs on the VDIP module indicate that data is being written regularly once a second. After a total of 100 seconds the measurement process is complete and PB0 drops to zero volts. Now you can remove the stick and plug it into the PC. The newly created file Log.txt now contains the measurement data that has been captured.

Measurement data:

11	11
11	11
11	11
54	1023
91	698
113	471

And so on.

Using the Tab symbol (ASCII 9) as separator between the individual channels renders this data easy to process in Excel.

The Excel chart in Figure 6 shows the measurements taken using the small circuit in Figure 7 — we are comparing the charge on two different capacitors that are linked by a resistor. The smaller of the two is 100 µF and is charged repeatedly with +5 V via the press-button switch. Prize question: what is the capacitance of the larger electrolytic?

(071152-1)

Internet Links

- [1] www.vinculum.com/documents.html
- [2] www.vinculum.com/documents/datasheets/DS_VDIP1.pdf
- [3] www.elektor.com/071152
- [4] www.elektor.com/080213
- [5] www.vinculum.com/documents/fwspecs/UM_VinculumFirmware_V205.pdf
- [6] www.vinculum.com/downloads.html
- [7] <http://staff.ltam.lu/feljc/electronics/basic/vinculum1.pdf> (if you don't read German you can still understand the pictures and use the Google translation engine at http://www.google.co.uk/language_tools?hl=en)
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BASCOM AVR

Course (3)

Timers and Interrupts

Burkhard Kainka (Germany)

Many practical tasks can only be solved by using accurate timing. The ATmega controllers are well equipped in this respect; the Mega8 to Mega32 controllers all have three timers, Timer 0 and 2 are 8-bit while Timer 1 is a full 16 bit wide.

The ATmega controller's timer/counter section looks a little daunting at first sight (**Figure 1**). They are highly configurable and require a certain amount of care to ensure they are set up correctly for your application. For those programming in Assembler this configuration procedure is quite involved but as you will see BASCOM simplifies things a lot.

The first thing to decide is the source of the timer/counter clock signal. It can come from the internal clock (directly or via a prescaler) or from an external source (e.g. connect to pin P1 for Timer 1). The counters can count on either the rising or falling clock edge and the counter value can be read or changed at any time via the TCNT1 register. When an overflow occurs it can generate an interrupt. The counters are commonly used for generating Pulse Width Modulated (PWM) signals. This is just a brief outline of some of the more basic properties of the timer/counters, as you become more familiar with the controller you will begin to get a better appreciation of their versatility.

Reading the timer

For the first exercise we are using the 16-bit timer driven by the system clock crystal and divided by 256 in the prescaler. In BASCOM all this information can be written on one line: `Config Timer1 = Timer , Prescale = 256`. The timer also begins counting so it is not necessary to use `Start Timer1`.

Listing 1 is the first test, as before we are using a `Goto` to reduce 'compilation clutter'. The listing as printed will only ever go to the first example, you will need to change fifth line to `Goto Test2` and recompile for the next exercise.

In `Test1 timer/counter1` just runs continuously and the counter value is displayed five times per second. The values are

in the range from 0 to 65535, and we can see that after roughly one second an overflow occurs:

```
088
17864
30706
43547
56389
69231
82072
94914
```

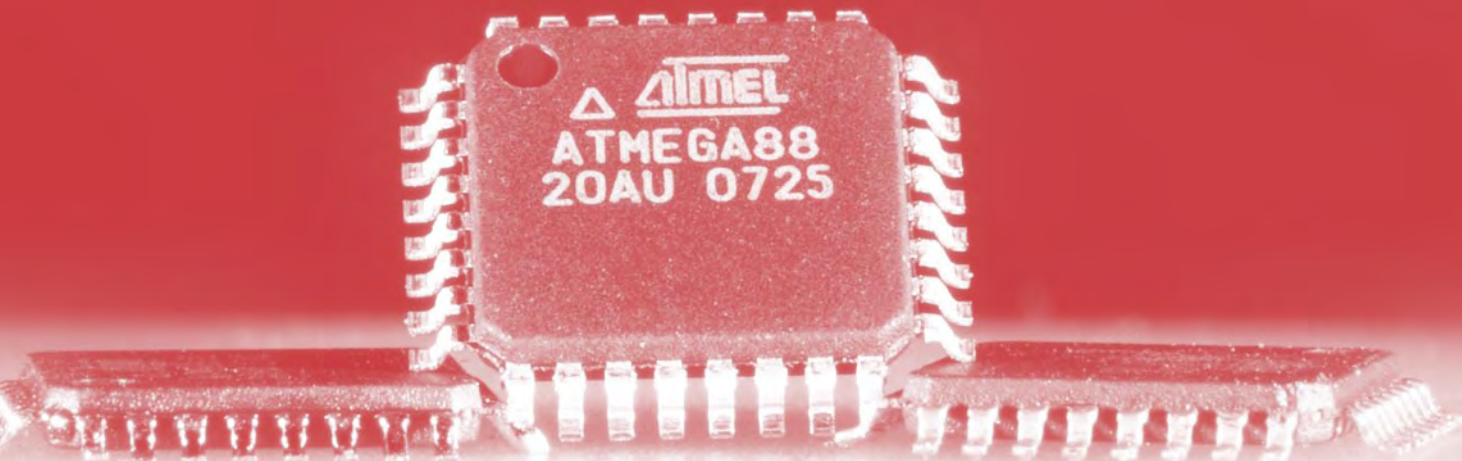
We know the clock frequency and the counter size so it is possible to work out the exact time between overflows: the counter clock is 16 MHz divided by 256 which gives 62.5 kHz. The counter overflows after 65536 clocks so the interval between each overflow is 1.049 s.

In this application the counter produces a precise time reference. We can now use this information to test how long the program takes to complete the two instructions: "Print Timer1" and "Waitms 200". Using for example the consecutive readings 43547 and 30706 the interval is $43547 - 30706 = 12841$ clock periods. One clock period equals $1 / 62.5 \text{ kHz} = 15.267 \mu\text{s}$.

The time between the two readings will therefore be $12841 * 15.267 \mu\text{s} = 196 \text{ ms}$ and not 200 ms. We can see that the `Waitms` instruction should not be used if it is necessary to make accurate time measurements.

Timer Interrupt

This exercise programs the controller to generate an accurate 1 second clock. The 16-bit Timer 1 is not necessary for this application; we can use 8-bit Timer 0. The timer will be programmed to overflow every 1000 μs and generate an interrupt.



An interrupt causes a forced interruption of the main program and directs the controller to execute a sub routine (Interrupt Service Routine or ISR) to service the interrupt. Different events can be programmed to generate an interrupt and an ISR is required to respond to each type of interrupt. Here Tim0_isr would be the subroutine name but in this example we have just used Tim0_isr: as a label which indicates where the program jumps to on interrupt. The last instruction of the interrupt routine must be a RETURN. In this example further interrupts will not be serviced until the return is executed.

Test 2 configures timer 0 with a prescaler of 64, which gives it a clock frequency of 250 kHz. The counter is 8-bits wide so without further programming it will generate an overflow interrupt every 256 clock cycles. We need the counter to interrupt every 250 clocks for an accurate 1 ms timebase so it is necessary to load the counter with the value 6 each time it overflows. A word variable called Ticks is incremented every time the counter overflows. When this variable reaches 1000 it indicates that one second has elapsed and the variable called Seconds is incremented. The value of either variable can be read by the main program. In this example the program sends the value of seconds to the terminal every second starting from zero at program start. It is necessary to allow the interrupts to occur by enabling the global interrupt (Enable Interrupts) and also allow the timer 0 overflow condition to generate an interrupt (Enable Timer0). The display shows the value of seconds:

```
0
1
2
3
```

All interrupt sources can be disabled by using Disable Interrupts.

Averaged measurements

Measurements made of analogue signal levels are often affected by a 50 Hz mains signal superimposed on the voltage level. The unwanted 50 Hz component can effectively be cancelled out by sampling the analogue voltage level several times during a complete cycle of the mains voltage (20 ms) and then averaging all the measurements.

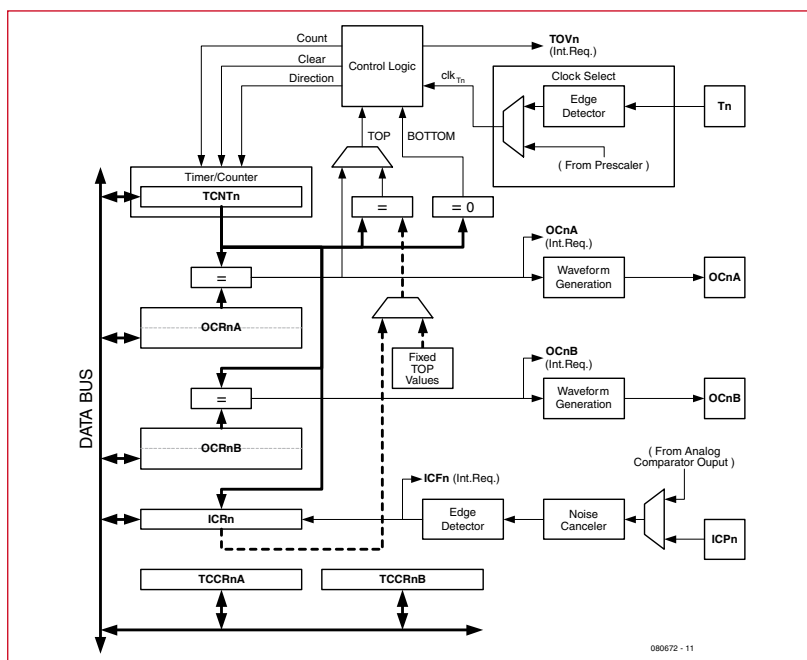


Figure 1. Block diagram of the timers.

Listing 1

Reading the timer registers

```
`Bascom ATmega88, Timer
$regfile = "m88def.dat"
$crystal = 16000000
Baud = 9600
Goto Test1

Test1:
Config Timer1 = Timer , Prescale = 256
`Start Timer1
Do
  Print Timer1
  Waitms 200
Loop
```

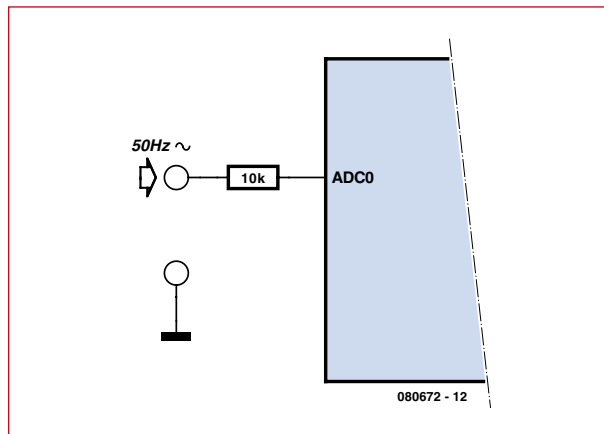


Figure 2.
Measuring an ac voltage.

For this exercise we will use a timer interrupt again to generate an accurate timebase. The average value is achieved by sampling the analogue signal 25 times in a 20 ms time window. The sampling interval is therefore 800 μ s. Timer 2 will be used with a prescale value of 64. Each time it overflows Timer2 is loaded with the value 56 so that the next overflow occurs 200 clocks later.

800 μ s is more than enough time to make the analogue measurement and calculate the sum and mean value. The variable Ticks is incremented each time a measurement is taken every interrupt. After 25 measurements the sum stored in AD0 is transferred to the variable AD0_mean. The main program averages the value and then sends it to the screen.

Averaging in this way gives such good suppression of the 50 Hz components that by using half wave rectification the system can be used to measure ac signals. The low voltage AC signal is connected to the ADC0 input via a 10 k

Listing 2

Exact seconds using interrupts

```
Test2:
Dim Ticks As Word
Dim Seconds As Word
Dim Seconds_old As Word
Config Timer0 = Timer , Prescale = 64
On Ovfo Tim0_isr
Enable Timer0
Enable Interrupts

Do
  If Seconds <> Seconds_old Then
    Print Seconds
    Seconds_old = Seconds
  End If
Loop

Tim0_isr:
  '1000  $\mu$ s
  Timer0 = 6
  Ticks = Ticks + 1
  If Ticks = 1000 Then
    Ticks = 0
    Seconds = Seconds + 1
  End If
Return
```

Listing 3

Measuring averages

```
Test3:
Dim Ad0 As Word
Dim Ad0_mean As Word
Config Adc = Single , Prescaler = 64 , Reference = Off
Config Timer2 = Timer , Prescale = 64
On Ovfo Tim2_isr
Enable Timer2
Enable Interrupts

Do
  Ad0_mean = Ad0_mean / 25
  Print Ad0_mean
  Waitms 100
Loop

Tim2_isr:
  '800  $\mu$ s
  Timer2 = 56
  Ticks = Ticks + 1
  Ad0 = Ad0 + Getadc(0)
  If Ticks > 24 Then
    Ticks = 0
    Ad0_mean = Ad0
    Ad0 = 0
  End If
Return
```

protection resistor (**Figure 2**). The program now finds the average value of the positive half wave which is equal to half of the absolute average value of the sine wave. A typical sequence of measurements would be:

```
226
227
226
226
226
226
```

Although there is some variation the measured average value is mostly 226. This can be converted into a real voltage level: $5\text{ V} * 226 / 1023 = 1.10\text{ V}$. The measured alternating voltage therefore has an absolute average value of 2.20 V. For a sine wave this equates to an RMS value of 2.44 V and a peak to peak value of 3.46 V_{p-p} . The relationship between the peak and RMS value of a sine wave is $\sqrt{2} = 1.414$. For arithmetic averaging the relationship of the peak value to the average value is $\pi/2 = 1.571$, so the absolute average value is 90.03 % of the RMS.

(080672-1)

Downloads and further information:

The programming examples and more information for this course can be downloaded from the project page at www.elektor.com. As always we look forward to your feedback in the Elektor forum.

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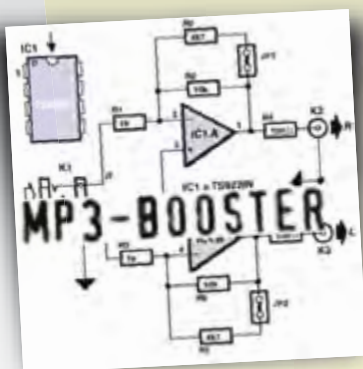
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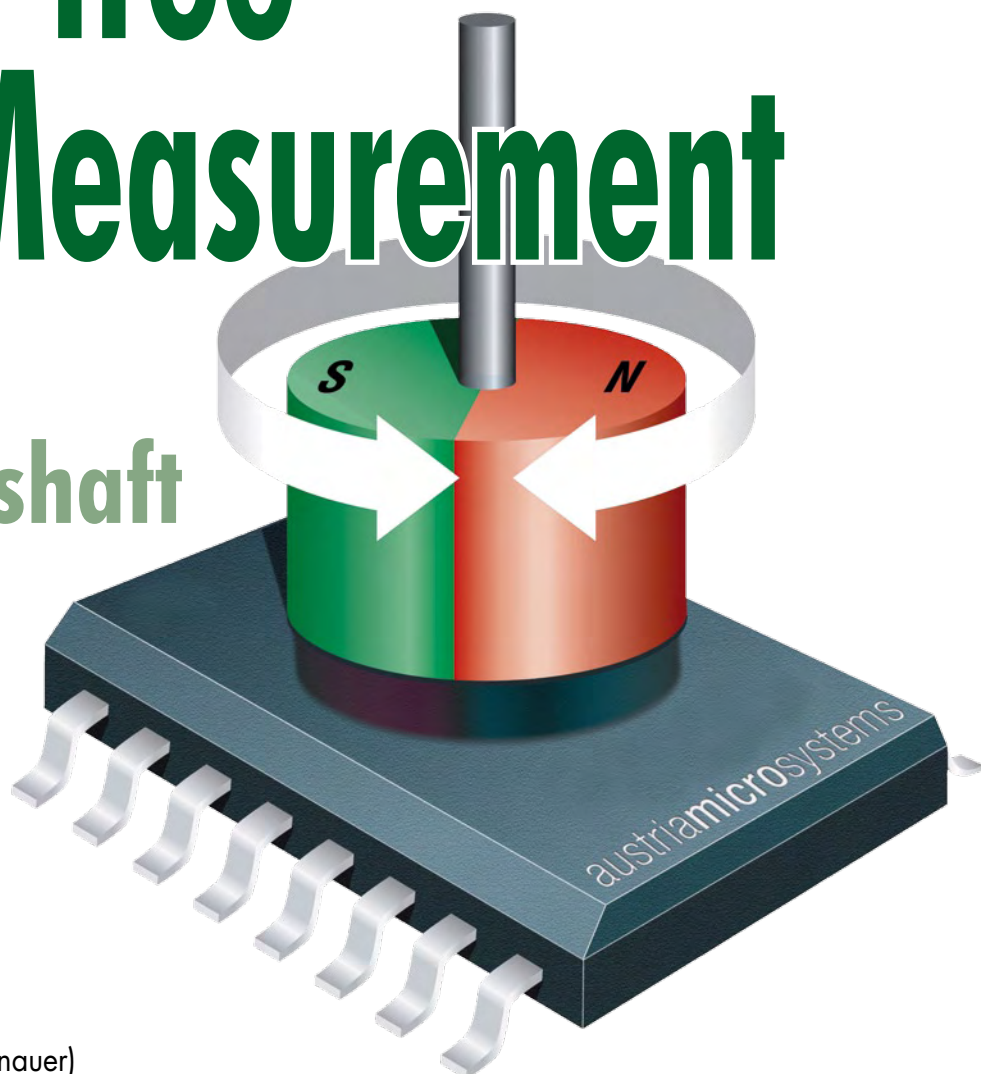
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Friction-free Angle Measurement

a magnetic shaft
encoder
using the
Hall effect



Josef Warta
(with the assistance of Andreas Riedenauer)

Measuring angles has until now involved a choice between potentiometers and optical encoders. Potentiometers are inexpensive, but have the disadvantages that they require calibration and create friction; optical solutions, although offering high accuracy and long-term stability, are mechanically more complicated and considerably dearer. In this article we describe a modern semiconductor-based solution: a magnetic shaft encoder using Hall effect sensors.

A potentiometer can measure a varying angle by converting it into a varying resistance. This has the advantage that an absolute angle reading is available immediately when the circuit of which it forms a part is turned on. The disadvantage is the friction created when the shaft is turned, and furthermore poor tolerance means that calibration is a necessity. The optical approach offers much greater precision,

service life and long-term stability, but on the other hand an absolute angle reading can only be obtained using a complicated optical system, increasing overall costs.

It is possible to construct an angle sensor by exploiting the Hall effect, offering high precision and low cost. There is a mechanical separation between the moving and fixed parts of the de-

vice, which means that it is possible to make units sealed against moisture and dust for use in robotics, industrial machinery, medicine, aerospace and many other application areas.

The basics

Hall effect sensors for measuring magnetic fields are already in widespread use, for example to determine the ro-

tor position in brushless DC motors. In these applications the sensors are simply used as switches to replace slow, unreliable mechanical contacts. The Hall effect is exhibited to some degree by any electrical conductor; the strength of the effect depends on the material and using modern semiconductor technology we can build highly sensitive Hall elements into integrated circuits at low cost.

The principle of operation of a Hall element is illustrated in **Figure 1**. A voltage proportional to the magnetic field strength is developed across the sensor when a current flows through it. A rotating bar magnet or bipolar magnet will therefore give rise to a sinusoidal voltage, just as a coil does in a rotating magnetic field. In contrast to this induced voltage, however, the output signal of the Hall sensor can be measured statically, since a stationary magnetic field gives rise to a constant Hall voltage.

A single Hall sensor can be used as an angle measuring device as shown in **Figure 2**. We are restricted to the quasi-linear region of operation of the sensor between -45° and $+45^\circ$. High precision of mechanical construction and alignment between magnet and sensor is required. Temperature variations can affect the magnet and hence the amplitude of the output voltage of the sensor, reducing accuracy unless temperature compensation is used. External magnetic fields directly affect the amplitude and phase of the output voltage, and so magnetic screening is essential.

Take four

These obstacles to the accurate measurement of angles can be solved elegantly using a circular arrangement of four (or even more) sensors. The rotational axis of the magnet should go through the middle of the circle. Each pair of diametrically opposite sensors is connected to a differential amplifier (**Figure 3**), and the difference voltage gives the gradient of the Z component of the magnetic field. These gradients vary sinusoidally with angle, and, if the sensors are accurately aligned, the two gradients will be 90° out of phase with one another, giving a sine and a cosine signal. These two signals are digitised, and a low-pass filter reduces jitter and noise. A DSP device implementing the CORDIC algorithm can be used to perform the coordinate trans-

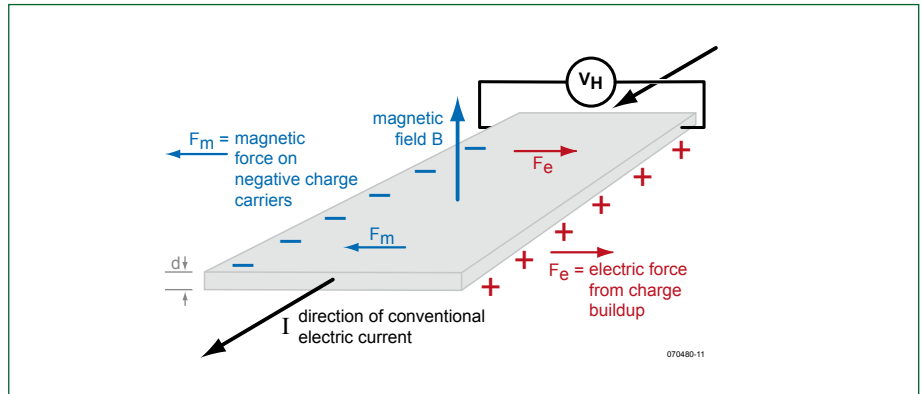


Figure 1. Principle of operation of a Hall element. In contrast to electromagnetic induction, the Hall element produces a voltage in a stationary magnetic field.

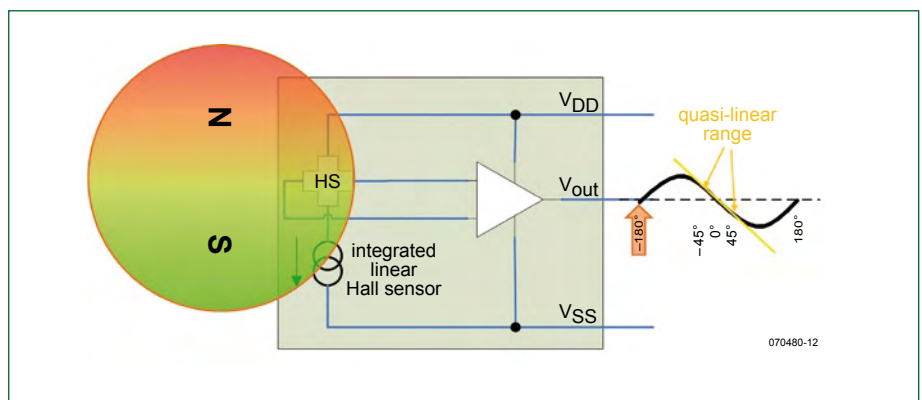


Figure 2. When a single Hall sensor is used the measurement range is limited to between -45° and $+45^\circ$.

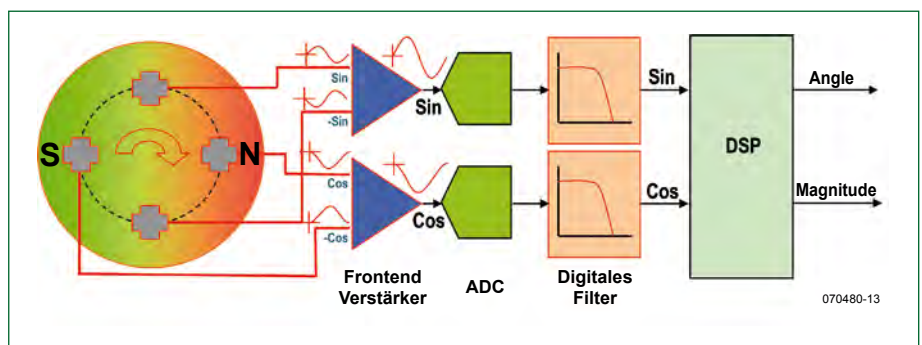


Figure 3. Measurement independent of stray fields using four Hall sensors.

formation from the sine and cosine signals to give amplitude and phase information. The amplitude output can be used to control the current source feeding the Hall sensors so that the device's sensitivity is independent of the magnetic field strength, as well as to give an indication of the distance between the magnet and the sensor circuit. If a sensor IC includes this output, it is simple to add a contactless pushbutton feature to a contactless rotary switch.

Shaft encoder ICs

Austriamicrosystems (AMS), based in Unterpremstaetten near Graz in Austria [1], has developed a family of magnetic shaft encoder ICs along the lines illustrated in Figure 3. The AS50xx series of shaft encoders offers resolutions from 8 bits to 12 bits and a range of output interfaces: serial, PWM, analogue, incremental, or combinations of these. As well as high accuracy and wide operating temperature range the sensors also feature rapid processing,

Accuracy of a shaft encoder system

There are two parameters of a shaft encoder that are often confused: resolution and accuracy. The two are not necessarily related to one another.

Resolution is the size of the smallest step, or the number of equal steps per revolution, that the encoder can distinguish. A 12-bit encoder therefore has a resolution of $2^{12} = 4096$ steps per revolution, or 0.08789° per step. The resolution is chiefly determined by the analogue-to-digital converters (ADCs) and by the precision of arithmetic used in the CORDIC calculation.

Accuracy is a measure of the deviation from the reported angle value from the true angle. Many factors affect the accuracy of a magnetic shaft encoder, jointly determining the overall quality of the device. The most important factors are as follows.

Phase error of the Hall signals

This error would be expected to be small, since the Hall elements are arranged exactly at right angles to one another. However, a problem can arise with a rapidly rotating magnet if there is a differential delay in the paths taken by the sine and cosine signals. This can happen if a single analogue-to-digital converter is used to sample the signals alternately. The AS5030 uses parallel converters, keeping the phase error negligibly small even at high rotation speeds.

Matching error between Hall sensors or amplifiers

This error is minimised by a carefully-optimised IC layout and advanced semiconductor manufacturing technology.

Offset errors in the signal path

An offset error will add a DC component to the sine or cosine signal. Such errors generally originate in the Hall sensors themselves or in poor matching between transistors in the analogue signal path, and can be minimised by design techniques such as spinning current compensation in the Hall element, chopper amplifiers and on-chip trimming adjustments.

Non-linearity of the ADC

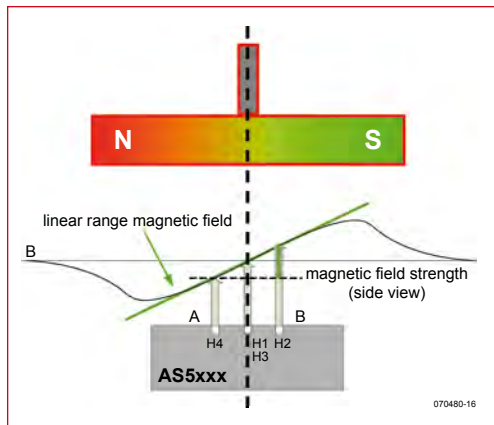
Non-linearity in the ADCs can only be compensated for by a tedious calibration process, and so the linearity requirement on these components is correspondingly demanding.

Non-linearity of the magnet

If we consider the vertical component of the magnetic field (to which the Hall elements are sensitive) parallel to the rotational axis, the maxima are at the poles. In between the poles the behaviour is broadly linear (see illustration).

As long as all the Hall elements are in this linear region the differential signal will be of constant amplitude, independent of the horizontal position of the magnet.

Larger diameter magnets therefore allow for greater horizontal offsets than smaller ones. On the other hand, the graph of field intensity against displacement is also flatter, which means that the amplitude of the differential signal is reduced. This in turn requires greater amplification, resulting in poorer signal-to-noise ratio. The best compromise is found using magnets with a diameter of approximately 6 mm: experience indicates that the maximum error induced by an imperfectly-centred magnet is well under 1° ; with a centred magnet the maximum error is under 0.5° .



allowing position measurements at rotational speeds of up to 30000 revolutions per minute.

We shall take the AS5030 [2] as an example device. This costs around five pounds bought individually, falling to just over three pounds each for fifty or more devices, and is therefore an economical solution in simple angle measurement applications. The Hall sensors are fabricated using a CMOS process and operate from a 5 V supply. The signal processing logic is integrated onto the device (see block diagram in Figure 4). Internal compensation assures reliable performance from -40°C to $+125^\circ\text{C}$, with parts for automotive applications specified for operation up to $+150^\circ\text{C}$. The differential measurement technique inherently compensates for external magnetic fields, ageing of the magnet and variations in temperature. The device offers eight-bit resolution, distinguishing 256 angles over a 360° revolution: this corresponds to an angular resolution of 1.4° . In addition to angle, the device also measures the overall field strength, which it reports using a six-bit code. This allows the distance to a rotating magnet to be estimated, or the implementation of a contactless pushbutton feature as described above.

The position value can be output over a serial digital interface (two-wire or three-wire) or using a PWM ('one-wire') output. A zero position can be programmed into the device's OTP (one-time programmable) memory to simplify assembly by obviating the need to align the magnet precisely. A low power sleep mode with rapid wake-up allows the device to be used in battery-powered applications.

The device can be used with hard-wired logic rather than a microcontroller for fail-safe operation, ideal for safety-critical applications employing redundant systems. A diagnostic facility provides a warning if the magnet works loose or is not present. A basic accuracy of $\pm 0.5^\circ$ means that in many applications calibration is unnecessary.

A complete position measurement system can be made using just an AS5030 (see pinout in Figure 5), a decoupling capacitor, and a bipolar magnet mounted perpendicular to the rotation axis.

Sources for the AS5030 and two kinds of magnet can be found at [2], while

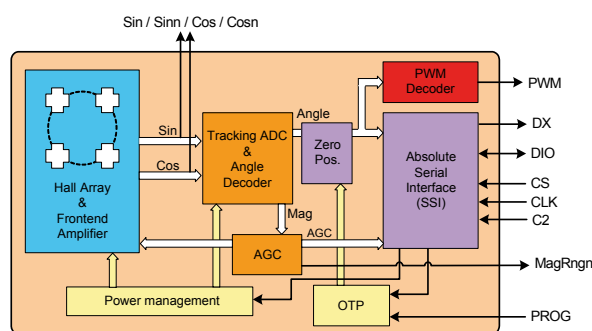


Figure 4. Block diagram of the AS5030 angle encoder IC.

data sheets and other downloads can be found at [3].

Magnets

The magnet can be press-fitted or glued directly to a non-magnetic axle. Rare earth magnets are recommended because of the higher field strengths obtainable: neodymium-iron-boron magnets are cheaper than samarium-cobalt magnets, but have a higher temperature coefficient and lower maximum working temperature. The main parameters when selecting a magnet are:

- temperature coefficient;
- dependence of field strength on magnetic field strength (automatically compensated for by AS5000 series encoders);
- Curie temperature;
- maximum working temperature;
- field strength, measured in Tesla or kilogauss.

In addition to the sample magnets available at [2], a wide selection is available at [4] and [5]. Software for simulation of magnetic fields is available at [6].

Demonstration board

AMS produces demonstration boards for all its encoder ICs to help designers gain practical familiarity with the de-

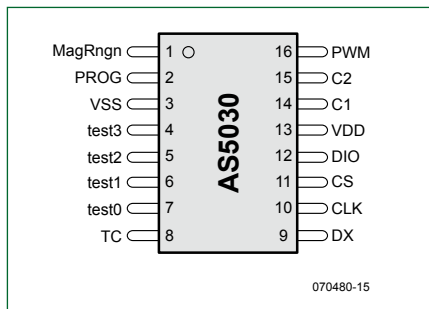


Figure 5. Pinout of the AS5030. The output signal is available on a serial digital output and as a PWM signal.

vices. The boards consist of a small printed circuit board which carries the sensor IC, a microcontroller, a four-digit seven-segment display, a USB socket for connection to a PC, and a header for connecting an expansion board. A hole in the Perspex cover accepts a rotary button fitted with a magnet. Figure 6 shows the AS5030 DB demonstration board for the AS5030 device, again available at [2]. An external angle sensor can be connected using the header, for example on an AS50xx adapter board, available as an optional extra. This external sensor can then conveniently be configured or permanently programmed using the demonstration board software, available for free download at [3]. More details about

the demonstration board and adapter board can be found in the PDF manuals available for download at [7]. A free encoder software development kit (SDK) is also available for download, including a DLL and example programs for dedicated applications based on the demonstration board. Further information can also be obtained from AMS' distributors [8].

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Web Links

- [1] <http://www.austriamicrosystems.com>
- [2] http://www.austriamicrosystems.com/03products/products_detail/AS5030/description_AS5030.htm
- [3] http://www.austriamicrosystems.com/03products/products_detail/AS5030/download_AS5030.htm
- [4] http://www.bomatec.ch/index_e.php
- [5] <http://www.arnoldmagnetics.com>
- [6] <http://www.invensense.com>
- [7] http://www.austriamicrosystems.com/03products/products_detail/AS5040/download_AS5040.htm
- [8] http://www.austriamicrosystems.com/06contactcenter/distributors_start.htm



Figure 6. An AS50xx demonstration board provides a development environment for dedicated applications using its accompanying free software.

Colourful Computer Light

Controlling the Living Colors lamp with USB

Jeroen Domburg

We live in a colourful environment these days. Everything is in colour: TV, advertising billboards, mobile phone displays and LEDs. Philips added a further dimension to all this with their Ambilight, Wake-up Light and Living Colors lamp. We will

work with the latter in this M&T article. The wireless remote control offers interesting possibilities once the protocol has been cracked...



In the February 2008 issue the editors disassembled a Living Colors lamp from Philips. In this article we will once again do something with this lamp. One of the disadvantages of the lamp is that it can only be controlled with the supplied remote control. Nice enough perhaps, if all you want to do is use it as a glorified table lamp. But controlling it with a PC offers many other possibilities. Turn the room red

when you've received mail, let the colour of the wall follow the movie you're watching, illuminate the room when it's time to get up, you mention it!

Lively colours

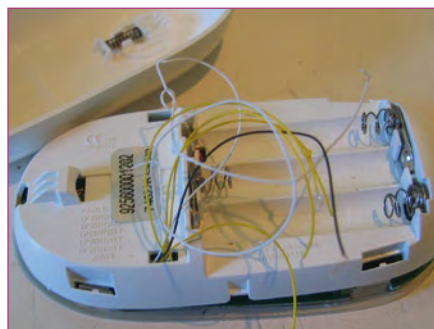
For those who missed the article mentioned earlier: a Living Colors lamp is an appliance made by Philips that with a few bright, coloured LEDs can illumi-

nate a room in just about any conceivable colour. In this way you can create or enhance a particular mood. The Living Colors lamp comprises the lamp itself and a remote control. The two are linked via a CC2500, a little IC from Texas Instruments, which can send data over a 2.4 GHz radio link.

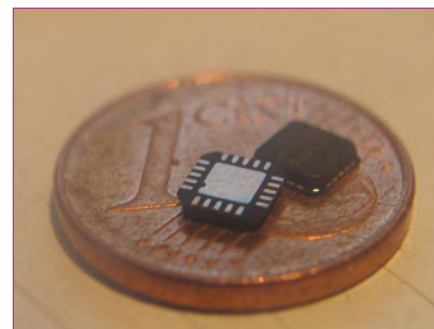
To be able to control the lamp we will first have to figure out how the data is sent. Measuring this without open-



In the remote control we find two printed circuit boards that are interconnected with a ribbon cable.



This is how we reverse engineer the protocol. It may not look like it, but apart from the wires the remote control is still completely intact.



The all-important CC2500 chip. They don't come any bigger than this, unfortunately...

ing the device is difficult. Firstly, because the CC2500 has several methods available for sending the data (MSK, FSK, OOK, with or without data whitening, Manchester-encoded, etc.) so it is a lousy job trying to dig out the transmitted data from the actual radio signal transmitted. Secondly, the author, in contrast to the RF people at the editorial offices, does not have SHF measuring equipment at his disposal, something that's crucial with this approach. We will therefore have to decode the information using some other method...

Eavesdropping

Taking a look at the datasheet for the CC2500, we read that the chip gets its data from the host-processor via a 4-wire serial connection, with the option of two more wires for status information. If we eavesdrop on the traffic on this 4-wire bus we should be able to learn a whole lot more about what is being transmitted.

Although there are two CC2500s, namely one in the remote control and one in the lamp itself, we decided to listen only to the one in the remote control. The reason for this is less philosophical than you may think: it proved to be impossible to open the lamp without damaging it, but it turned out that opening the remote control was a lot easier. The remote control consists of two printed circuit boards. The PCB for the touch sensitive 'push buttons' plus the controller for these, a QT1106 is connected with a ribbon cable to the smaller main PCB that contains the MSP430 processor and the CC2500. Tapping into the bus is rather difficult, but with the aid of thin wire and some instant glue it was eventually possible to make a mechanically strong tap. Because interpreting the protocol using only an oscilloscope is rather tedious,

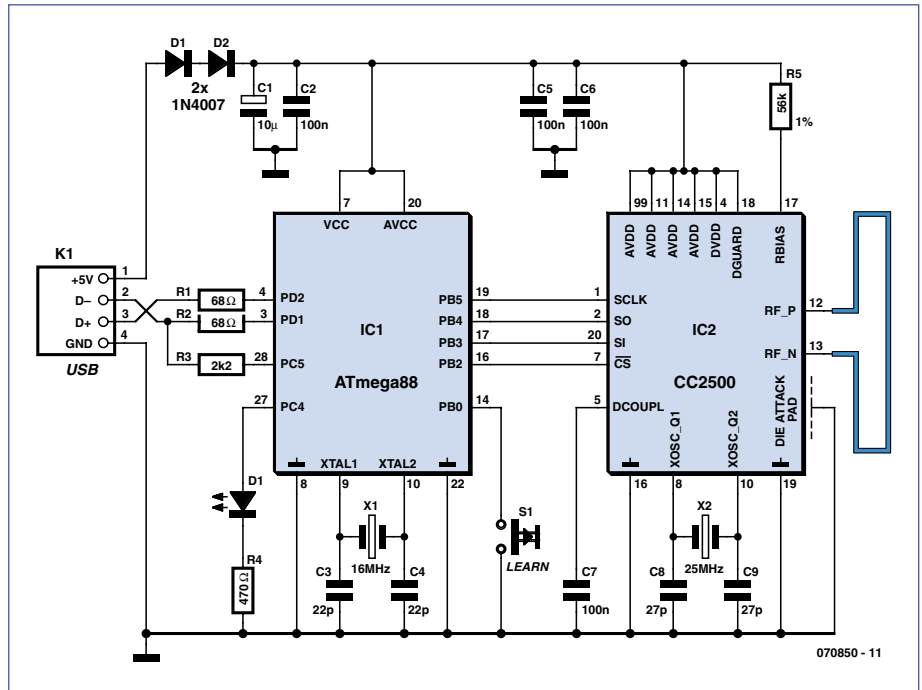


Figure 1. It can't be much simpler than this: we do the control of the CC2500 with an ATmega88 via USB.

ous, we use an AVR with hardware SPI support for the actual 'sniffing'. This AVR then sends the eavesdropped signal via a serial port to the PC where the actual decoding can begin. When we push a few buttons on the remote control, it is immediately clear that the protocol is more complicated than we had initially anticipated. When the remote control is first turned on, the CC2500 is initialised with data regarding the frequency, the type of modulation and the data rate. The actual communication is based on packets. A packet is loaded into the CC2500 and transmitted by the chip in RF form. Reception is done in the same way. The CC2500 is set to receive mode and as soon as a packet has been received a particular pin

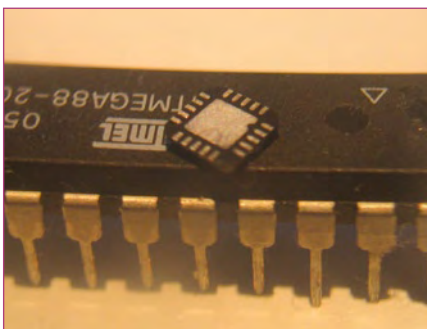
goes high and the packet can be read by the microcontroller.

Data format

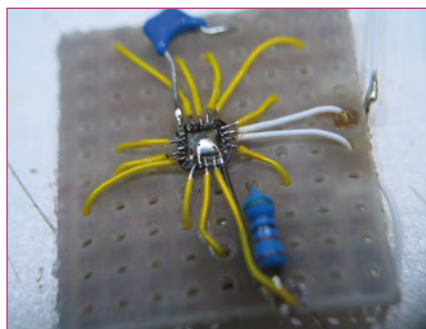
The packets consist of a number of fields. The first thing that emerges is that both the remote control and the lamp have a, probably unique, address. Therefore, the packets for setting the colour, for example, start with the address of the lamp followed by the command.

The commands correspond with the buttons on the remote control. There is, among others, a command to turn the lamp on, to turn it off again, to set the colour and to set the lamp in demo mode.

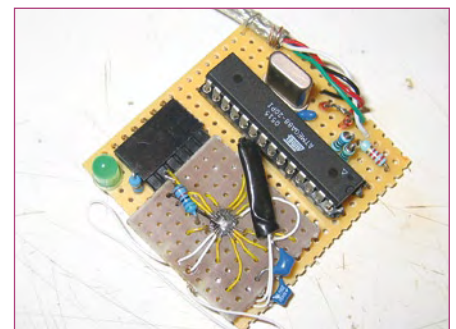
The command is followed by a se-



In comparison with the ATmega88 the latter is indeed quite 'mega'.



The size does not make it impossible to solder. A steady hand, a magnifier and thin wire go a long way.



This is how the transmitter is mounted on the USB PCB. The thing with black tape around it is a 25-MHz SMD crystal.



quence number. This is a number that increments by one after each command is sent. When the lamp sends a response, this same sequence number is sent back so that the remote control can determine which response goes with which command.

It gets more interesting after the sequence number byte. There now follow three bytes with colour information. The fact that colour information is being sent is somewhat remarkable, since the average remote control only passes on which button is being pushed. The decision to store the selected colour in the remote control makes sense. In this way Philips ensures that if you use the remote control with multiple lamps they will all be set to the same colour. For our purposes this is also very practical: it is, after all, much easier to sent the desired colour than to emulate all sorts of button pushing.

To send the colour, Philips decided to use the HSV system. The Hue gives the colour, the Saturation the intensity of that colour and Value the amount of light the lamp has to generate. By giving the appropriate command with certain HSV-values the desired colour can be set immediately. And because the wireless connection operates at a speed of 500 kbaud, this is relatively quick as well.

Control

Okay, we have the protocol, we have the initialisation data and we know how we can set the colour of the lamp. What are we now going to do with that knowledge? The author decided that an Ambilight-ish functionality would be nice to do. The plan therefore, was to build a device that could be connected to the PC and control several lamps.

For the control we can use existing software: on the internet there is a community of people who make their own PC controlled Ambilight clones. This has resulted in a few nice Linux and Windows applications that are very useful for this project. The most

common protocol used in this software is the MoMoLight protocol, which is actually nothing more than sending the RGB values for three different light sources directly to the serial port.

To be compatible with the software we need a few things. Firstly we'll have to emulate a serial port over the USB bus and secondly we'll have to convert the incoming RGB data to the HSV format that's expected by the lamps.

The first requirement is easily met with one of several ready-made solutions: a number of companies make USB-to-RS232 converter ICs that can be directly connected to the bus. For this project however, we chose a different approach. The heart of the circuit consists of an ATmega88 which is connected directly to the USB port. If we look at the datasheet for this AVR we will however not find any mention of hardware to support USB. So how does this work then?

The solution is to be found in a trick: with some clever programming most of the AVRs can be made to 'mimic' a low-speed USB device. There even exist special libraries for this purpose [1]. Several projects have been made around these libraries: USB-programmers, bootloaders, display controller, just name it. One of these projects is called AVR-CDC and its purpose is to implement a USB to serial converter in software. That's just what we need! The software is licensed under the GPL, which means that if you build a device using it, you also have to supply the source code. That is not a problem for this project.

An RGB to HSV converter is also easily picked from the Internet. There are multiple solutions on various websites, but they are often based on floating point, which means that the already busy AVR has to do even more. After an extensive search we fortunately also found an integer version, which costs far fewer clock ticks. This software is released under the MIT license, which, after a little searching, appears to be compatible with the GPL. So after a copy-paste operation we've already

gathered half of the required code. The code to control the wireless chip is all that remains. Because this chip has a comprehensive datasheet and we have a good example obtained by eavesdropping on the data from the remote control, this is not a big deal.

Hardware

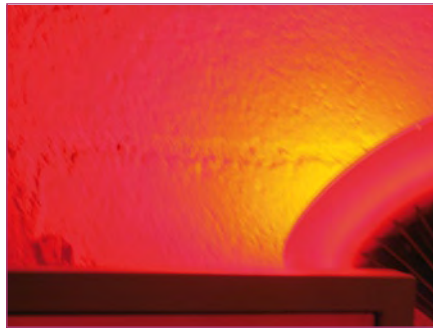
Because we've solved a number of requirements in software, the circuit that remains is not tricky at all (**Figure 1**). On the left is the USB connection, which is connected with a few, and according to the USB specification, mandatory resistors to the AVR. The CS2500 and the USB data lines require a power supply voltage of 3.3 to 3.6 V. This is obtained in a simple way from the 5 V on the USB connector. Connect two diodes in series with this 5 V and the voltage drops to about 3.5 V.

On the right of the schematic is the CC2500, in a configuration which is nearly entirely a direct copy from the datasheet. The loop between RP_P and RP_N is the antenna. Although there are quite specific requirements for this antenna in the datasheet, a wire about 11 cm long and bent into the shape indicated suffices in practice and works well over a short distance.

The schematic looks quite simple, but the assembly of the circuit is much trickier than it looks. This is because the CC2500 chip, which deals with the necessary RF communication, is only available in a QFN package. For those that are not familiar with SMD pack-



And the end result: the Living Colors lamps



ages: the five pins on each side of this tiny chip all fit between two pins of a normal DIP package. As if that is not bad enough, most of the 20 connections to the IC have to be actually connected as well. How do we solve this as hobbyist without access to an expensive SMD equipped workshop?

Of course, there are conversion PCBs available, but they are generally quite expensive and certainly the versions for QFN are not readily available. The author therefore chose for the 'dead bug' method: the chip is glued upside down with a drop of instant glue to a small piece of prototyping board. The connections are now made with thin wire to the copper tracks of the prototyping board. This type of wire is sold with the name Kynar- or wirewrap wire, but a cheaper alternative is salvaging an 80-way IDE cable; the individual wires are about the same size. Once the module with the CC2500 is done, the remainder is not too much trouble. That is because these are all through-hole parts. In the end the diligent effort results in a little PCB about the size of a match box, with the USB connector as its only connection.

Compatibility problems

All that is left to do is plugging in the connector and testing of the assembly. The first tests appear to go really well, but several colours look absolutely nothing like those on the screen. How can this be? A quick test with a graphics program that can generate



in use as an Ambilight clone.

HSV colours indicates that the HSV-to-RGB conversion in the lamps does not follow the official standard entirely. Although the saturation and value are correct, there is a certain non-linearity in the hue curve. Fortunately this can be fixed. After a few observations of the differences in colour, a table can be constructed which converts 'real' hue-values to their equivalent Living Colors hue values. The table is not really an ideal solution, but if you notice the colour differences when watching a movie you will have to ask yourself whether that movie is really worth your time... Because there is little chance that other lamps have the same addresses as the lamp we used, there is a learning routine in the AVR. This works as follows. First make sure that all lamps that have to be controlled can be operated with one remote control. You can 'add' a lamp to a remote control by holding the remote against the Philips logo on the front and pushing the '1'-button on the remote. Do this for all the lamps and if all is well, all lamps will now react to that remote control.

Once the remote control knows all the lamps it is possible to transfer the addresses to the AVR: push button S1 and press the '0' button on the remote control until the LED on the PCB (D1) turns off. What is happening? The remote control attempts to turn off all the lamps by sending each lamp the 'off' command. The AVR also listens on this channel and stores every passing address. These addresses are saved in EEPROM. 'Acquired' addresses remain in the AVR until replaced by other ones after the learn-button is pressed again. The addresses are also retained when the power supply voltage is removed.

The last mile

How does all this work on the PC side? As already mentioned, the AVR presents itself as a serial port that understands the so-called MoMoLight protocol. This means that any program that supports this protocol can control the Living Colors lamps. A few exam-

ples of these are, just like the firmware for the Atmel, on the website of the author [2] and on the project page at www.elektor.com.

For programmers who would like to write their own software: the MoMoLight protocol supports up to three RGB light sources. To set the lamps to the desired colour the emulated serial port needs to be opened at a baud rate of 4800, no parity and 8 data bits. The RGB values for the lamps can now be sent in nine bytes in the order of R1,R2,R3,G1,G2,G3,B1,B2,B3.

A final remark: it has come to the author's attention that the software USB stack is not quite as compatible with all computers as it should have been. Should there be a problem with a particular PC, you can try to connect the device via a USB2.0 hub to the PC. If this is all to no avail then there is also a serial version available on the author's website.

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Web Links

- [1]: www.obdev.at/products/avrusb/index.html
- [2]: <http://meuk.spritsserver.nl/projects/livcol>

About the author:

Jeroen Domburg is a student at the Saxion Technical University in Enschede, the Netherlands.

He is an enthusiastic hobbyist, with interests in microcontrollers, electronics and computers.

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

Universal Remote Switching with any remote control

Jeroen Hoppenbrouwers (Netherlands)

The Universal Remote Switch Box is a universal remote control receiver, fitted with 16 open-collector outputs. Each of these can be configured either as a momentary or a toggle output. In addition there is also a master/slave function built in.

This Universal Remote Switch Box was inspired by the 'Easy Home Remote Control' circuit in the 2006 July/August issue (page 72).

This circuit has only 4 outputs, however, and accepts only RC5 codes. To eliminate the latter limitation, the firmware of the circuit described here is based on the 'Universal Infrared Receiver' (UIR, see sidebar), which makes it suitable for all types of remote control.

How it began

A few years ago I wanted to build an IR-receiver for my PC. First I built the receiver by Holger Klabunde [1], but I was really disappointed with the software that comes with it. After much looking around I came across UIR on the website of Srdan Milostic (now no longer on-line). The hardware was practically identical, but UIR could handle all kinds of remote control. After replacing the PIC I had a good remote control for my PC.

Later on, I had the idea of using UIR with a second microcontroller for a remote switch box that doesn't require a PC. But two microcontrollers, that is just a little bit extravagant. Because only the HEX-code was available, I converted the original code into assembler. Around this assembler code I subsequently built an additional shell. And with this the Universal Remote Switch Box was born.

The schematic

The hardware is straightforward:

- a TSOP1736 receives and demodulates the IR-signals;
- with a dip-switch and three push buttons the circuit can learn different codes;
- three (bi-colour) LEDs are used as status indicators;
- there are two ULN2803 output buffers for driving the outputs;
- an LTC485 (or similar) is used for the RS485 port;
- the brain of the whole thing is the PIC16F877.

There is not much else to say about the schematic, except that the output buffers are capable of driving relays directly. The 'learning' of the different IR-signals and the RS485 connection are described a little bit later on.

To make the PCB compact, a number of SMD components are used. These are standard parts however. The PCB is single-sided, although this results in the need for two wire links.

The Firmware

When the circuit receives a signal from the remote control it is decoded with the aid of the UIR software into a 48 bit code. This is compared, via the RECEIVED_CMD subroutine, which checks whether a valid command was received, with the codes that are stored in the EEPROM. When a valid code

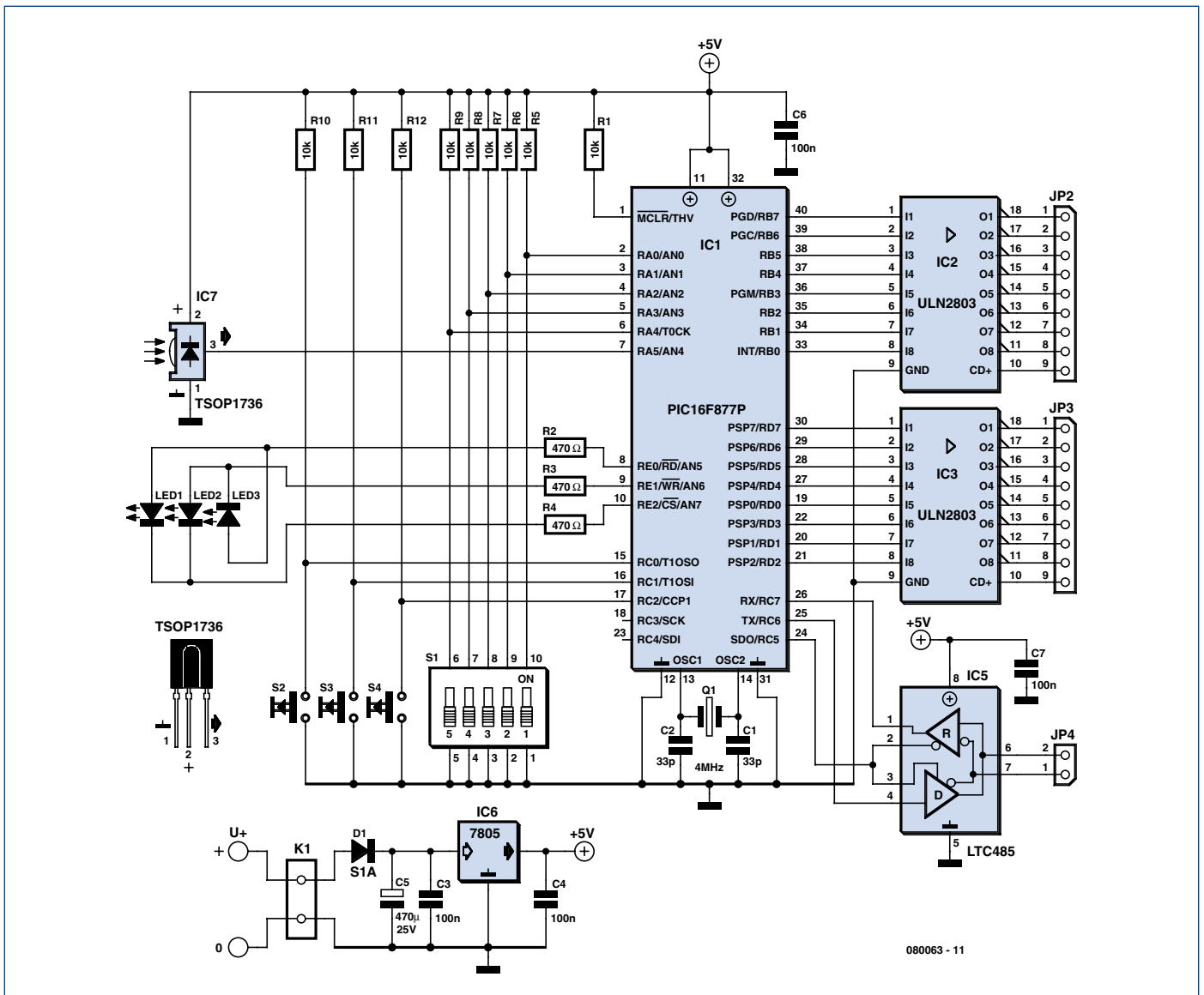
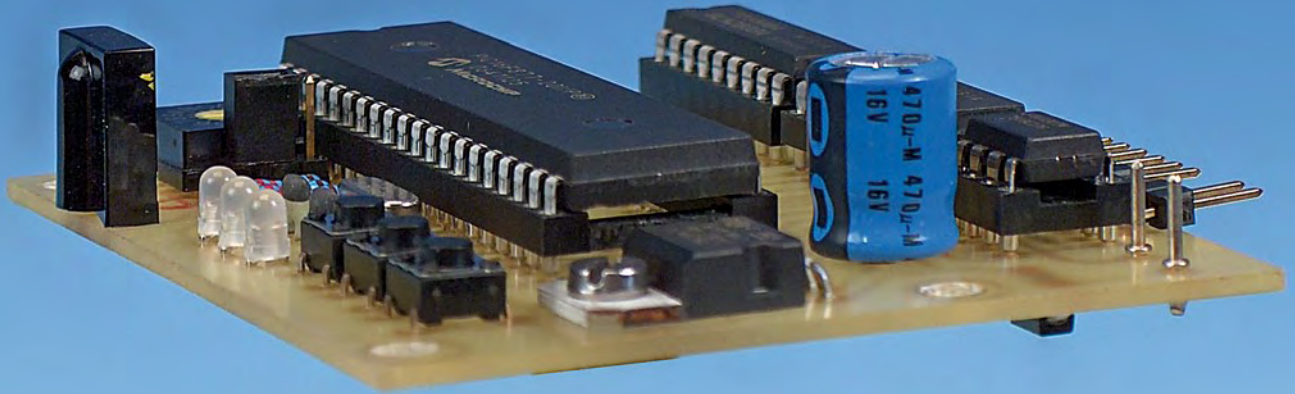
is found, the corresponding output is set appropriately. At the same time Timer1 is set to zero. This generates an interrupt after about 262 ms, which turns off the pulse-output(s) and clears a blocking flag.

There is a peculiarity in the firmware, which is caused by the hardware: the last four outputs are not connected in order to the microcontroller. In addition the other outputs are wired in reverse. This is corrected in the software using a look-up table (PORT_CONV). The four configuration bytes for the type of output (TOGGLE 1/2 and MASTER 1/2) therefore have to be also in this same order. This is taken into account in the PC software. As a result of these adjustments the outputs nevertheless appear to be in order.

The size of the EEPROM is 256 bytes. Of this, 192 bytes are used for the codes (two codes can be programmed for each output) plus four bytes are for the output configuration. The output number is also transmitted via the RS485 port. To be more accurate, this port, in fact, passes on each of the 32 individual codes that are possible. In addition of this serial connection, the configuration can also be sent to a PC, which makes the programming somewhat easier (for more details look under the heading 'PC software').

Figure 1. At the centre is the PIC16 microcontroller, which is supported by the buffer ICs and the RS485-interface chip.

Switch Box



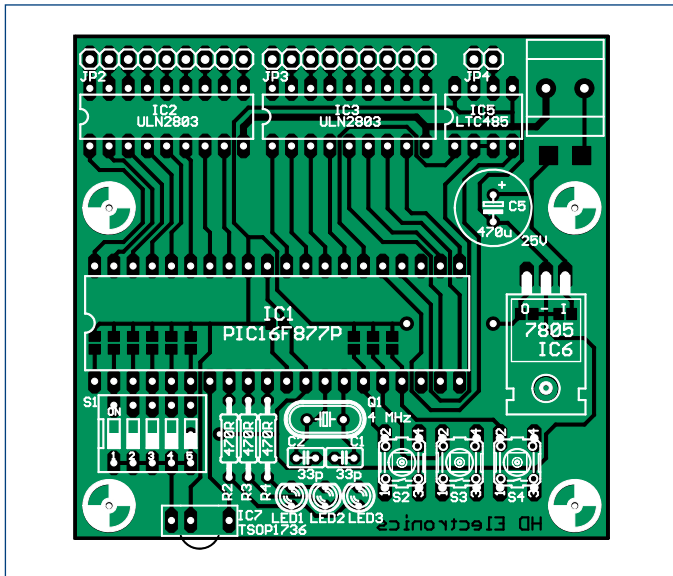


Figure 2. The component layout for the top of the board shows the neatly arranged design of the PCB

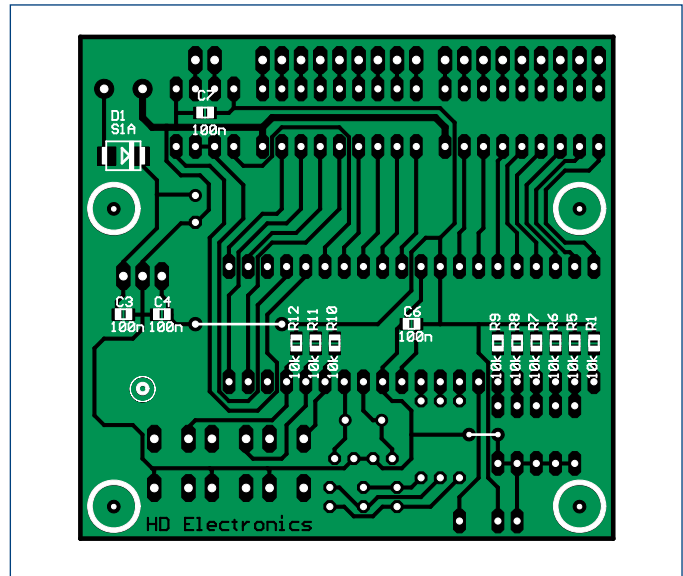


Figure 3. On the bottom of the board we recognise the SMD parts.

The serial connection operates with the settings 9600 Baud, no parity, 8 data bits, 1 stop bit (9600-N-8-1). The protocol is as follows:

- 0xFF (start byte)
- 0x40 + output number
- 0xFE (stop byte)

The RS485 driver is always active, except in edit-mode. This is therefore effectively only an output. For future possibilities the RX- and TX-pins are already connected to RC6 and RC7 of the microcontroller.

The programming mode

Normally the outer two LEDs are illuminated green. When receiving a valid code the middle LED briefly (5 ms) flashes red. With an invalid code the outer two LEDs turn off briefly, but this is barely visible (1 ms); these times were deliberately chosen to be this short because of the receive routine.

The programming (or 'learning') is initiated by pressing the left push button, the left LED will turn red. On reception the middle LED briefly flashes green. When the same code has been received twice in a row, the two LEDs on the left turn green and no further codes are received. With the right button the code can be stored in RAM, with the left button a new attempt can be made.

With an incorrect reception (not the same code twice), the second LED briefly flashes green and the third LED briefly red.

Universal IR receiver

UIR stands for Universal Infrared Receiver. This is a PIC12C508 connected to the COM-port of a PC, which can be used (in conjunction with the appropriate software) to operate multimedia programs. Originally, this was probably made by Srdan Milostic, although there is no further information because his website has been gone for years. More information about UIR can be found on the author's website [2].

Two UIR codes can be stored for each output. Each code is represented as a 12-digit hexadecimal number (6 bytes).

When storing the code with the right button, the dip-switch is used as the output number. This dip-switch could also be replaced with a rotary version (see photo), so that it is easy to change from one output to the next. The fifth switch on the DIP block (a jumper in the photo) selects the second block of 16 codes.

Leaving programming mode is done with the middle push button. Only

then are all the codes stored in the EEPROM.

The Edit mode

With a press of the right push button we enter edit mode. This is indicated by the right LED turning red. In this mode it is possible to remove a code. This is done by simultaneously pressing the left and right buttons. The middle LED briefly flashes red as confirmation. The output number is again determined by the dip-switch.

Leaving edit mode is also done by pressing the middle button. In this

Protocol	
Uploading:	
0xAA	start byte
output 0, code A	binary coded, 6 bytes
output 0, code B ... output F, code B	total 192 bytes
4 bytes output configuration	0x40 - 0x5F
1 byte checksum	modulo 2 - XOR, not including start byte
Ack (0x06) or Nak (0x15) as confirmation	
Downloading:	
0xAB	download command
Response from the circuit is the same as when uploading (including start byte and checksum).	

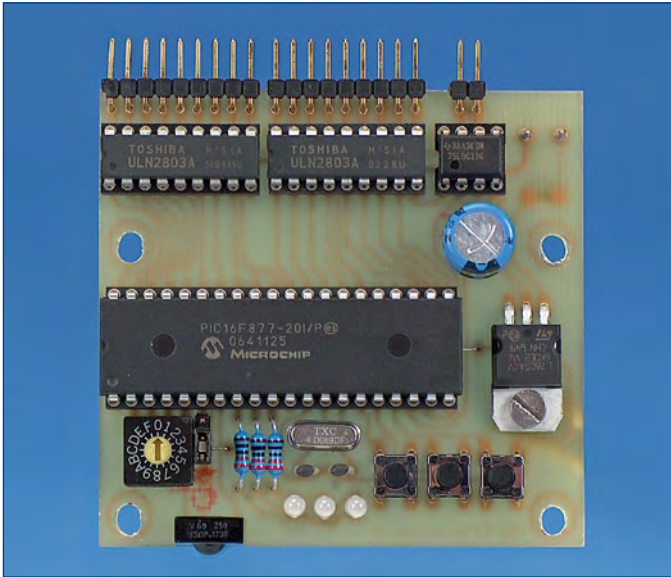


Figure 4. The prototype uses a rotary encoder, but a DIP switch works just as well.

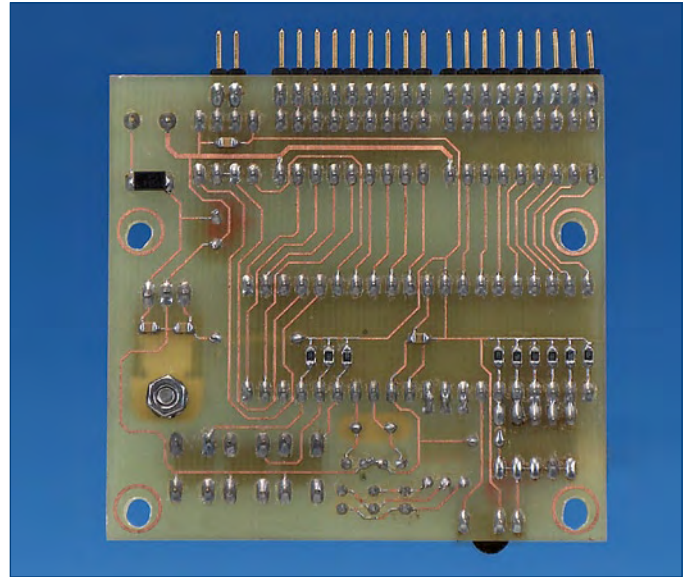


Figure 5. As can be seen here, the SMD parts save quite a bit of space.

mode too, the changes are only saved to the EEPROM when leaving the mode.

PC software

In edit mode the microcontroller also listens to the RS485 port (normally this is only an output, as previously mentioned). In this mode it is possible to read the configuration and to modify it. This configuration is stored as an ini-file. A 'back-up' file in such a format can also be loaded.

When the PC program first starts, it checks whether any of the ports COM1 through COM16 exist. The result is shown in a combobox after which the first available port is opened. With

'Download' you can retrieve the configuration and with 'Upload' you can load a configuration into the PIC.

Using the software you can also set the type of output. There are four options:

- Toggle: press once → on; press again → off.
- Pulse: output active for about 262 ms.
- Master: the same as Toggle, but when switching off all slaves turn off as well.
- Slave: when switching on, the masters also turn on, switching off is not possible.

Multiple masters is possible, but whether this is useful is questionable. There is also a function for the middle button when in the idle state. Press-

ing this button results in the code '0xEEEEEEEEEE'. When this button is programmed using the PC program (normal programming is not possible with this button), it can be used as the local control for an output.

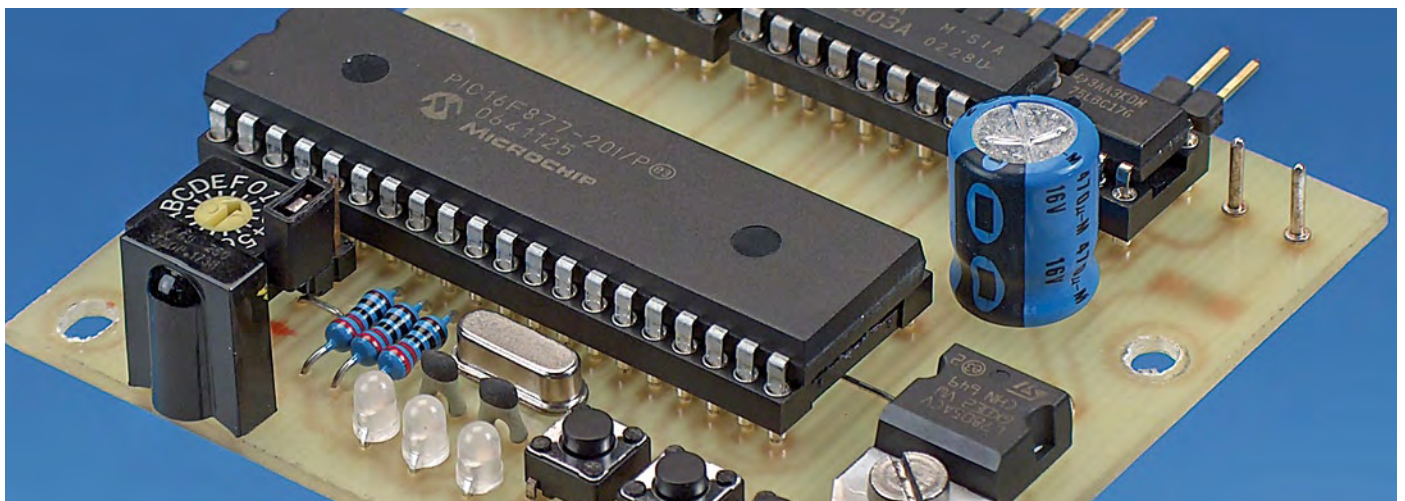
The table shows the protocol that has been used. For connecting the RS485 port to a PC the 'Low-cost RS232-to-RS485 Converter' in the January 2005 issue, page 69 is eminently suitable.

(080063-1)

Note: This circuit has not been tested the Elektor Laboratory.

Internet Links

- [1] www.holger-klabunde.de
- [2] www.hdelectronics.nl



Water Alarm

Timely warning against flooding

Ton Giesberts

Water is vital for humans, but too much of it has an undesirable effect, particularly when it turns up in the wrong places. This is what two Elektor designers discovered after a blocked drain of a combination boiler and a leaking filter of an aquarium. This will quickly suggest the idea of designing a small circuit that will give a clear signal when this type of flooding occurs, in this case with a loud alarm.

It is not always possible to prevent a water leak, of course. But in this case it is essential to discover it as quickly as possible. That is the purpose of this circuit: a clear warning when water appears somewhere where it doesn't belong.

What are the most important design criteria to keep in mind when designing a flood alarm? Seeing that it could be years, or hopefully never, before there is a leak, the circuit has to be always ready and should not rely on the mains voltage. If the circuit is powered from batteries it is very important that the circuit has very low or no power consumption when everything is dry. To detect the water we make use of the fact that (non distilled) water is conductive to an extent.

The Design

Water is a poor conductor then and consequently we should be able to measure a relatively large resistance between the two electrodes. The best way to do this is to make the gate of a MOSFET the input of our circuit. We prefer to measure with respect to ground, so we use a P-channel version for T1, in the form of a BS250. This FET switches the oscillator that follows. When it is dry, T1 has to stay off. This is achieved with R1. C1 prevents the circuit reacting to noise. With a value

of 10 M Ω the circuit is sensitive enough and the current that flows is less than one micro-ampère (1 μ A). R2 protects the gate from high voltages (when the electrode it touched, for example) and forms in combination with C1 a low-pass filter, so that any AC (noise) voltages are filtered out and the oscillator that follows is switched cleanly. R3 ensures that this oscillator is completely off (no current consumption at all).

To minimise the power consumption when water is detected the (active) buzzer is intermittently turned on. The buzzer is activated for about 1 to 1.5 seconds every 10 seconds. The oscillator that makes this happen is implemented with discrete parts. For this we chose an astable multivibrator with two transistors. The advantage of this is that one of these two transistors (T3) switches the buzzer and the buzzer also functions as the collector resistor. C4 is necessary because most active buzzers (the version with a built-in oscillator that generates the bleeping noise) are a very noisy load. The buzzer that is used here, without a parallel capacitor, prevented the operation of the oscillator (the buzzer remained on).

The component values of the circuit around T2 and T3 have been designed with the specific requirements of this application in mind (highly asymmetric square wave) so that these values are

quite different from the standard implementation. This is also why the off-time deviates from the value resulting from the standard formula that is normally used to calculate the component values for this AMV.

T3 is a Darlington device so that the base resistor R6 can be as large as possible. This ensures that C3 has a reasonable value. When the buzzer is not activated the collector resistor of T2 determines the largest share of the current consumption. During the time when the buzzer is activated, C3 has to be charged again. Since the time (R4 \times C3) required to recharge C3 is longer than the time set by R5 \times C2, the expected time of R6 \times C3 is therefore shorter. The theoretical times in an optimal case may be calculated from

$$\ln 2 \times R5 \times C2$$

and

$$\ln 2 \times R6 \times C3.$$

The expected time would have been 15 seconds, but has been reduced to 10 seconds by the combination of values chosen for these components. Increasing the value of C3 to lengthen the off-time does not work. R4 would have to be reduced by the same ratio and that would increase the current consumption.

You could experiment with the value of R6, but make sure that T3 still switches on properly. The voltage drop will be around 0.8 V.

For the 'sensor' for this water alarm you can use two short wires with the insulation stripped off. The circuit is sensitive enough to sense a drop of tap water on a table with the ends of the sensor wires.

To prevent the circuit from drowning in a large pool of water and therefore won't work properly any more, you can build it into an enclosure that floats. Alternatively you could mount the PCB, buzzer and battery on a block of polystyrene. The wires for the sensor can be pushed through the block and bent over on the underside. The block of polystyrene has to be big enough to carry the weight of the circuit, of course. A third possibility is to mount the circuit sufficiently high up in the room. The sensor can be connected to the circuit with twisted wires, preventing them from picking up noise.

Current consumption

For the buzzer we used a type that can be found at Digi-Key, the CEP-2260A. This buzzer, at a power supply voltage of 9 V, uses less than 5 mA. The actual buzzer that we have, used even less, only 4 mA. There are however 12-V buzzers that use 20 mA or more. Using one of these would considerably reduce the amount of time that the alarm can remain active.

The current consumption of our prototype averaged less than 0.5 mA, so with a standard 9-V PP3 battery rated at 500 mAh it will run continuously for 1,000 hours. If nobody has taken any action after the alarm has been going for 40 days, well then...

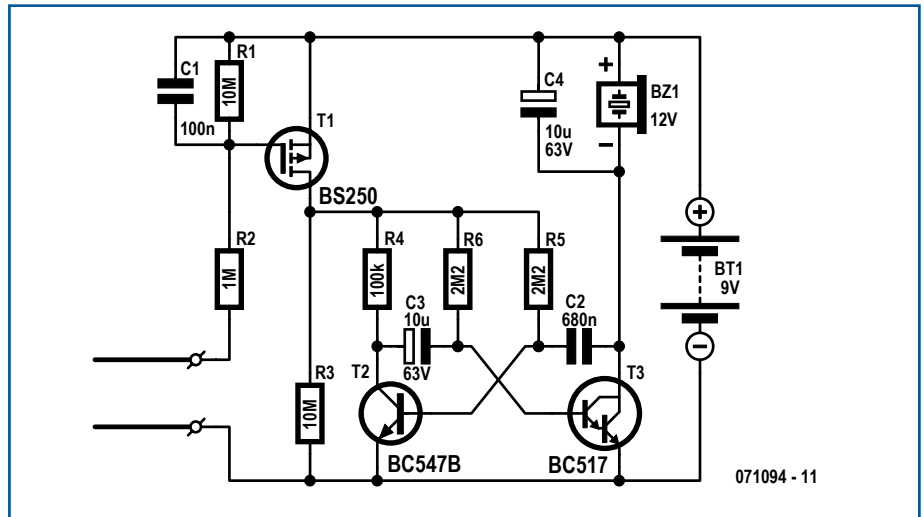
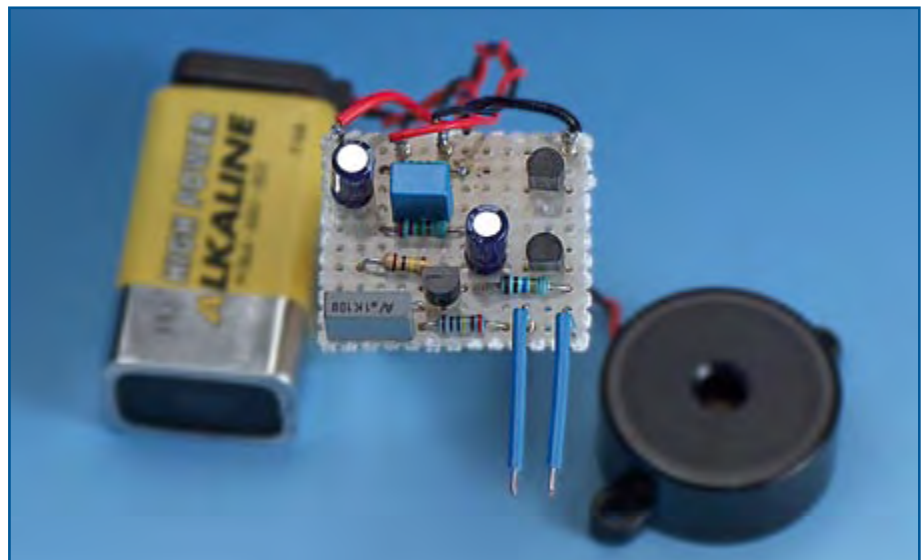


Figure 1. The circuit comprises a detector section with a MOSFET and an astable multivibrator with two transistors.



Since the current consumption in the idle state is negligible ($<1 \mu\text{A}$), there is a risk that the battery may leak after a few years. So keep an eye on the life expectancy of the battery and make

sure it is mounted in the separate compartment or a plastic bag, so should the battery leak, it cannot cause any damage.

(071094-1)

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The instructions for this puzzle are straightforward.

In the diagram composed of 16 x 16 boxes, enter numbers such that **all** hexadecimal numbers 0 through F (that's 0-9 and A-F) occur once only in each row, once in each column and in each of the 4x4 boxes (marked by the thicker black lines).

A number of clues are given in the puzzle and these determine the start situation.

All correct entries received for each month's puzzle go into a draw for a main prize and three lesser prizes. All you need to do is send us the numbers in the grey boxes. The puzzle is also available as a **free download** from our website.

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

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

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An **Elektor SHOP voucher worth £40.00** goes to: Colin Wilson (UK); Hannu von Essen (FIN); Jeff Debooy (AUS).

Congratulations everybody!

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

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

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Tektronix 7D01 Logic Analyser (1978)

Martin Cooke (United Kingdom)

Back in the 70's when engineers were bread-boarding their designs using the new fangled microprocessors they soon found that the traditional diagnostic tools were falling a little short of the job. Many found themselves in the equipment store rummaging in vain for an eight-channel storage scope. In 1973 Hewlett Packard announced their HP5000A logic analyser (US: analyser) which was a basic two-channel machine designed for use with combinational logic and using LEDs to represent digital levels. Tektronix had for a long time been using a modular approach to their oscilloscope designs; a scope chassis housed the CRT together with its high and low tension supplies and a number of bays which accommodate plug-ins to amplify the input signal and generate the time-base. If you wanted more bandwidth or channels it was a simple job to swap the plug-ins.

Around 1976 Tektronix announced the type 7D01 logic analyser plug-in for their 7000 series oscilloscope chassis. The 7D01 can display and store up to 16 channels of digital data. Triggering options include a 16-bit word recogniser which is set up from a row of three-way switches (hi/lo/don't care) on the front panel. The word recogniser also has a BNC output on the front panel useful for triggering other test equipment. A cursor

knob scrolls through the captured data. Storage options allow pre, post or centre trigger and a variable data filter (up to 300 ns) helps to prevent false triggering when sampling in asynchronous mode. Voltage threshold for the logic under test is adjustable between

or as a map. It contains memory to store data captured by the 7D01 as a reference which can then be compared with successive captures to detect errors.

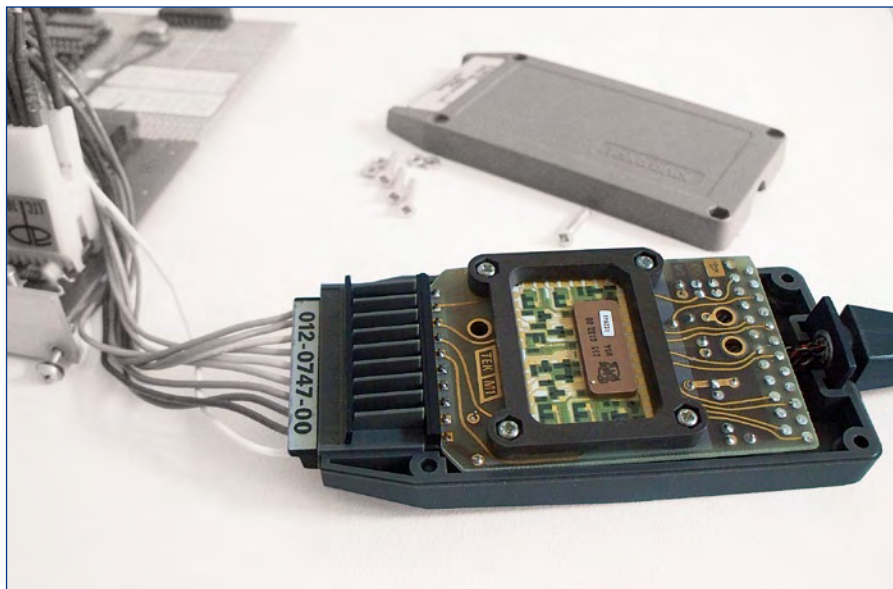
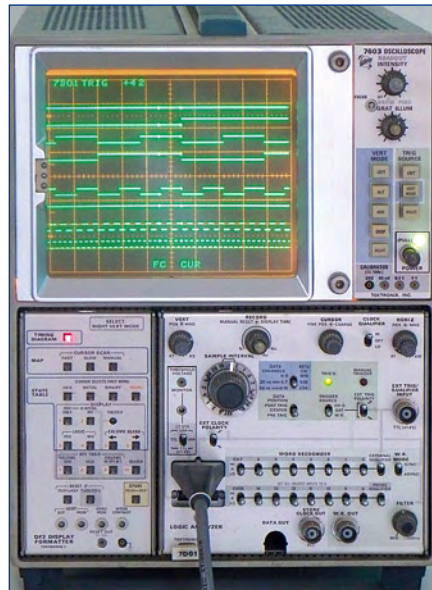
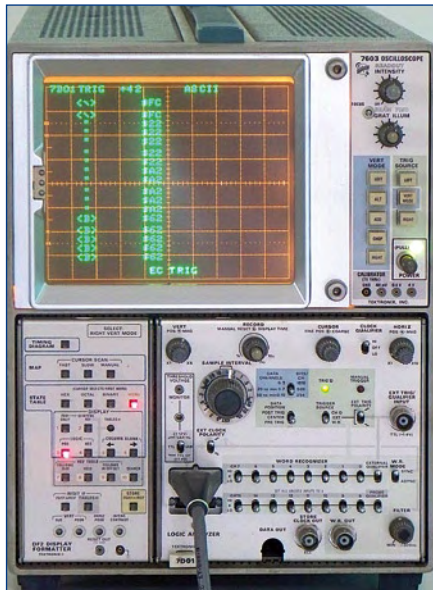
Connecting to the circuit under test was always the most frustrat-

better still is to design the PCB to include pin headers specifically for analyser connection.

Lifting the side panels on this unit is something of a revelation; all of the gold plated connectors still retain their original lustre and the use of perforated aluminium panels allow optimum air circulation while providing EMI shielding. A closer look shows a liberal use of the high speed Motorola MECL 10000 family of chips (including the 4Kx1 data storage RAM) and reveals that all ICs and transistors from T092 up to T03 outline are mounted on sockets. The build quality and attention to detail verges on the obsessive and explains partly why Tektronix has such a good reputation amongst repair and calibration engineers. With this build quality comes a price; in 1979 the cost of the 7D01 and DF2 alone would have set you back over 11,000 US dollars, the price of a very nice car. All the operator manuals are famously comprehensive and can be found on the Internet.

With modern desktop PCs clocking at several GHz you may wonder if there is still a place on the workbench for an analyser that can only manage a maximum asynchronous clock of 100 MHz, but for the majority of microcontroller designs the unit has proved to be more than adequate.

(080644-1)



plus and minus 12 V. The DF2 display formatter in the left hand bay displays the captured data as a 16-channel timing diagram or as a state table in either binary, hex, octal (there is also an ASCII display option)

ing aspect of this and most other early analysers; the test clips supplied have a habit of pinging off the IC lead or shorting adjacent pins. A much better solution is the spring peg type of IC test clip which fits over the IC body or

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Kits & Modules

Communicating with CAN

(October 2008)

The CAN (Controller Area Network) protocol was originally developed for use in the automotive sector. It is now over 20 years old, but is still frequently used these days. It was specially designed for use in environments where you have a lot of electromagnetic interference. Despite the fact that the CAN protocol is a serial protocol, it can't just be connected to (the serial port of) a computer. The all-round USB-CAN adapter described in last month's Elektor is a compact and simple solution. With the help of the accompanying software you can follow all data communications taking place and carry out operations such as filtering and storage at the flick of a (mouse) switch.

PCB, partly populated

Art. # 071120-71 • £54.90 • US\$ 109.80



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Elektor SMT Reflow Oven

(October 2008)

The Elektor SMT reflow oven will faithfully handle most if not all your soldering of projects using surface mount devices (SMDs). The oven is particularly suited for use not just in Colleges, workshops, clubs and R&D laboratories, but also by the advanced electronics enthusiast. This precious workbench tool is at home where SMD boards have to be produced to a variety of requirements on size, components and soldering materials.

Size: 418x372x250 mm
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DCC Command Station

(September 2008)

Electronics is making more and more inroads into the domain of model trains. Trains are now controlled with digital codes, and in many cases the entire system can be operated from a computer. Elektor presents a design for the device that forms the heart of a digitally controlled model railway: the DCC Command Station. The computing power in this design is provided by a highperformance ARM7 processor.

Kit of parts incl. programmed ARM module

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SAPS-400

(May 2008)

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

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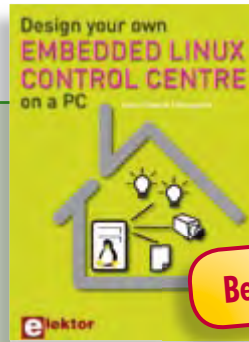
DigiButler

(May & April 2008)

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

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

Art. # 071102-71 • £29.00 • US\$ 58.00



Bestseller!

A DIY system made from recycled components

Design your own Embedded Linux control centre on a PC

This book covers a do-it-yourself system made from recycled components. The main system described in this book re-uses an old PC, a wireless mains outlet with three switches and one controller, and a USB webcam. All this is linked together by Linux. This book will serve up the basics of setting up a Linux environment – including a software development environment – so it can be used as a control centre. The book will also guide you through the necessary setup and configuration of a webserver, which will be the interface to your very own home control centre. All software needed will be available for downloading from the Elektor website.

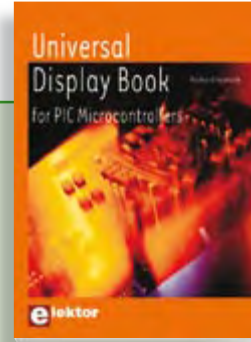
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From LED to graphical LCD

Universal Display Book for PIC Microcontrollers

This book begins with simple programs to flash LEDs, and eventually by stages to use other display indicators such as the 7-segment and alphanumeric liquid crystal displays. As the reader progresses through the book, bigger and upgraded PIC chips are introduced, with full circuit diagrams and source code, both in assembler and C. A tutorial is included using the MPLAB programming environment, together with the PCB design package and EAGLE schematic to enable readers to create their own designs.

192 pages • ISBN 978-0-905705-73-6
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PIC Microcontrollers

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446 pages • ISBN 978-0-905705-70-5
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Principles and Practice

Computer Vision

Computer vision is probably the most exciting branch of image processing, and the number of applications in robotics, automation technology and quality control is constantly increasing. Unfortunately entering this research area is, as yet, not simple. Those who are interested must first go through a lot of books, publications and software libraries. With this book, however, the first step is easy. The theoretically founded content is understandable and is supplemented by many examples.

320 pages • ISBN 978-0-905705-71-2
£32.00 • US\$ 64.00



5.0, 6.0, VBA, .NET, 2005

Visual Basic for Electronics Engineering Applications

This book is targeted towards those people that want to control existing or self-built hardware from their computer. After familiarizing yourself with Visual Basic, its development environment and the toolset it offers are discussed in detail. Each topic is accompanied by clear, ready to run code, and where necessary, schematics are provided that will get your projects up to speed in no time.

476 pages • ISBN 978-0-905705-68-2
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Bestseller!

Modern technology for everyone

FPGA Course

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

ISBN 978-90-5381-225-9 • £14.50 • US\$ 29.00



Software Tools & Hardware Tips

Ethernet Toolbox

This CD-ROM contains all essential information regarding Ethernet interfaces! Ethernet Toolbox includes a collection of datasheets for dedicated Ethernet interface ICs from many different manufacturers. It provides a wealth of information about connectors and components for the physical layer (PHY) and specific software tools for use with the Ethernet (Software). To help you learn about the Ethernet interfaces, we have compiled a collection of all articles on this topic that have appeared in Elektor and complemented them with additional documentation and links to introductory articles on Ethernet interfaces. The documents are PDF files.

ISBN 978-90-5381-214-3 • £19.50 • US\$ 39.00

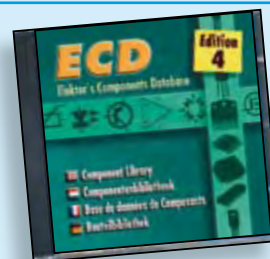


All articles published in 2007

Elektor 2007

This CD-ROM contains all articles published in Elektor Volume 2007. Using the supplied Adobe Reader program, articles are presented in the same layout as originally found in the magazine. An extensive search machine is available to locate keywords in any article. The installation program now allows Elektor year volume CD-ROMs you have available to be copied to hard disk, so you do not have to eject and insert your CDs when searching in another year volume. With this CD-ROM you can produce hard copy of PCB layouts at printer resolution, adapt PCB layouts using your favourite graphics program, zoom in / out on selected PCB areas and export circuit diagrams and illustrations to other programs.

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Communicating with CAN

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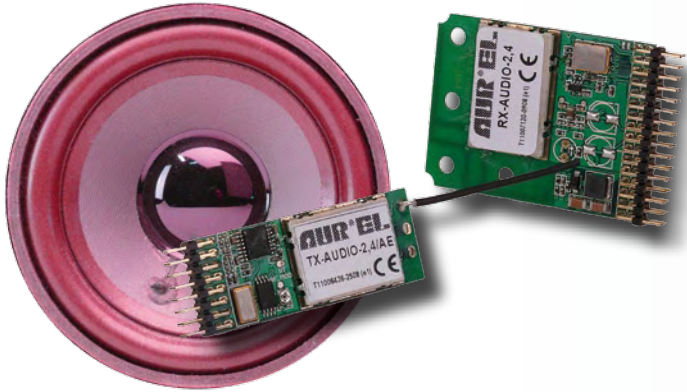
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Free Supplement: the i-TRIXX Collection

If you hate those complex projects, *rejoice!* This year too, the December issue of *Elektor* comes with a 24-page supplement called *i-TRIXX Collection*. These free pages contain about 20 circuits supplied by the Elektor lab and selected free-lance contributing authors. This year's collection is again aimed at those of you starting out in electronics or on a modest budget. If you like scavenging components from the junk box, the circuits presented are just the ticket to making something quickly in an afternoon or so.

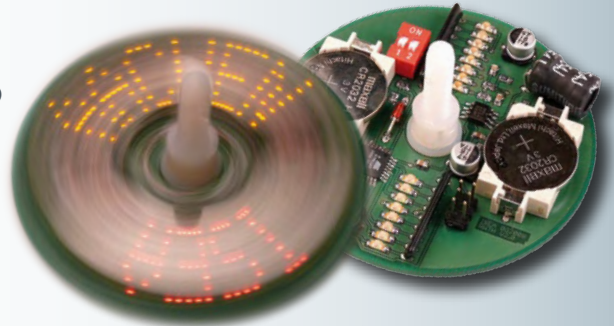


Wireless HiFi

Until recently, radio links were rare birds in the audio hi-fi scene, probably because of issues with the transmission quality. Some manufacturers did manage to bite the bullet however and now supply surround sound sets incorporating remote speakers on a wireless link. If it looked like high-quality audio transmission over RF is outside the realm of home construction, new modules from Aurel make it all possible and Elektor (who else) is the first to come up with a tried and tested DIY project.

Electronic Spinning Top

A really impressive gadget, this electronic spinning top capable of displaying a text if you make it spin at good speed. A round circuit board with a diameter of about 70 mm accommodates a microcontroller, 2 button cells, 2 LED bars and a number of components. The earth's magnetic field is detected in an ingenious way to enable the LEDs to be driven such that the toy actually produces legible text!



Article titles and magazine contents subject to change, please check 'Magazine' on www.elektor.com

The December 2008 issue comes on sale on Thursday 20 November 2008 (UK distribution only). UK mainland subscribers will receive the issue between 15 and 18 November 2008.

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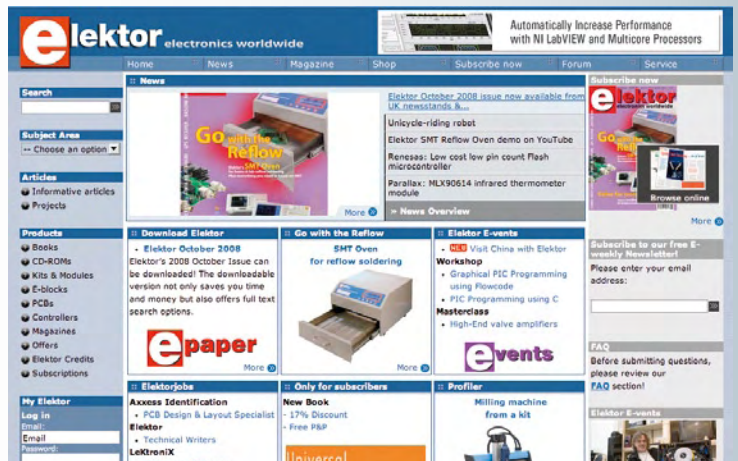
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January 2008



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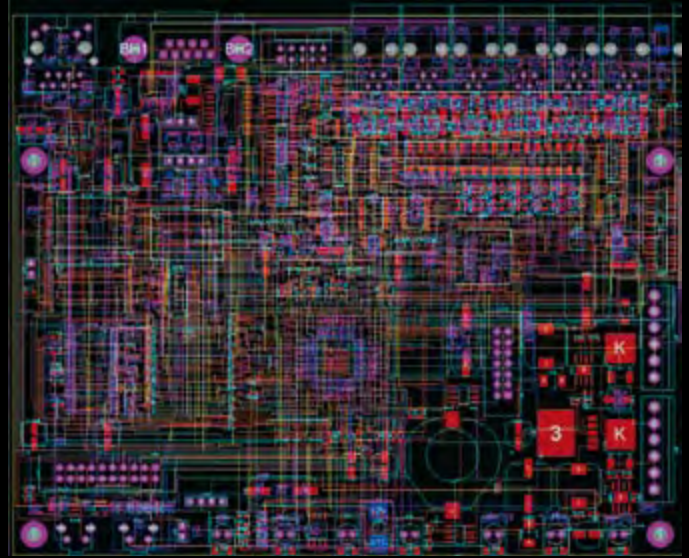
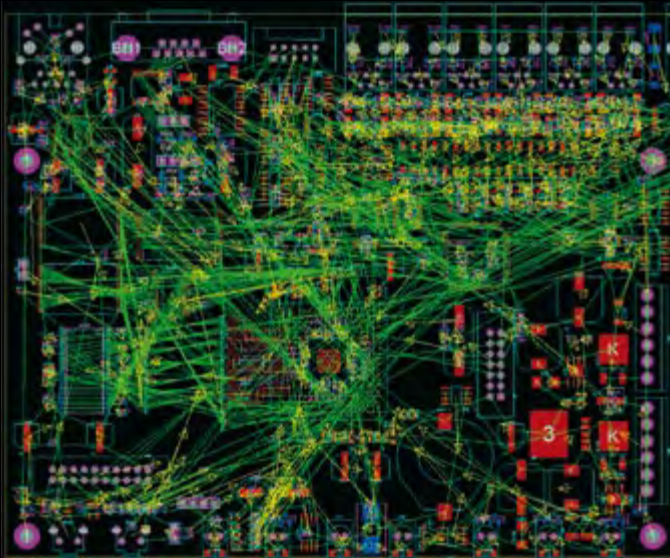
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