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**EasyPIC5 Development Board**
Complete Hardware and Software solution with on-board USB 2.0 programmer and mikroICD

**Uni-DS 3 Development Board**
Complete Hardware and Software solution with on-board USB 2.0 programmer and mikroICD

**LV 18FJ Development Board**
Complete Hardware and Software solution with on-board USB 2.0 programmer and mikroICD

**EasyPIC5 development board** provides the following features for the price of one: System supports 8, 14, 16, 20, 28 and 40 pin microcontrollers (supplied with PIC18F4520). EasyPIC5 development board is an easy-to-use development board for PIC microcontrollers. EasyPIC5 development board enables very efficient debugging and very fast prototype development. Touch screen controller with connector is available on-board.

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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 exuding ‘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!

**Come see us at**

- **Embedded Systems** — Boston, USA, October 27-30.
- **Matelec** — Madrid, Spain, October 28 - November 1.
- **Elektronica** — München, Germany, November 11-14.
- **Elektor Live!** — Eindhoven, The Netherlands, November 22.

**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.
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!
Elektor International Media provides a multimedia and interactive platform for everyone interested in electronics. From professionals passionate about their work to enthusiasts with professional ambitions. From beginner to diehard, from student to lecturer. Information, education, inspiration and entertainment. Analogue and digital; practical and theoretical; software and hardware.
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Main technical specifications
Line voltage: 230 Vac / 1650 W
Line frequency: 50-60 Hz
Size: 418 x 372 x 250 mm (16.5 x 14.6 x 10 inch)
Weight: 16.7 kg (net)
Effective PCB area: 280 x 280 mm (11 x 11 inch)

Apart from the handle on the drawer giving access to the PCB tray, the user interface consist of an LCD and five buttons on the front panel.

Art. # 080663-91 • Price: £ 882 • € 1095 • US$ 1525

Further information and ordering at www.elektor.com/smtoven
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 Elektor.

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 \( V_s \) 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: \( V = V_x \), \( A = 1 \) (where \( A \) 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 \( A = 1 \). 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 \( G = 0.95 \) (which is a reasonable estimate of the transfer function of the buffer plus the output stage) and \( K = 1 \), 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 \( R_i \) 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 \( I_i \) (shown here for the sake of the analysis) connected to the output produces a voltage across \( R \). 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

You did not include DIPTRACE (hwww.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 Rk 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 pX 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 trimpots. 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 milli-ohms. For comparison, the resistance of 1 metre of speaker cable with a 2-mm wire diameter is approximately 10 milli-ohms. 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

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 port 80 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 27888 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.

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

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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 (ETSII), 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 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 stock complements the new MRF24J40MA 2.4 GHz FCC-certified transceiver module. 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 PIC18F4620 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**

VI 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, outdoor advertising and architectural installations.

The board provides a precisely regulated current as required for direct-drive multi-LED applications where the intensity and brightness 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 isolated source or can be combined with the range of VTM™ transmitters 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 backlighing.

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 VI 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 VI Chip pushpin heat sink, and system enable and disable.

www.vicorpower.com/ccdemo/ (06624-33)

**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 10x10xmm x 1.2 mm, the Venus634LP integrates LNA, SAW filter, RF frontend, 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 TTIFF, 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 acquisition and 30 mA during full power continuous tracking. The dedicated signal parameter search engine within the Venus634LP is capable of performing 9 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 (06624-33)
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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.

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 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 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-I)
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 microC compiler, USB and serial cables, blue backlit 16x2 character and 128x4 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, 16, 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, PS2 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 mikroC—the 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.

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.
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 touchscreen 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

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 Electronics 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, Cimetrics, Cisco, Duke Energy, Dust Networks, eka systems, EDF (Electricité 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 Zenys.

IPSO Alliance membership is open to any organisation advocating an IP-based approach to connecting smart objects.

www.ipso-alliance.org

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When a power-cut hits a company, they need to be sure that their UPS system performs immediately and for as long as possible until mains power is re-established. The life of a battery back-up system is partly dependant on its stable temperature control which is often achieved using electronic means. As an alternative to electronic sensors, the Matsuo MQT thermostat supplied by ATC Semitec Ltd. offers moisture is an issue. This feature 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 organic conductive ink and must be 6×6mm or larger. Widely different electrode sizes and shapes are possible, giving the product designer great flexibility in tailoring the user interface.

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The 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 4×4 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 channel feature helps prevent false 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 organic conductive ink and must be 6×6mm or larger. Widely different electrode sizes and shapes are possible, giving the product designer great flexibility in tailoring the user interface.

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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 Second) 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.

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6-channel touch controller with integral LED driver

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

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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:

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

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

### Internet Links


### 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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Speed Camera Warning Device

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 powerful, 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.

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). The 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...
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 PIC16F876A ISP connector. The second section, the program, handles the reception of GPS frames and the transmission of data to a computer via USB or RS-232.
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.

**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.
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 PIC 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 EB006 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 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.

**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 time to connect the circuit to your computer’s USB port.
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 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!

Acknowledgements

Dominique Kerjean: design engineer at ENSIETA.
Pierre Cambon: research lecturer at ENSIETA.
André Mininno: design engineer with Multipower.

Internet Links

Remote Control by Mobile Phone

Receive back: confirmation and GPS position data

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.

Florian Schäffer (Germany)

Mobile phone (GSM/Cellphone) controlled switching devices have been around for a while now, without earning 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 back 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 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 directly 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

---

**Table 1. Typical Status-SMS with a GPS module connected**

<table>
<thead>
<tr>
<th>Status: TelTyp:1 Exit2Typ:0 Time:15mn Exit1:0 Exit2:1 Exit3:1 <em>GPS OK</em></th>
<th>15:50:23</th>
<th>N52°58.0674 E012°48.3217</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Message</strong></td>
<td><strong>Meaning</strong></td>
<td></td>
</tr>
<tr>
<td>TelTyp:1</td>
<td>Switch TelTyp is On</td>
<td></td>
</tr>
<tr>
<td>Exit2Typ:0</td>
<td>Switch Output2Typ is Off</td>
<td></td>
</tr>
<tr>
<td>Time:15mn</td>
<td>On Output 3 a switching time of 15 minutes has been set</td>
<td></td>
</tr>
<tr>
<td>Exit1:0</td>
<td>Output 1 is enabled</td>
<td></td>
</tr>
<tr>
<td>Exit2:1</td>
<td>Output 2 is enabled</td>
<td></td>
</tr>
<tr>
<td>Exit3:1</td>
<td>Output 3 is enabled</td>
<td></td>
</tr>
<tr>
<td><em>GPS OK</em></td>
<td>GPS reception is operational. Data valid [&quot;<em>GPS INVALID</em>&quot; if reception is disturbed]</td>
<td></td>
</tr>
<tr>
<td>UTC time</td>
<td>15:50:23</td>
<td></td>
</tr>
<tr>
<td>GPS coordinates: 52° 58.0674’ Northerly latitude [&quot;52 Degrees 58,0674 Minutes&quot;]</td>
<td>E012°48.3217</td>
<td></td>
</tr>
<tr>
<td>GPS coordinates: 12° 48.3217’ Easterly longitude</td>
<td>E012°48.3217</td>
<td></td>
</tr>
</tbody>
</table>
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 stabilised 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

<table>
<thead>
<tr>
<th>Resistors</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>R1, R3, R5, R7, R9, R11 = 1kΩ</td>
<td></td>
</tr>
<tr>
<td>R2, R4 = 10kΩ</td>
<td></td>
</tr>
<tr>
<td>R6, R8, R10 = 1kΩ</td>
<td></td>
</tr>
<tr>
<td>R12 = see text</td>
<td></td>
</tr>
<tr>
<td>R13, R14, R15 = 1Ω/volt, 2W (see text)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Capacitors</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>C1 = 220µF 35V</td>
<td></td>
</tr>
<tr>
<td>C2, C11 = 100nF</td>
<td></td>
</tr>
<tr>
<td>C3 = 3µF 50V</td>
<td></td>
</tr>
<tr>
<td>C4, C5, C6, C7, C8 = 1µF 16V</td>
<td></td>
</tr>
<tr>
<td>C9, C10 = 22µF</td>
<td></td>
</tr>
<tr>
<td>C12, C13, C14 = 0.1µF/ampère (see text)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Inductor</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>L1 = 40µH 2A (e.g. EPCOS)</td>
<td></td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Semiconductors</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>D1 = P6KE30A, TVS (30V / 600W)</td>
<td></td>
</tr>
<tr>
<td>D2, D3 = S8320 or 1N5820 (Schottky; 3A / 20V)</td>
<td></td>
</tr>
<tr>
<td>D4 = LED, red, low current, 3mm</td>
<td></td>
</tr>
<tr>
<td>D5 = LED, green, low current, 3mm</td>
<td></td>
</tr>
<tr>
<td>D6-D9 = LED, yellow, low current, 3mm</td>
<td></td>
</tr>
<tr>
<td>D10, D11, D12 = 1N4148</td>
<td></td>
</tr>
<tr>
<td>D10, D11, D12 = 1N4148</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Semiconductors</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>T1, T2, T3 = BC337 (TO92 case)</td>
<td></td>
</tr>
<tr>
<td>IC1 = L78S05CV (TO220 case)</td>
<td></td>
</tr>
<tr>
<td>IC2 = MAX232CPE+ (DIP16 case)</td>
<td></td>
</tr>
<tr>
<td>IC3 = ATMEGA8-16PU, DIP28 case, programmed, Elektor SHOP # 080324-41</td>
<td></td>
</tr>
<tr>
<td>OC1 = FC817X2J000F, optocoupler, DIP4 case</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Semiconductors</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>F1 = auto-resetting PTC fuse, 30V, sustain current 1.1A, activation current 2.2A, e.g. Multifuse MF-R110-0-99 (Bourns)</td>
<td></td>
</tr>
<tr>
<td>Polyfuse 30R110 (Littlefuse) or Polyswitch RUEF110 (Tyco), ES-LP30-110 (ESKA) = PFR110 (Reichelt.de)</td>
<td></td>
</tr>
<tr>
<td>P1-P8 = 1mm dia. solder pin</td>
<td></td>
</tr>
<tr>
<td>IC sockets for IC2 (DIL16), IC3 (DIL28), OC1 (DIL6 used as DIL4)</td>
<td></td>
</tr>
<tr>
<td>Heatsink for IC1 (U profile, 25x15x20 mm, 17K/W, slotted hole)</td>
<td></td>
</tr>
<tr>
<td>M3 screw, 10 mm, with nut (for securing heatsink)</td>
<td></td>
</tr>
<tr>
<td>Blue transparent enclosure, 150x80x50 mm (LxWxH), e.g. Conrad Electronics # 522498</td>
<td></td>
</tr>
<tr>
<td>PCB, Elektor Shop # 080324-1 or kit incl. PCB, # 080324-71</td>
<td></td>
</tr>
</tbody>
</table>

11/2008 - elektor
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 ARVs 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 +491234567890. 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:

```text
AT+CMGW=26
0011000F919421132547698F000000A08C8329BF0D65DDF723619
```

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:

- 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, Polyfuse, 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 operating 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
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 electrically. Byte (Hex) Meaning

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Hex</th>
<th>Binary (7 Bits)</th>
<th>mirrored</th>
</tr>
</thead>
<tbody>
<tr>
<td>H</td>
<td>48</td>
<td>100 1000</td>
<td>00 01001</td>
</tr>
<tr>
<td>e</td>
<td>65</td>
<td>110 0101</td>
<td>10 10011</td>
</tr>
<tr>
<td>l</td>
<td>6C</td>
<td>110 1100</td>
<td>00 11011</td>
</tr>
<tr>
<td>o</td>
<td>6F</td>
<td>110 1111</td>
<td>11 10011</td>
</tr>
<tr>
<td>w</td>
<td>57</td>
<td>101 0111</td>
<td>11 10101</td>
</tr>
<tr>
<td>o</td>
<td>6F</td>
<td>110 1111</td>
<td>11 10011</td>
</tr>
<tr>
<td>r</td>
<td>72</td>
<td>111 0010</td>
<td>01 00111</td>
</tr>
<tr>
<td>l</td>
<td>6C</td>
<td>110 1100</td>
<td>00 11011</td>
</tr>
<tr>
<td>d</td>
<td>64</td>
<td>110 0100</td>
<td>00 10011</td>
</tr>
</tbody>
</table>

4. The mirrored bits are written one after another as a bit sequence: 0001001100110001011100000110110110110010011001101011000101100100110011010110011010110011000100001011101110100111001100110010011000.

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: 0001001100110001011100000110110110110010011001101011000101100100110011010110011010110011000100001011101111010100111001100110010011000.

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 C8329FD065DDF723619.
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:

\[
(R12 = \frac{U_{K2} - 1.2 \, V}{20 \, mA})
\]

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

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
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-µF 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 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).

Internet Links

WinAVR: http://sourceforge.net/projects/winavr
AT command set for GSM/GPRS telephones: www.communica.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
Online PDU Encoder and Decoder: http://twit88.com/home/utility/sms-pdu-encode-decode
Online coordinate conversion: www.cached-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 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 reduces the number of parts).

For the motorised potentiometer we assumed the version with the connections for the IR receiver (IC2) that is used here, is via a 3-way row of connections. So you can either connect 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 available (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 are implemented as a row of pins. So 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.

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 connections 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 available (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
Code-tangle

Not everyone will have a remote control from a Philips receiver or tuner (or another brand that uses RC-5) handily 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).

<table>
<thead>
<tr>
<th>Button</th>
<th>EuroSky 8 (AMP code 1112)</th>
<th>RC5 (Tuner)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>11</td>
<td>3F</td>
</tr>
<tr>
<td>2</td>
<td>0C</td>
<td>3F</td>
</tr>
<tr>
<td>3</td>
<td>17</td>
<td>3F</td>
</tr>
<tr>
<td>4</td>
<td>12</td>
<td>3F</td>
</tr>
<tr>
<td>5</td>
<td>05</td>
<td>3F</td>
</tr>
</tbody>
</table>

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

COMPONENTS LIST

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

Capacitors
- C1, C7, C8 = 100nF ceramic, lead pitch 5mm
- C2, C6 = 10µF 63V, radial, lead pitch 2.5mm
- C3 = 100pF, lead pitch 5mm
- C4, C5 = 22pF, lead pitch 5mm
- C9 = 220µF 25V 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 = SFHS110-36 (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
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 having 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
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 ‘Wii-mote’ (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 PixArt 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 ±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 1. The Nintendo Wii remote control unit.**

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

**Figure 3. PCB ahoi!**

**Figure 4. Camera sensor and IR filter.**
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

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**Figure 5.** Desoldering the pins is not difficult. **Figure 6.** The solder tabs of the sheet-metal screen are a bit more stubborn. **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 I^2C 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/hta/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!)

(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 I^2C 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 I^2C 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 I^2C 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,
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 simplicity 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, date is read out at regular intervals in sets of 16 bytes. Each blob requires three bytes. As each coordinate is processed, they can be converted into graphic form.

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

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.

Internet Links

```
Waitms 200
Loop
Sub Send2bytes
    I2cstart
    I2cwrite Slave
    I2cwrite D1
    I2cwrite 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 = &HCO : Send2bytes : Waitms 10
    D1 = &H1A : D2 = &H40 : Send2bytes : Waitms 10
    D1 = &H33 : D2 = &H33 : Send2bytes : Waitms 10
Waitms 100
End Sub

Sub Readsensor
    I2cstart
    I2cwrite Slave
    D1 = &H36
    I2cwrite D1
    I2cstop
    Waitms 1
Sub Convertdata
    X1 = Din(4) And &H30
    X1 = X1 * 16
    X1 = X1 + Din(2)
    Y1 = Din(4) And &HCO
    Y1 = Y1 * 4
    Y1 = Y1 + Din(3)
    X2 = Din(7) And &H30
    X2 = X2 * 16
    X2 = X2 + Din(5)
    Y2 = Din(7) And &HCO
    Y2 = Y2 * 4
    Y2 = Y2 + Din(6)
    X3 = Din(10) And &H30
    X3 = X3 * 16
    X3 = X3 + Din(8)
    Y3 = Din(10) And &HCO
    Y3 = Y3 * 4
    Y3 = Y3 + Din(9)
    X4 = Din(13) And &H30
    X4 = X4 * 16
    X4 = X4 + Din(11)
    Y4 = Din(13) And &HCO
    Y4 = Y4 * 4
    Y4 = Y4 + Din(12)
End Sub
End
```

The ATM18 project at Computer:club

ATM18 is a joint project of Elektor and Computer:club (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:club member Wolfgang Rudolph in the CC-tv programme broadcast on the German NRW-TV channel. The ATM18-avr board with the IR camera was described in Instalment 23 of CC-tv, which was broadcast on 18 September 2008.
CC-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). CC-tv is also available as a podcast from www.cczwei.de and – a few days later – from sevenload.de.

Parameter 8 80 27

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

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://zeept.wordpress.com/
www.elektrischefiets.be/index.html

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.
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TION control. Optoisolated inputs make it ideal for CNC applications using a PC running suitable software. Board supply: 8-30Vdc. PCB: 75x65mm. Kit Order Code: 3158KT - £17.95

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Assembled Order Code: AS3166v2 - £27.95

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Assembled Order Code: AS3180 - £54.95

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sired. User settable Security Password, Anti-

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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 developers of a significant amount of development work.

Experiment-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 without 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

The 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.

Table 1. Vital Vinculum connections

<table>
<thead>
<tr>
<th>Pin</th>
<th>Description</th>
<th>Connection</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>VCC</td>
<td>to +5V</td>
</tr>
<tr>
<td>6</td>
<td>AD2</td>
<td>data output TXD</td>
</tr>
<tr>
<td>7</td>
<td>GND</td>
<td>to ground</td>
</tr>
<tr>
<td>8</td>
<td>AD1</td>
<td>data input RXD</td>
</tr>
<tr>
<td>10</td>
<td>AD4</td>
<td>Handshake line CTS, to GND</td>
</tr>
</tbody>
</table>

USB-Srial 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

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
Command Set (SCS):

SCS <Enter>

Vinculum responds in like manner in small Bytes (for example 13 corres-
ponds to CR):

62 13

To return to Extended Command Mode you use the command ECS. Other com-
mands 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 \fbrf\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 ‘fbrf.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 opera-
tions:  (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.
Measurement program

Our measurement program is implemented here in Bascom-AVR [8] for an ATmega88. In principle the only commands 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 intricably 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 symbol of the next line.

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 Delayms As Word
Dim Channels As Word
Dim N As Integer
Dim I As Integer
Dim S As String * 20
Dim Ad As Integer
Config Portb = Output
Config Adc = Single, Prescaler = 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
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, L
Put #1, 13
Print S;
Input S
Waitms Delayms
Next N
Print “CLF Log.txt” + Chr(13);
Input S
Portb.0 = 0
End

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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 send 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 together and plug the USB stick into the microcontroller system. After about a second the stick is recognised and the command file is read. The ATmega sets its pin PBO high and (for example) lights up an LED, to show that measurement is now in progress and the 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 PBO 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?

![Figure 6. Data evaluation using Excel.](image1)

![Figure 5. Connections between VDIP1 and ATmega88.](image2)

![Figure 7. Mini measurement circuit.](image3)

Internet Links

[8] www.mcselec.com
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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:

<table>
<thead>
<tr>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>088</td>
</tr>
<tr>
<td>17864</td>
</tr>
<tr>
<td>30706</td>
</tr>
<tr>
<td>43547</td>
</tr>
<tr>
<td>56389</td>
</tr>
<tr>
<td>3695</td>
</tr>
<tr>
<td>16471</td>
</tr>
</tbody>
</table>

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 kHz = 15.267 µs.

The time between the two readings will therefore be 12841 * 15.267 µs = 196 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.

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.
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.

**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 1. Block diagram of the timers.](image)
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 µs. Timer 2 will be used with a prescale value of 64. Each time it overflows Timer 2 is loaded with the value 56 so that the next overflow occurs 200 clocks later.

800 µs 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 kΩ 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

Although there is some variation the measured average value is mostly 226. This can be converted into a real voltage level: 5 V * 226 / 1023 = 1.10 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.

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 Ovf2 Tim2_isr
Enable Timer2
Enable Interrupts
Do
Ad0_mean = Ad0_mean / 25
Print Ad0_mean
Waitms 100
Loop
Tim2_isr:
'800 µs
Timer2 = 56
Ticks = Ticks + 1
Ad0 = Ad0 + Getadc(0)
If Ticks > 24 Then
Ticks = 0
Ad0_mean = Ad0
Ad0 = 0
End If
Return

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 Ovf0 Tim0_isr
Enable Timer0
Enable Interrupts
Do
If Seconds <> Seconds_old Then
Print Seconds
Seconds_old = Seconds
End If
Loop
Tim0_isr:
'1000 µs
Timer0 = 6
Ticks = Ticks + 1
If Ticks = 1000 Then
Ticks = 0
Seconds = Seconds + 1
End If
Return

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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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 device, 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 °. 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 transformation 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 ASS0xx 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 $0.08789^\circ$ 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 offset 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. 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 $1^\circ$; with a centred magnet the maximum error is under $0.5^\circ$.

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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 $1^\circ$; with a centred magnet the maximum error is under $0.5^\circ$. allowing position measurements at rotational speeds of up to 30000 revolutions per minute.

We shall take the 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
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 devices. 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 5 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].

**Web Links**


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

Figure 6. An AS50xx demonstration board provides a development environment for dedicated applications using its accompanying free software.
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 illuminate 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-
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 and oscilloscope is rather tedious, 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 packed 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, 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 sequence of four bytes, which contain the address of the lamp followed by a 5-bit field. 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.
sequence 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 send 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-
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 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 lists 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 examples 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.

Web Links
[1]: www.obdev.at/products/avrusb/index.html
[2]: http://meuk.spritesserver.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!
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 a 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.
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 3 briefly flashes green and the third LED 3 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 state all codes for this output are removed. The dip-switch is now used as the output number.

Protocol

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<th>Protocol</th>
<th>Description</th>
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<tr>
<td>Uploading:</td>
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<tr>
<td>0xAA</td>
<td>start byte</td>
</tr>
<tr>
<td>output 0, code A</td>
<td>binary coded, 6 bytes</td>
</tr>
<tr>
<td>output 0, code B ... output F, code B</td>
<td>total 192 bytes</td>
</tr>
<tr>
<td>4 bytes output configuration</td>
<td>0x40 – 0x5F</td>
</tr>
<tr>
<td>1 byte checksum</td>
<td>modulo 2 – XOR, not including start byte</td>
</tr>
<tr>
<td>Ack (0x06) or Nak (0x15)</td>
<td>as confirmation</td>
</tr>
<tr>
<td>Downloading:</td>
<td></td>
</tr>
<tr>
<td>0x8B</td>
<td>download command</td>
</tr>
<tr>
<td>Response from the circuit is the same as when uploading (including start byte and checksum).</td>
<td></td>
</tr>
</tbody>
</table>
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. 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.

**Internet Links**


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Note: This circuit has not been tested the Elektor Laboratory.
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 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 MΩ the circuit is sensitive enough and the current that flows is less than one micro-ampère (1 µA). 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×C3) required to recharge C3 is longer than the time set by R5×C2, the expected time of R6×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...

Since the current consumption in the idle state is negligible (<1 µA), 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.

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

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Congratulations everybody!
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: analyzer) 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 frustrating 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 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 4K×1 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.

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

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(October 2008)

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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.

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**ECD 4**

The program package consists of eight databanks covering ICs, germanium and silicon transistors, FETs, diodes, thyristors, triacs and optocouplers. A further eleven applications cover the calculation of, for example, LED series droppers, zener diode series resistors, voltage regulators and AMVs. A colour band decoder is included for determining resistor and inductor values. ECD 4 gives instant access to data on more than 68,000 components. All databank applications are fully interactive, allowing the user to add, edit and complete component data. This CD-ROM is a must-have for all electronics enthusiasts.

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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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080324-41 ... Programmed controller ATMEGA8-16PU ............................ 5.90 .... 11.80
080324-31 ... Kit of parts ......................................................................... see www.elektor.com
Tracking Hot Spots
080358-1 ... Printed circuit board .......................................................... 9.10 .... 18.20
Atema meets Vinculum
071152-91 ... YDIP1 module .............................................................. 22.5 .... 45.00

October 2008 (No. 382)

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070369-41 ... Programmed controller PIC18F2220 .................................. 11.60 .... 23.20
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September 2008 (No. 381)

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July/August 2008 (No. 379/380)

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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.

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!

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.

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Elektor on the web

All magazine articles back to volume 2000 are available online in pdf format. The article summary and parts list (if applicable) can be instantly viewed to help you positively identify an article. Article related items are also shown, including software downloads, circuit boards, programmed ICs and corrections and updates if applicable. Complete magazine issues may also be downloaded.

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

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