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Pico farad – mega prospect

With trade magazines it is customary for the editorial planning for the year to be based on themes or a slight focus defined for each edition. However the theme planning is not just a crucial bit of information to the magazine editors — it also offers guidance to press and PR agencies, advertisers and, importantly, potential authors who will typically use the list to submit a relevant article to... the editor! Elektor's theme plan for 2011 is available for all & sundry to view at www.elektor.com if you click on the Service tab.
For sure, a number of our themes can be accessed from so many angles that they can easily fill the magazine pages on their own strength. The March 2011 edition had a strong focus on System-on-a-Chip (SoC), covering the theme in ways that can be described as exploratory, hands-on, hardware-based, software-based and fun. For this month, test and measurement forms the plot, unmistakably. Immediately after releasing our theme plan, articles and projects on T&M got initiated to the extent that they could easily have filled the pages of an Elektor issue exclusively on electronics testing.
Test and Measurement is a diehard subject as we've noticed from the response to relevant news items on our News & New Products pages and in the Elektor E-weekly. Many of our readers thoroughly enjoy building and using their own test equipment and I'm happy to say Elektor has a long record of success stories in this field. However with the arrival of both the microcontroller on the one hand and the cheap DMM on the other, the focus has shifted from the classic ohm/volts/amps & farads cluster to more specialized applications like OBD, gigahertz RF and contactless temperature monitoring to mention but three examples found in this edition.
The farad and the microcontroller are happily united in Pico C (page 24) , a jewel of a test instrument that beats most DMMs hands down in terms of small capacitance measurements, say below 10 picofarads. Some say such values are "irrelevant", others, "in the realms of RF wizardry" or even "black magic". At the same time, there's a pile of worrying reports on my desk about a serious lack of RF-educated engineers in the industry, everyone having gone embedded. The humble picofarad may have a lot of potential.

Enjoy reading this edition,
Jan Buiting, Editor

elektor

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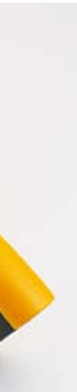

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Elektor International Media provides a multimedia and interactive platform for everyone interested in electronics. From professionals passionate about their work to enthusiasts with professional ambitions. From beginner to diehard, from student to lecturer. Information, education, inspiration and entertainment. Analogue and digital; practical and theoretical; software and hardware.

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Electrical Vehicle (EV) cup to launch summer 2011

The EV Cup, the world's first circuit race series exclusively featuring zero-emission electric vehicles, unveiled plans today for the launch of its inaugural 2011 season and announced a newly-formed partnership with CAA Sports, a division of Creative Artists Agency. CAA is the world's leading entertainment and sports agency, representing many of the most successful professionals working in film, television, music, sports, video games, theatre, and the Internet, and provides a range of strategic marketing and consulting services to corporate clients.

The historic seven-race green motorsport series, the EV Cup, will include two principle classes of zero emission electric cars — the City EV cars, where drivers will compete in carbon-free, race-prepared urban THINK cars, and the Sports EV class, which will feature teams racing 185 kph Westfield iRacers. A third category, the Prototype EV class, will not feature races, but rather base its results on time trials that showcase the latest non-production electric vehicles on circuits through street and race courses. Models of the THINK City EV Cup Edition and the Westfield iRacer are on display at the International Autosport Show.

Planned races in the EV Cup are being staged in the UK, Portugal, Spain, and the United States, with a city street race also expected to take place in the near future. Several tracks and dates in the UK have already been confirmed, including Silverstone (6 August), Snetterton (20 August), Rockingham (10 September) and Brands Hatch (23 October). Race day will include qualifying rounds and all car batteries will be recharged at on-site facilities. Each sprint race will be contested over 20 to 30 minutes of competitive laps.

The EV Cup will have access to CAA Sports' global resources and expertise to create innovative opportunities for the circuit across a wide array of areas including corporate partnerships, business development, brand marketing, event management, and media advisory, among others.

Former Formula One British champion Damon Hill is a supporter of the EV Cup. "I think the time is fast approaching when we will have to rethink our expectations regarding private road transport generally. The advantages of electric vehicles in urban environments are too many to miss. Less noise and less direct pollution are just two. The race is to save the planet from us! Racing electric vehicles should convince the wider public of their potential. Racing was initially used to develop and prove a new product called the motor car. I see no reason why electric vehicle development will not benefit in the same way. Who knows what is ultimately possible?"

Ben Collins, who appeared in the popular television series Top Gear as The Stig, and who will attend the launch and plans to be a regular EV Cup driver, said: "Electric Vehicles represent a new dawn in motoring by running on clean energy that can be sourced as locally as organic sausages. It's surprising that mankind has taken so long to embrace the technology.

"Motorsport still offers the purest research and development platform to deliver the true potential of electric power and dynamic energy recovery; perhaps to a level that will shame the carbon combustion engine the way rubber tyres did the wooden cartwheel. EV is developing fast and the current crop of road cars are superb to drive. With a dedicated racing series that encompasses both road and racecar development, the next steps will be more like a quantum leap."

(110048-XI)

www.evcup.com

Serial protocol host adapter supports dual- and quad-SPI protocols

Saelig Company, Inc. has introduced SPI Storm — an advanced Serial Protocol Host Adapter from Belgian company Byte Paradigm — controlled from a PC through a USB interface. SPI Storm can access ASICs, SoCs, FPGAs and other digital embedded systems that use serial protocols at speeds of up to 100 MHz at the I/O lines. Various serial protocols can be chosen from a standard library that includes: SPI (Serial Peripheral Interface), variants of SPI on 3 wires, and for the first time, dual-SPI and quad-SPI protocols. SPI Storm Studio software, provided free with SPI Storm, allows user-specific definition of custom protocols, including those requiring bi-directional signal lines.

In addition, SPI Storm features an 8-bit general-purpose output port that can be synchronized with the serial port, to extend the number of available signals for even more complex interfaces. With 32 MB memory, 100 MHz operation and 3 specialized ports (a flexible serial port, 8-bit GPO and an 8-bit input trigger port), SPI Storm targets ASIC, SoC, FPGA and embedded system testing and debugging, when there is a need to access and interact in real time with interfaces that use standard and user-defined serial protocols.

Powered either from the USB bus or from an external power supply, SPI Storm is a versatile 3- and 4-wire SPI exerciser/analyzer which uses a USB 2.0 high speed interface. This permits very fast signal analysis for debug, programming and testing of chips and electronic boards that use SPI for chip-to-chip communications. SPI Storm can act as both a PC-controlled master (exerciser) and as a SPI protocol sniffer (analyzer).

SPI Storm was introduced at the recent DesignCon conference and exhibition in Santa Clara on February 1-2, 2011. Target applications include both in-lab development and on-site, after-installation servicing for: chip-to-chip communication emulation, SPI-based flash memory access, SPI system development and debug, custom 3- and 4- wire serial protocol communication, RF chip characterization and test, SPI sniffing, IP evaluation, etc.
Made in Europe by Byte Paradigm, a leading embedded test equipment manufacturer, SPI Storm will be available in March 2011 with cables, standard options and SPI Storm Studio software at the introductory price of $999, from Saelig Co. Inc. Pittsford NY.

www.saelig.com

(110048-I)

Concept-to-testing expertise for Electric Vehicle charging system design

TRaC has announced that its comprehensive offering of test and analysis for the automotive industry is fully prepared and ready to assist makers of Electric Vehicle Charging Systems.
As electric vehicle use expands, attention is turning to the development of an infrastructure for charging of automotive battery solutions, so that drivers of electric vehicles will be able to achieve re-charging as safely, easily and universally as today's drivers obtain petrol and diesel fuel.
During 2010, the European Commission issued a Mandate to the European standardisation bodies — CENELEC, CEN and ETSI — to develop a common European solution for the charging of electric vehicles. The mandate aims to ensure the widespread availability of safe charging facilities and services, including the necessary measures to ensure that chargers and the vehicles themselves can interoperate with the electricity supply system; and, further, that emergent standards take into account 'smart charging' architectures that will enable drivers to recharge their vehicles at off peak rates.
TRaC has been closely involved with the evolution of standards in this area: TRaC's Director for EMC and Safety, Steve Hayes, is nominated as the UK expert for the Commission's Mandate on Vehicle Charging.
Building an infrastructure for electric vehicle charging will involve issues extending far beyond simply replenishing the batteries. Substantial amounts of energy are involved, and standards will have to ensure the safety of both users and equipment — on both the mobile and fixed side of the process. Systems will have to meet numerous standards already established in both electrical and vehicle domains, as well as complying with whatever new regulations emerge as the standardisation programme proceeds. Issues will range from the straightforward — defining and enforcing use of a common charging connector, for example — to much more complex and subtle matters such as ensuring that the equipment causes no electro-magnetic interference, or disturbance to the electricity supply grid, and that communication between the vehicle and the infrastructure conforms to standard protocols.

www.tracglobal.com

(110048-II)

Online: a ten minute tour of The National Museum of Computing at Bletchley Park

A new video made by TVUK gives everyone the chance to have a ten-minute tour of The National Museum of Computing at Bletchley Park.
It gives a glimpse of a few of TNMOC's growing number of displays: from the codebreaking Colossus through the restoration of the Harwell-WITCH computer, the Elliot 803, the ICL2966, to the home computing revolution in the PC gallery and the NPL Technology of the Internet gallery.
"This is not just a techie museum with machines in glass boxes. This is a working environment to show how machines worked — that's the essence of The National Museum of Computing. As the Museum continues its rapid growth, there are many opportunities for new sponsors, new members and volunteers," said Tony Sale, a trustee and director of The National Museum of Computing.
The National Museum of Computing warmly thanks Phil Fothergill of TVUK for creating the video.
The National Museum of Computing at

Bletchley Park, an independent charity, houses the largest collection of functional historic computers in Europe, including a rebuilt Colossus, the world's first electronic programmable computer.
The Museum complements the Bletchley Park Trust's story of code breaking up to the Colossus and allows visitors to follow the development of computing from the ultra-secret pioneering efforts of the 1940s through the mainframes of the 1960s and 1970s, and the rise of personal computing in the 1980s. New working exhibits are regularly unveiled and the public can already

view a rebuilt and fully operational Colossus, the restoration of the Harwell / WITCH computer, and an ICL 2966, one of the workhorse mainframes computers of the 1980s, many of the earliest desktops of the 1980s and 1990s, plus the NPL Technology of the Internet Gallery. In June 2010 TNMOC hosted Britain's first-ever Vintage Computer Festival.

Funders of the Museum include Bletchley Park Capital Partners, InsightSoftware.com, PGP Corporation, IBM, NPL, HP Labs, BCS, Black Marble, and the School of Computer Science at the University of Hertfordshire.

You can follow The National Museum of Computing on Twitter and on Facebook.

(110048-VIII)

http://www.youtube.com/watch?v=_Sw15F2QzMQ&feature=player_profilepage

www.tnmoc.org

Triangle Research: Embedded PLCs with Ethernet

The FMD88-10 and the FMD1616-10 PLCs are Triangle Research International's (TRi) latest Ethernet-equipped programmable logic controllers for OEMs. With the new FMD PLCs, Triangle Research now has a full range of highly integrated 'Super PLCs', starting from the compact Nano-10 to the powerhouse F-series. This super PLC series combines the powerful and easy-to-use i-TRiLOGI Ladder+BASIC software with a wide array of features, including but not limited to: built-in digital and analog I/Os, PWM, PID, encoders, stepper controls, and on-board communication ports for connecting to other devices.

As the model name implies, the FMD88-10 comes with 8 digital inputs, 8 digital outputs and 10 analog I/Os while the FMD1616-10 comes with 16 digital inputs, 16 digital outputs and 10 analog I/Os. Both

models are equipped with an I/O expansion port, a LCD display interface, RS232 and RS485 serial ports, and of course, the Ethernet port, which has become increasingly indispensable today. Triangle Research's iTRILOGI client/server software and the support of MODBUS TCP/IP protocols not only make the FMD model PLCs remotely accessible for machine monitoring and OEM troubleshooting/reprogramming, but also enables their easy integration into mixed-brand PLC environments and networks.

The sub-$300 pricing of the FMD PLCs is rare for full-feature, Ethernet PLCs in this popular I/O range, making this PLC a particularly accessible choice for value-conscious OEMs. The FMD88-10 and the FMD1616-10 single unit prices are $229 and $295 respectively, and are further discounted with OEM quantity price breaks.

(110048-VI)

www.tri-plc.com/fmd-ek.htm

First development kit for NXP LPC1227 microcontroller

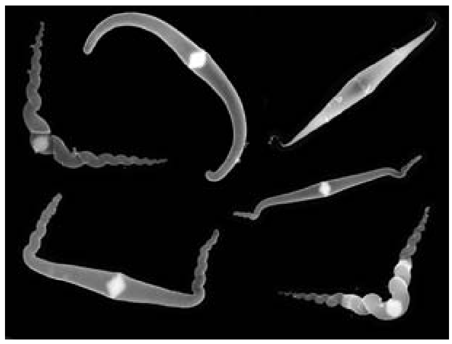
IAR Systems announced that IAR KickStart Kit for LPC1227 is now available. The kit includes a development board with an ARM Cortex-M0 based LPC1227 microcontroller, peripherals and connectors, an IAR J-Link Lite debug probe providing SWD debugging, software development tools and board support packages for various RTOSes. This is believed to be the world's first commercial starter kit for the ARM Cortex-M0-based LPC1227 microcontroller. The strong partnership and tight cooperation between NXP and IAR Systems during the development project has led to IAR Systems latest starter kit being the first to the market. Included in the kit is a code size limited version of IAR Embedded Workbench, a set of development tools for building and debugging embedded system applications using assembler, C and C++. It provides a completely integrated development environment that includes a project manager, editor, build tools and the C-SPY debugger.

IAR KickStart Kit for LPC1227 is priced at € 129 / $ 169. It can be bought online at www.iar.com/eshop.

(110048-V)

www.iar.com

Carbon nanotache with 3D symmetry



Researchers at the University of Surrey show the controlled synthesis of nanomaterials by subjecting pure organic molecular gas to high temperatures and pressures that allow symmetry breaking events to create the different carbon nanostructures. Spheres, nanotubes and mirrored spirals can be created under the appropriate isovolumetric conditions that show the versatility of this unique growth system. The report was published in the January 2011 issue of the premiere journal in nanotechnology, Nano Letters.

Self-organisation of matter is essential for natural pattern formation, chemical synthesis, as well as modern material science. Mechanisms governing natural formation of symmetric patterns have long intrigued scientists and remain central to modern science from attempts to understand spirals and twists of climbing plants to the studies of bacterial macrofibers and DNA. Self-assembly of atoms and molecules is the key to understanding the natural shape formation and is elemental to the production of modern materials, such as silicon, synthetic polymers, and various nano- and microstructures.

Dr Hidetsugu Shiozawa, of the Advanced Technology Institute (ATI) at the Univer-

sity of Surrey, said: “The work represents a concept to experiment with self-assembly process and demonstrates how morphological symmetry of nano- and microstructures can be controlled. The study of such physical phenomena helps us understand why certain symmetry of structure emerges amongst others, and how this is correlated with physical quantities of thermodynamic equilibrium such as temperature and pressure.”
Professor Ravi Silva, FREng, Director of the ATI and co-author, indicated: “The creation of new technologies and businesses are highly dependent on this ability to create designer materials of the highest quality. The UK is renowned for its highly creative and innovative research force, for which this is a prime example. To create a strong manufacturing base, we must back high quality research that has potential to create new markets and novel products such as those enabled by these symmetric carbon nanostructures. It will lead to transformative technologies.” The work appears in: DOI: 10.1021/nl1032793

http://pubs.acs.org/doi/abs/10.1021/nl1032793
(110048-III)

Higher reliability and efficiency for ultra-compact LED lamps

The first in a new family of mains-operated LED lamp drivers from STMicroelectronics will enable designers to deliver more reliable and efficient LED retrofit lamps featuring primary-side current regulation.
LED lighting, including retrofit bulbs, is

expected to account for 80% of the lighting market by 2020 or sooner. Primary-Side Regulation (PSR) cuts bill-of-materials costs for retrofit bulbs, thereby reducing the payback time, while also simplifying design and reducing the space occupied by LED control circuitry.
The new HVLED805 integrates an 800 V avalanche-rugged MOSFET, achieved using ST’s high-voltage integration process, which is higher than in competing devices and hence offers greater reliability. The high-voltage on-chip startup circuitry allows the device to start reliably when the AC line voltage is applied to the lamp.
Primary-side regulation maintains the constant LED current that is needed to ensure consistent light output, without requiring the current-sensing components and opto-coupler used in conventional secondary-side regulation. The elimination of these components decreases the cost and size of the LED driving circuitry and saves current-sensing losses, improving overall efficiency.
Using PSR, the HVLED805 guarantees LED current regulation to within 5% accuracy. Reliability is also enhanced, due to the elimination of the opto-coupler in the secondary side, whose degradation can significantly decrease the mean-time-between-failure of the lamp.
The HVLED805 PSR controller integrates high-voltage startup for efficient power-on, and the robust 800V power MOSFET allows a reduction of the snubber network. The highly efficient quasi-resonant (QR) operating mode further boosts energy savings for LED lighting and dramatically reduces the EMI filtering required, saving space and costs.

Major features of HVLED805:

- 800V avalanche-rated MOSFET power switch
- 5%-accurate constant-current regulation
- Quasi-resonant operation
- High-voltage startup circuitry
- Open- or short-circuit LED string management
- Automatic self supply
- Input voltage feed-forward for mains-independent constant-current regulation

The HVLED805 is in mass production now in the SO-16N narrow package.

(110048-IV)
www.st.com

The Five Rules…
…when choosing a DSO

By Andreas Grimm (Germany)

The oscilloscope marketplace has not become any clearer over recent years. Their capabilities have been expanded with the addition of many new and innovative features to increase their usefulness. More recently new manufacturers have also appeared. The oscilloscope is the hub of any test and development environment, it will most likely be in daily use for many years to come so it is vital to consider as many factors as possible before you choose a new model.

The majority of Elektor readers will be able to tell you that the most important things to look out for when buying a digital oscilloscope (DSO) is its bandwidth and sample rate. These are indeed two of the most important or key features but there is also a list of other things that need to be considered. An oscilloscope is such an important piece of test gear that it's worth investing some time to make sure you will not be disappointed.

1. The key features

Your choice of bandwidth and maximum sample rate will depend on the fastest signals that you anticipate will need to be observed. Digital signals are more prevalent in circuits these days so the rise time of the input stage is very important.

As a real world example you may be working on a system containing a processor running at 8 MHz. The rise and fall times for the clock will typically be 10 ns. The rise time of the scope's input amplifier must be faster than the input signal otherwise you will just be displaying the characteristics of the scope's input amplifier rather than the observed signal. A practical figure for the rise time is that it should be about 30 % of the signal under observation. In this example observing an edge with a 10 ns rise time indicates that the scope's input amplifier must have a rise time T_r of 3 ns or better. Using the formula

$$B = 0.3 / T_r$$

indicates a 100 MHz oscilloscope is needed. **Figure 1** shows the effect of the input rise time of a 100 MHz DSO on a signal with a 10 ns rise time.

Once the bandwidth has been calculated we can turn our attention to the required sample rate. We can use the formula SR = 8 to 10 x B where B is the scope's analogue bandwidth. For a 100 MHz scope this results in a sample rate of 1 GSamples. This ensures that the square wave fundamental and a sufficient number of harmonics can be captured in accordance with signal theory.

Why do we so often get feedback from engineers who have just used these two basic criteria to select a DSO and are unhappy with their scope when they come to use it? The answer is usually because they have overlooked the importance of memory depth.

We may indeed be interested in the step response of a circuit to a single repetitive edge but more often than not in digital circuits we also need to capture a complex sequence of edges or a data stream. This is where the third criterion, the size of the waveform memory, plays an important part. A very simple formula can be used here to give the necessary memory depth, which is equal to the product of the sample rate and the observed time window. The optimal time window length is determined by the types of signals to be observed. For example in a mains powered switched mode power supply we will need a window in the millisecond range to observe the switching control signals but to observe effects over several mains cycles we would require a window of around 100 ms.

Analysing microprocessors systems will typically require the display of data transfers occurring over a few memory cycles. The observation window will be in the submicrosecond range, or in the millisecond range to take in several transfers. To sum up, a display window of 1 to 100 ms is a good practical value.

Taking the example given above (8 MHz processor clock, T_r = 10 ns, SR = 1 GSamples/s) and displaying a 1 ms time window gives:

Memory = 1 GSamples/s × 1 ms = 1 MPoint

i.e. one million memory points (see **Figure 2**).
Conversely with a fixed recording time (1 ms) and a given memory depth using the above formula we get the resulting sample rate. This can be seen to decrease dramatically with a smaller memory depth as shown in the table.

Time window	Memory depth	resulting sample rate
1 ms	2M Points	2 GSamples/s
1 ms	100k Points	0.1 GSamples/s = 100 MSamples/s
1 ms	10k Points	0.01 GSamples/s = 10 MSamples/s
1 ms	2,5k Points	0.004 GSamples/s = 4 MSamples/s

From this we can see that the memory depth is a very important property of a DSO and one which is all too often overlooked.

2. Measuring properties

The usefulness of the scope is largely determined by the properties of the input analogue amplifier stages and its triggering properties. The analogue signal path should offer high sensitivity and low noise. The best models on the market offer a maximum input sensitivity of 1 mV/DIV but this is by no means the standard value. To make use of this high sensitivity it's important that the input amplifier introduces as little noise as possible to the measured signal: even at its most sensitive setting the noise should be less than one quarter of a scale division. These properties for example allow meaningful measurement of ripple levels (small signals superimposed on much larger signals) to be made. Trigger sensitivity is also important here to enable measurements to be made on the waveform of interest. The

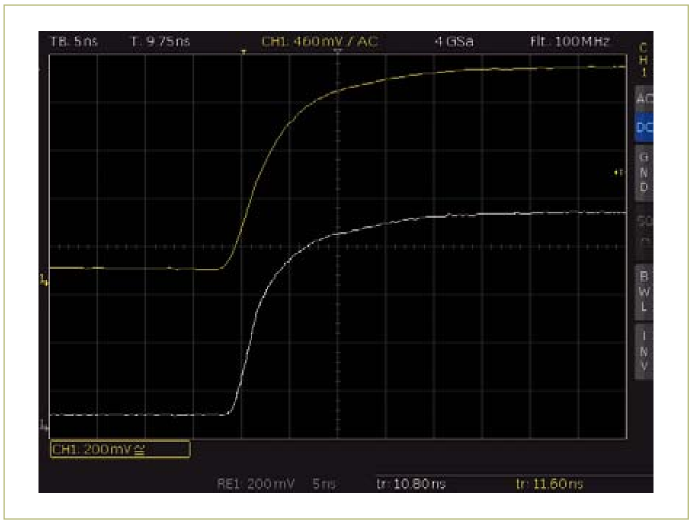


Figure 1. The effect of input rise time of a 100 MHz DSO measuring a signal with a 10 ns rise time (white), the resulting curve is shown in yellow.

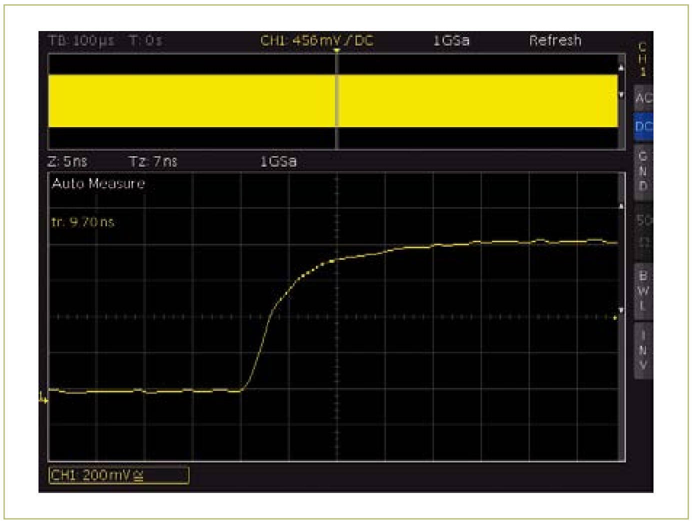


Figure 2. Fast signal changes (<10 ns) can be resolved with a one million point acquisition memory and a recording time of 1 ms.

trigger sensitivity should be much better than one scale division.

Particularly during the development of power electronic systems it can be useful to perform mathematical analysis on the channel waveforms. Any high frequency interference can first be eliminated with a low pass filter then the energy value can be calculated by multiplying the voltage channel by the current channel and then integrating the result. The 'chained math function' capability is often an optional feature and is not seen in scopes under 6,000 Euros.

A standard feature of the DSO is the cursor measurement function. It is especially useful if the cursor can follow the waveform whilst displaying in real time the values of time information and voltage level. This is far more convenient than switching back and forth between the time and amplitude cursor. In addition it is also useful

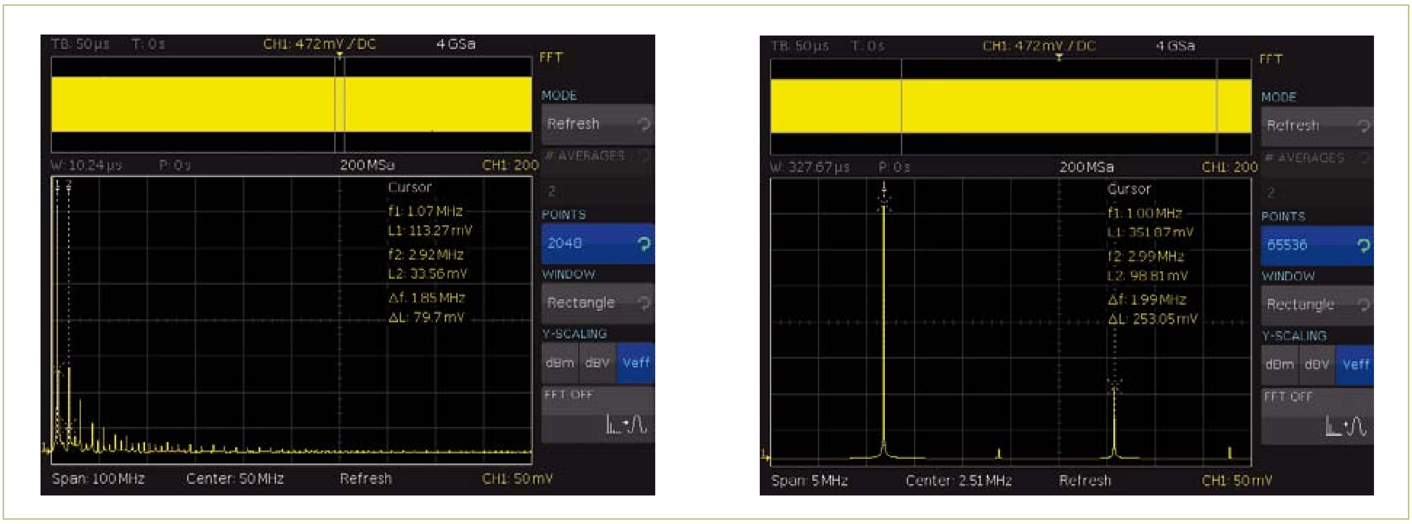


Figure 3. An FFT feature is only really practical if it uses a sufficient number of points for the calculations (left 2048 Points, right 65536 Points).

to be able to configure Automatic parameter measurements allowing say signal pulse width or overshoot to be calculated. The advantage of using parameter instead of cursor measurements is that it only needs to be switched on once and gives reproducible results.

A pass/fail test is useful to continuously monitor the observed signal waveform by means of a configurable mask. The reference waveform mask plus tolerances is first defined and when a violation occurs the scope can be programmed to stop measurement, output a signal or perform a screen print.

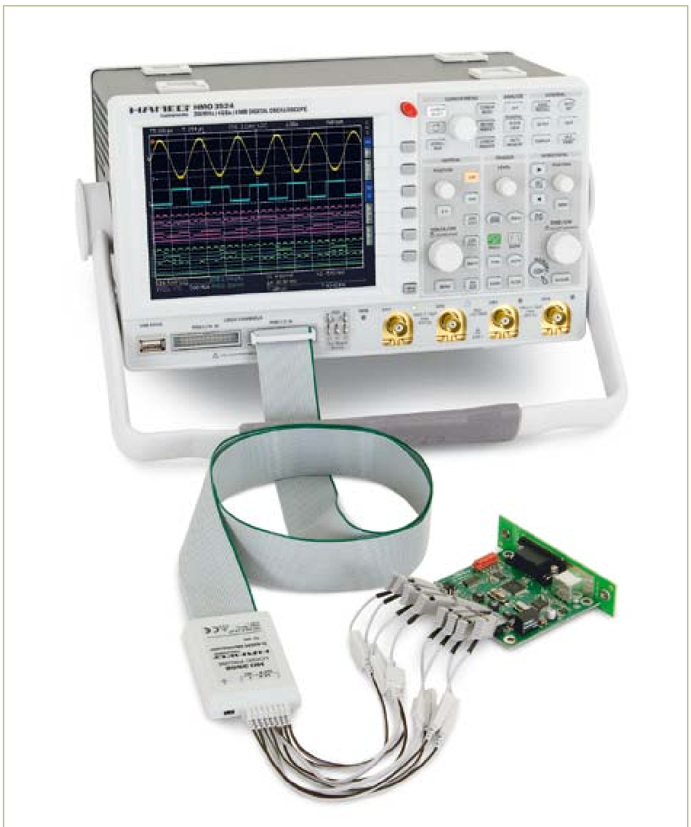


Figure 4. A mixed signal oscilloscope.

Meanwhile almost all DSOs come with an ability to perform frequency domain analysis in the form of the FFT function. This can be used to identify the source of any in-band interference. In practice however with some budget scopes this feature is poorly implemented using too few points to be of any use. The number of points used in the calculation (together with the time period) determines the FFT resolution. Using just 1,000 points is insufficient and meaningful results can only be achieved using 32,000 or more points (see **Figure 3**).

3. User friendliness

In addition to the hard facts and figures of the scopes specification there are also features which can best be appreciated by using the equipment. The display size and resolution would be in this category. While 6 inch (and above) colour TFT screens are the norm today what often is disappointing is the screen resolution. A VGA display (640 x 480 pixels) with almost full horizontal and vertical viewing angles and high contrast should be the minimum requirement. QVGA displays (320 x 240 pixels) are generally disappointing especially on a MSO (Mixed Signal Oscilloscope) where up to 20 channels of information may need to be displayed. A port for connection of an external mon itor or LCD projector may be beneficial. During the development of complex hardware designs it doesn't take long for the work bench to fill up with test equipment. Equipment which can be stacked or which have a small footprint will therefore be advantageous. Other factors such as high fan noise can be irritating especially as the equipment will typically be running continuously throughout the day.

4. Future proofing

The proliferation of embedded systems seems is relentless and with them comes the need for engineers to display time-synchronous analysis of analogue and digital signals. While memory is usually connected to the processor using a parallel bus other peripherals such as FPGAs, sensors or displays are often connected over a serial bus such as a UART, I2C or SPI. During development of such designs it is useful if the oscilloscope can display parallel data and also trigger and decode serial data (**Figure 4**).

The oscilloscope will prove far more useful if it offers the flexibility to work in MSO operation or has the capability to decode serial data protocols in common usage or those which may be introduced in the future. With a tight test equipment budget it is worth considering whether the decoding and triggering from serial protocols is necessary on both analogue channels and if the external trigger is necessary on the dual channel scope.

Documentation is an important part of project development and it is advantageous to be able to include test results. The DSO should provide at least a USB port for connection of an external PC to transfer data. With the DSO in an automated test environment a GPIB (or more increasingly Ethernet) will be necessary to connect to the test control computer. If not fitted as standard it should at least be available as an optional upgrade. Before purchase it is also worth considering after-sales support, good support will be easy, fast and low-cost to protect your investment for at least five years or more.

5. The price/power trade off

It is clear that your choice of DSO should not just be made on the basis of its most important technical features and cost. There are a number of other factors that also need to be considered. To simplify the process we have collected them together in the form of a checklist:

- Bandwidth (rise time), sensitivity and noise of the input amplifier.
- Sample rate, Memory depth
- Trigger modes and sensitivity
- Display size, resolution and viewing angle, external monitor port
- Functions such as cursor and parameter measuring and 'math' channels
- Pass/Fail waveform test
- Mixed-Signal-Option (or as an optional upgrade)
- Triggering and decoding of serial protocols (or as an optional upgrade)
- Interfaces such as USB, LAN, GPIB (or as optional upgrades)
- Service und support for as long as possible to achieve maximum lifetime from your investment.

The majority of the most important equipment characteristics can be found on the equipment's data sheet or user's manual. Other properties such as the noise level produced by any fan fitted to the equipment or the screen viewing angle can often be answered by calling the appropriate customer services. Best of all is to arrange a hands-on test of the DSO before purchase.

(100896)

Andreas Grimm is head of product management for HAMEG Instruments GmbH (www.hameg.com).

Non-Contact Temperature Measurement

What about that heat sink: is it the right size? With an infrared thermometer, you can quickly measure the temperatures of all sorts of objects at a (reasonable) distance. Thermometers of this sort are available with prices starting at a few dozen euros/pounds. What do you need to pay attention to when buying or using an infrared thermometer? This article sets you on the right path and provides information on a selection of meters priced under 200 euros/pounds.

By Harry Baggen (Elektor Netherlands Editorial)

At first glance, IR thermometers appear to be very handy instruments for measuring temperatures at a distance with high accuracy over a wide temperature range. Furthermore, they are now available at relative modest prices, so quite a few people buy one without giving much thought to the significance of the various features and how to use them properly. It's the same as what happens with a lot of consumer goods nowadays: just press the buttons and see what happens. Nobody bothers to read through the user guide, and most people ignore it until they run into a problem that can't be sorted out any other way.

Fortunately, the situation is better among electronics enthusiasts. We are all aware of the importance of knowing what we are measuring, and most of us also want to know what we need to pay attention to when using a measuring instrument.

Although an IR thermometer can be very handy, you can't expect to obtain good results unless you use it properly and its specifications match what you want to use it for. It makes a difference whether you simply wish to measure a variety of objects with no need for especially high accuracy, or you need to know the exact temperature of a small surface located a metre away from the instrument. You need two different types of meters for these tasks. Accordingly, you should read this article before you buy an IR thermometer.

Radiant heat

All objects radiate infrared energy. The warmer an object is, the faster the molecules in the object move about, and as a result the more infrared energy it radiates. The wavelength of this radiation lies roughly between 0.5 and 100 μm. This depends on the temperature: the higher the temperature, the shorter the wavelength of the radiated IR energy, as illustrated in **Figure 1** for several different temperatures. This means that an IR thermometer must be able to detect energy radiated in a specific spectrum in the IR band in order to be able to measure temperatures accurately over a wide temperature range. In addition, you should bear in mind that only perfect radiators (in technical terms, 'black bodies') actually radiate all of their thermal energy. With other types of objects, the amount of energy radiated also depends on factors other than the temperature of the object, such as the properties of the material and surface reflection. This is expressed by the emissivity or emission coefficient of the material, and it can strongly affect the accuracy of IR temperature measurements. See the inset for more about this.

Features

What features should you look for when you buy an IR thermometer? To start with, the price will naturally be a major factor. For professional use, you need an instrument that is more reliable and better calibrated than what you need for home or hobby use. Aside from this, the price is largely determined by two factors: the measuring range of the instrument and its angular field of view (opening angle).

A large measuring range imposes more severe demands on the IR sensor. Most inexpensive instruments can easily handle temperatures up to around 200 to 300 degrees. Nowadays you can also find instruments with ranges up to 500–1000 °C at reasonable prices. There are some models priced as low as 100 euros/pounds that can manage 1000 °C, at least if the manufacturer's specifications can be taken at face value. However, most of the money goes into the optics, and instruments with a small angular field of view are significantly more expensive. Whether you actually need a small field of view (FOV) depends on the intended use. A small FOV is certainly worthwhile for making measurements on electronic components, such as small heat sinks and the like, where the rule is 'the smaller the better'. The angular field of view is usually stated as a ratio, with 10:1 being a common value. This means that the diameter of the measuring spot is one-tenth of the measuring distance (see **Figure 2**). With this ratio, at a distance of 10 cm

Using IR thermometers: guidelines and practical tests

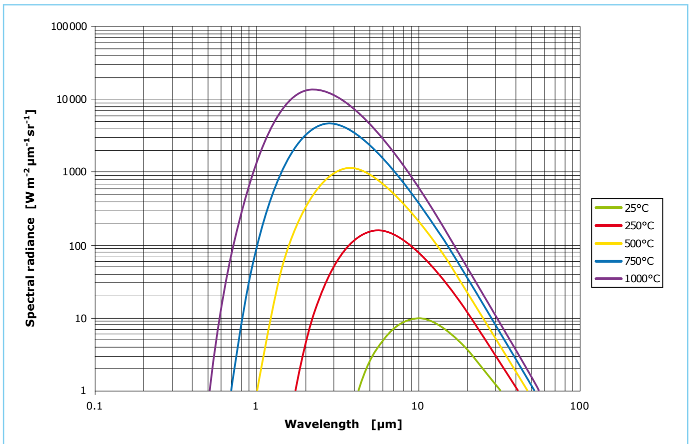


Figure 1. IR radiation emitted by a black body at various temperatures (source: Scitec Instruments).

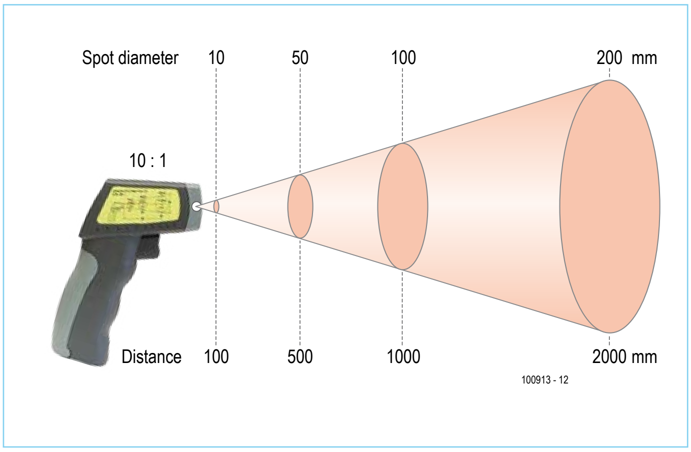


Figure 2. The angular field of view of an IR thermometer is specified as the ratio of the distance and the diameter of the measuring spot.

the diameter of the measuring spot is 1 cm, while at a distance of 1 m it is 10 cm. Incorrect estimation of the size of the measuring spot during an IR temperature measurement is the most common cause of incorrect readings. An IR thermometer indicates the correct temperature only if the spot lies fully within the area to be measured (**Figure 3**), and usually the spot area accounts for only 90% or so of the measured energy. Accordingly, if you want accurate readings you should hold the instrument as close as possible to the object being measured. A good rule of thumb is that for high-accuracy measurements, the area to be measured should be at least twice as large as the measuring spot.

Another key factor with regard to the accuracy of the readings is the properties of the material whose temperature is being measured. The reflectivity of the material is indicated by the previously mentioned emission coefficient. Simple IR instruments are permanently calibrated for a value of 0.95. This is suitable for a wide variety of materials, including wood, plastics, rubber, stone, water, concrete and ceramics, but metals in particular have significantly lower emission coefficients, especially if they have a shiny surface. This can lead to measurement errors as large as 50%. This means that there's no point in measuring the temperature of an aluminium heat sink with a natural finish if your IR thermometer does not support emissivity

The following companies kindly supplied products for this test:

- Amprobe (www.amprobe.eu)
- BASETech: Conrad (www.conrad.com)
- BK Precision (www.bkprecision.com)
- Black & Decker (www.blackanddecker.com)
- ELV (www.elv.de)
- Extech (www.extech.com)
- Fluke (www.fluke.com)
- HT Italia (www.htitalia.it)
- Optris GmbH (www.optris.com)
- Peaktech (www.peaktech.de)
- Testo (www.testo.com)
- Uni-Trend (www.uni-trend.com)
- Velleman (www.velleman.eu)
- Voltcraft: Conrad (www.conrad.com)

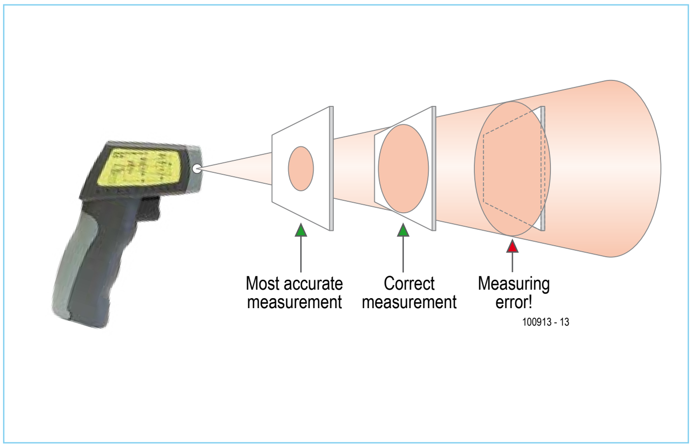


Figure 3. Always hold the thermometer close enough to the object to measured that the entire measuring spot is located within the area to be measured.

Figure 4. We used this Fluke 572 IR thermometer as a reference for our tests. It has a 50:1 FOV.

adjustment.
To check this in practice, we ground one side of a small black anodised heat sink down to bare metal, warmed the heat sink, and measured the temperature on both sides. The reading on the black side was 65 °C, but on the bare side it was only 40 °C. To obtain a reasonably accurate indication of the temperature on the bare side with the instrument, it would be necessary to reduce the emission coefficient to approximately 0.15.

Methods for obtaining more accurate readings

There are three different methods for obtaining more accurate readings with materials for which the emissivity is not known or deviates too much from the default value of 0.95:
- Stick a piece of thin, matt black tape on the surface to be measured; it will have an emissivity fairly close to 0.95. Of course, this works only at temperatures that the tape can withstand. Some manufacturers of IR thermometers offer special tape for this purpose.
- Paint the surface to be measured matt black. Radiator paint can be used for temperatures up to around 80 °C, and special heat-resistant paints can be used for higher temperatures (up to 600 °C).
- Drill a hole in the object to be measured, with a depth at least five times its diameter. Using the thermometer, measure the temperature inside this hole (the hole diameter must be greater than the measuring spot diameter). With materials whose emissivity is greater than 0.5, this hole forms a nearly ideal black body. Unfortunately, this is a relatively destructive method.

If it is possible to adjust the emissivity setting of the thermometer (this is indicated in the summary table), you still need to know the right value for the material to be measured. The user guides for most instruments usually include a table of values for a large number of materials, and the values for various materials commonly used in electronics are shown in a table in the inset. This gives you a more or less reliable reference point, but you still can't be entirely

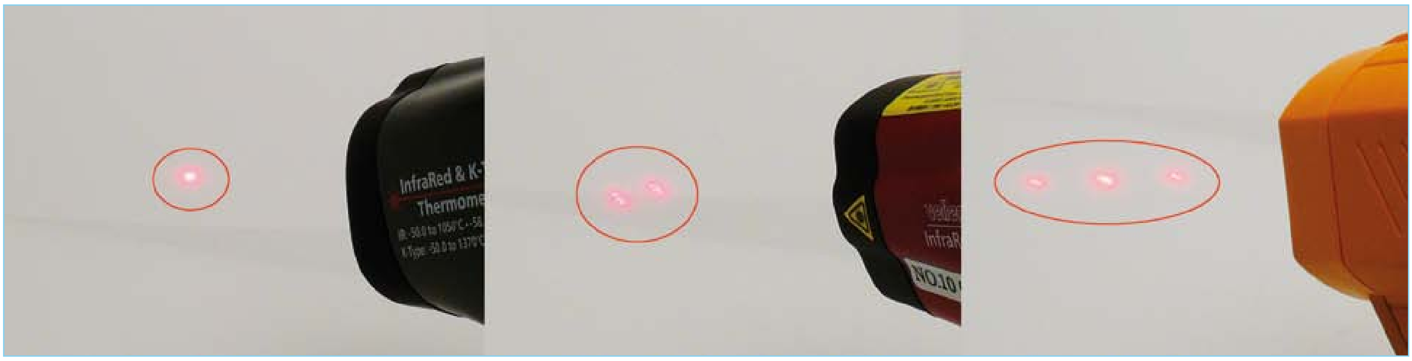


Figure 5. Some IR thermometers have a single laser pointer, while others have two and a few even have three.

certain of the value. The best way to determine the exact value of the emissivity of a particular material is to use an accurate contact temperature sensor and compare the value measured with this senor to the value indicated by the IR thermometer. Then you can adjust the emissivity setting until the IR thermometer shows the same value.

From economical to affordable

To see how usable IR thermometers are for various purposes, in the Elektor lab we tried out a number of instruments of different makes with prices below 200 euros/pounds, testing them under a variety of conditions. We intentionally selected models covering a wide range of prices, extending from 23 euros/pounds for the least expensive model to 175 euros/pounds for the most expensive. Incidentally, it's remarkable how many different types of IR thermometers are available. It looks like they're just as indispensable as multimeters. As most IR thermometers are very similar in terms of appearance, operation and features, there's no need to describe them all individually. The key features, such as field of view, temperature range and emissivity adjustment, are summarised in the accompanying table. To provide a reference standard for all of this, Fluke kindly loaned us a model 572 IR thermometer, which sells for around 700 euros/pounds (ex VAT) and has a field of view of 60:1 (**Figure 4**). In the near future we also plan to present a comparison of measurements with an IR thermometer and a thermal imaging camera; unfortunately we weren't able to complete it in time for this article.

The differences

So what are the biggest differences? As already mentioned, they can be found in the measuring range, field of view and adjustment options. A measuring range up to 200 °C or so is more than adequate for most home-and-garden variety electronics applications, and nearly all of the tested models are suitable for this. The field of view varies considerably among the different models. For instance, the cheapest models have a field of view of 1:1, with which it is practically impossible to make selective measurements unless you hold





Figure 6. Some instruments come with a type K thermocouple, which can be used as contact sensor to measure the surface temperature so that the emissivity setting can be adjusted for IR measurements.

the instrument right next to the object to be measured. For a bit more money, you get a thermometer with a field of view of 8:1 or 10:1, which is more like what you're looking for. However, if you want to measure something on a PCB or inside an enclosure, you should be looking for an instrument whose optics provide an FOV of 20:1 or 30:1.

Another important feature is the option of adjusting the emission coefficient setting. Particularly for measurements on metallic objects, such as a bare aluminium heat sink, a fairly radical adjustment of the coefficient is necessary to obtain correct readings. However, this feature is usually found only instruments at the upper end of the price scale. Of course, this is all highly relative because we're talking about fairly inexpensive instruments here. Professional models can easily cost more than 200 euros/pounds, but for that money you get an officially calibrated device with guaranteed long-term accuracy. With 'no-name' (or better said, imaginatively named) instruments, only time will tell how stable they are.

All but two of the instruments we tested have a pointer beam, usually in the form of a laser beam (see **Figure 5** for the different types). Only the Black&Decker unit has an LED beam, whose colour depends on the measured temperature. Some of the instruments are equipped with two laser beams that indicate the size of the measuring spot, which is very handy and considerably reduces measurement errors. However, you should bear in mind that this indication is usually incorrect at short distances because the laser beams cross at a distance of 10 to 15 cm. Here as usual, you should use your common sense when making measurements. For comparison, the professional-quality Fluke 573 instrument we used as a reference has three laser beams that indicate the centre and diameter of the measuring spot.

An especially handy feature with some IR thermometers is the option of connecting a type K thermocouple so you can measure the temperature with a contact sensor. Then you can compare this with the IR temperature reading and adjust the emission coefficient precisely (**Figure 6**). For example, the HT3301 unit provides this capability, and it has a measurement memory for up to 20 readings. Most of the devices also have several other features, such as a memory for saving minimum and maximum temperature readings or an alarm with an adjustable threshold level. All of this is noted in the summary table.

Unusual models

There are few unconventional instruments in the group. The first is the Peaktech 5090, which has a totally different appearance than the other instruments and looks more like a multimeter. It also has two measurement functions: temperature and relative humidity. Both quantities are shown at the same time on a large display. The humidity sensor is housed in a separate probe that is connected to the meter by a coiled cable. Unlike the other instruments, the IR thermometer function is continuously enabled after the unit is switched on, which takes a bit of getting used to. The laser pointer can be switched on or off with a separate button.

Speaking of multimeters, the Extech EX470 combines a standard multimeter with an IR and thermocouple (type K) thermometer. Although the IR measuring function does not offer many setting options, this is a handy solution for an electronics hobbyist or professional who needs an all-in-one instrument. The multimeter even features true RMS readings along with capacitance and frequency measurement.

To give you an idea of the variety of products that are available, we also included an IR thermometer from Black&Decker in our selection. You can buy this device in an ordinary DIY home improvement store. It is actually intended to be used for tracking down heat leaks in your house, but it can be use for other purposes as well. The spot size is too large for measuring small objects, but that's also true of quite a few of the other models in our selection. A special feature of this instrument is that it has a user-settable hysteresis range (with three steps), and the colour of the LED spot changes when the measured temperature goes outside the hysteresis range (relative to the initially measured value). Although the LED spot is smaller than the measuring spot and not as easy to see at longer distances, the colour change is very a practical feature for the original application.

Practical experience

To test the instruments under practical conditions, we made several measurements on different enclosures and heat sinks. These results showed that all of these instruments are reasonably accurate; they deviated only a few degrees from our Fluke 572 reference instrument. However, you should bear in mind that the deviations are relatively large at low temperatures (room temperature), where a difference of 2 °C is much more significant than at high temperatures. We also used a small electric hot plate to check the spot size and the

Table 1a. Key specifications.

						
Model	Amprobe IR608A	BASETech MINI 1	BK Precision 635	Black&Decker TLD100	ELV 8835	ELV VA 6520
Temp. range	−18 to 400 °C	−33 to 220 °C	−20 to 550 °C	−30 to 150 °C	−50 to 1050 °C	−50 to 500 °C
FOV	8:1	1:1	10:1	6:1	30:1	8:1
Emissivity	0.95 fixed	0.95 fixed	Ajustable	0.95 fixed	Ajustable	0.95 fixed
Laser	1	–	1	LED	1	1
IR band	7 to 18 μm	–	6 to 14 μm	-	8 to 14 μm	8 to 14 μm
Resp. time	0.5 s	1 s	1 s	-	1 s	0.5 s
Max-Min High/Low alarm	- / -	- / -	X / X	- / -	X / X	X / -
Extras	–	–	–	–	Case, K-type thermocouple, 20-reading memory	Case
Price	€ 94 (ex VAT)	€ 23	€ 157(ex VAT)	€ 55	€ 100	€ 62

						
Model	Extech EX470	Fluke 62	HT3301	Optris MS LT	Peaktech 4975	Peaktech 5090
Temp. range	−50 to 270 °C	−30 to 500 °C	−50 to 1050 °C	−32 to 420 °C	−50 to 550 °C	−50 to 500 °C
FOV	8:1	10:1	30:1	20:1	12:1	8:1
Emissivity	0.95 fixed	0.95 fixed	Ajustable	0.95 fixed	Ajustable	0.95 fixed
Laser	1	1	1	1	2	1
IR band	-	-	8 to 14 μm	8 to 14 μm	8 to 14 μm	6 to 14 μm
Resp. time	-	0.5 s	1 s	0.3 s	0.15 s	0.4 s
Max-Min High/Low alarm	- / -	X / -	X / X	X / -	X / X	X / -
Extras	Multimeter functions, K-type thermocouple	–	Hard case, K-type thermocouple, 20-reading memory	–	Case	Case, built-in humidity meter
Price	€ 145	€ 125	€ 148 (ex VAT)	€ 89	€ 63	€ 84

						
Model	Testo 830 T1	Uni-Trend UT 300B	Velleman DVM105	Velleman DVM8861	Voltcraft IR260-8S	Voltcraft IR800-20D
Temp. range	−30 to 400 °C	−18 to 380 °C	−33 to 220 °C	−50 to 550 °C	−30 to 260 °C	−50 to 800 °C
FOV	10:1	10:1	1:1	12:1	8:1	20:1
Emissivity	Ajustable	0.95 fixed	Ajustable	Ajustable	0.95 fixed	Ajustable
Laser	1	1	-	2	1	2
IR band	-	-	5 to 14 μm	8 to 14 μm	-	8 to 14 μm
Resp. time	0.5 s	0.5 s	1 s	0.15 s	-	0.15 s
Max-Min High/Low alarm	- / X	X / -	X / -	X / X	X / -	X / X
Extras	–	–	Storage case	Case	–	Case
Price	€ 121	€ 29	€ 40	€ 85	€ 30	€ 96





accuracy of the laser pointer. Although this may not sound especially professional, in practice it turned out to be very effective. In particular, with some of the instruments we had the feeling that the built-in laser (or the IR sensor) was not properly centred. Especially in the case of instruments with a small field of view, it is important that the laser pointer marks the exact centre of the measuring spot. We found that this was not entirely true with various instruments; the laser pointer was often misaligned by a few degrees. Sometimes a few taps on the instrument were enough to cause the laser to suddenly shift by a few degrees. The worst in this regard was the Voltcraft IR800-20D with its dual laser. Although the spot size stated in the specs was very close to reality, the lasers clearly pointed too far to the right and were offset from the actual measuring spot by nearly half its diameter. The dual-laser units of the Peaktech 4975 and the Velleman DVM8861, which came from the same factory, did not exhibit this problem, so we assume that it was an isolated problem.

Nevertheless, it's a good idea to not trust the laser spots blindly, and it's advisable to have some extra surface around the measuring spot to ensure that you're measuring the right thing. The three laser spots of the Fluke reference instrument were perfectly aligned, despite its narrow 60:1 field of view (actually, we hardly expected anything else).

You should also take parallax errors into account at short distances.

A difficult choice?

An IR thermometer can be a very handy instrument if you use it properly. We haven't said anything about accuracy yet in this article. Almost all of the devices have an accuracy of around 2%, which yields a negligible error compared with all the other measurement errors that can occur with an IR reading.

The important factors for making measurements with relatively small objects, especially in the electronics area, are a small measuring spot (preferably 20:1 or better FOV) and the possibility of adjusting the emissivity setting. The ELV 8835, HT3301 and Voltcraft IR800-20D meet this requirement. However, suitable models are available from nearly all brands; here we only made a more or less random selection from the wide range of available products. Still, it's clear that you can buy an instrument that fulfils these requirements for as little as 100 euros/pounds.

An instrument with a field of view of 8:1 or 10:1 (1 cm spot size at a distance of 10 cm) is also perfectly adequate for measuring the temperatures of somewhat larger objects, such as heat sinks, as long as you remember to stay close to the object being measured. Particularly for readings on electronic circuits, instruments with a fixed emissivity setting of 0.95 will generally not yield usable results.

It's noteworthy that many instruments come from the same factories in China (just like multimeters), with the only difference being the colour or the printing on the housing. Consequently, you should pay careful attention to appearance when comparing different brands of thermometers.

We were especially taken by the two mini-instruments in this selection: the BASETech Mini 1 and the Velleman DVM105. They are cute little gadgets for making the occasional quick measurement. Although they don't have any optics (a tube in front of the sensor gives them a 1:1 ratio), the Velleman instrument does allow you to set the emissivity value.

(100913-I)

We thank Fluke Netherlands for making a Fluke 572 IR thermometer available for use as a reference for our tests.

Emissivity

Emissivity (or the emission coefficient) is an indication of the extent to which the thermal infrared radiation emitted by an object is determined by the object's own temperature. A value of 1 means that the infrared radiation is determined solely by the object's own temperature. A value less than 1 indicates that the emitted radiation depends in part on factors other than the object's own temperature, such as nearby objects or heat transmission. Simple IR thermometers usually have a fixed emission coefficient setting of 0.95. If the emissivity of the object to be measured differs from this, the resulting readings will be inaccurate. More expensive instruments have an adjustable emission coefficient setting.

Metal	Emissivity	Non-metal	Emissivity
Bare aluminium	0.02–0.4	Concrete (rough)	0.93–0.96
Gold	0.02–0.37	Glass	0.76–0.94
Copper	0.02–0.74	Wood	0.8–0.95
Lead	0.06–0.63	Carbon	0.96
Brass	0.03–0.61	Human skin	0.98
Nickel	0.05–0.46	Paper	0.7–0.95
Steel	0.07–0.85	Plastic	0.8–0.95
Tin	0.04–0.08	Rubber	0.86–0.94
Silver	0.01–0.07	Water	0.67–0.96
Zinc	0.02–0.28	Sand	0.76–0.9

The emissivity values of a number of materials are listed in the table. They have been compiled from lists provided by various manufacturers of IR thermometers. The emissivity of metals is strongly influenced by the processing undergone by the metal and the surface treatment.

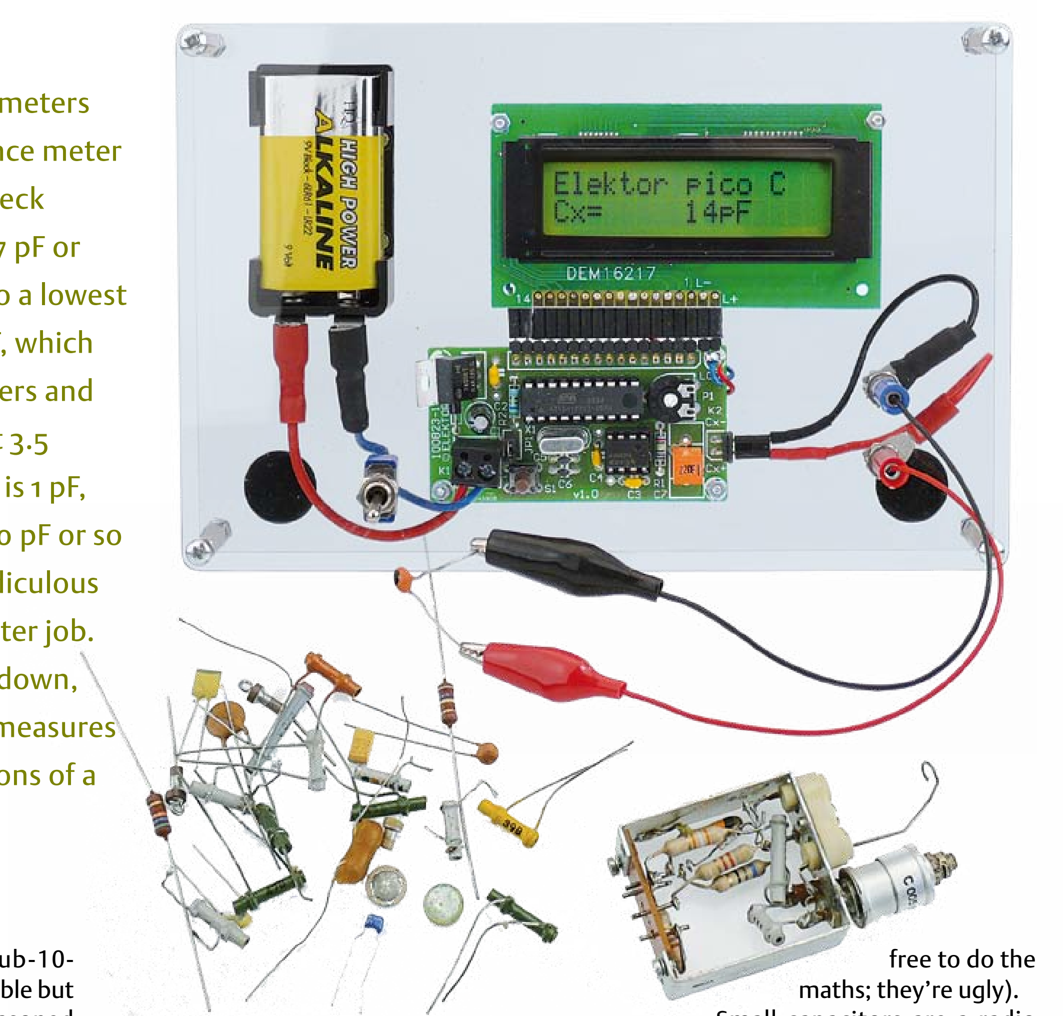
When compiling this table, we noticed that every manufacturer states somewhat different values, which makes it rather difficult to derive the correct emissivity settings for an instrument from the table supplied with the instrument. The only sure way to determine the correct setting is to measure the temperature with a contact sensor.

Pico C

Please welcome ATtiny & The Low Picofarads

By Vladimir Mitrovic (Croatia)

Even upmarket digital multimeters boasting a built-in capacitance meter are useless if you want to check out tiny capacitances like 2.7 pF or 5.6 pF. Usually, you're tied to a lowest measuring range of 2000 pF, which is a good laugh to RF designers and radio amateurs. Although at 3.5 digits the DMM's resolution is 1 pF, any measurement below 200 pF or so will produce coarse if not ridiculous results. Pico C does a far better job. Beating many DMMs hands down, this little instrument easily measures capacitances down to fractions of a picofarad.



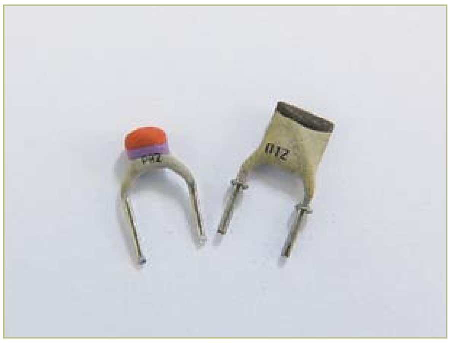
Small capacitances like in the sub-10-picofarad (pF) range are often invisible but by no means insignificant. The seasoned RF designer will know not just where to sniff them out but also explain to the more DC-minded just how a few stray pF in a circuit may decide between wild oscillation and controlled behaviour, EMC Go/No-Go, volume production in China or 'forever-a-prototype'. Here's a solder blob with a residue of blackish dried resin around it: 1.5 pF and no wonder the 2 GHz CPU oscillator fails to operate because it sees a significant reactance (feel free to do the maths; they're no fun). Likewise, a 10 cm long PCB track carrying pulses in the nanoseconds range across a cheapo 4-layer board: easily 5 pF, causing ringing and other unwanted effects like resonances upsetting digital logic at the far end (feel free to do the maths; they're ugly).

Small capacitors are a radio amateur's and radio repairman's delight and your Editor could not resist scavenging his vintage component drawer and show you a few specimens in **Figure 1**. We've also seen relatively small polystyrene capacitors — say, in the 500 pF range — used in high-end audio circuits and these you might also want to check for accuracy and drift due to ageing. Specifically in active (opamp)

Features

- range: <1 pF to 2000 pF (guaranteed); 2500 pF possible
- resolution: 0.1 pF
- readout: 2-line LCD
- low-cost, no SMD parts
- ATtiny2313 DIP20 microcontroller
- free source and hex code
- easy calibration with 1000pF 1% reference capacitor
- microcontroller, board and kit available from Elektor

(a) Philips ‘beehive’ trimmers. Low loss. Ingenious construction ensures linear response across range(!) The rotor (moving part) is usually connected to ground (why?). **5–30 pF adjustable**.



(b) Ceramic capacitors, lead pitch 5 mm. Pushing the limits of Elektor photography. Note the print to indicate value.
0.82 pF and 120 pF.

(c) Ceramic tubular capacitors. High working voltage (250 V typ.).
12 pF, 39 pF, 320 pF.

(d) Feedthrough capacitors. Low stray inductance. Ideal for RF decoupling.
200 pF, 470 pF, 1 nF.

(e) Coffin and disc capacitors. Low loss factor, zero stray inductance. On-PCB coupling and decoupling. Fragile devices! Connect straight to a PCB track and copper earth plane. **27 pF**, **820 pF**.

(f) Ceramic trimmer capacitor.
3.5–10 pF adjustable.

(g) Tubular trimmer capacitors. Unless in series, the rotor is best grounded.
0.3–3 pF, **1-6.5 pF**.

(h) Silvered mica capacitor. 500 V working voltage, 1966 NOS. Ebay-able.
470 pF.

(i) ‘Twister’ is the cheapest ultra-small C you can make. Twist the wires to increase capacitance, stop and cut off approaching target value. Okay for use up to 200 VDC.
0.2-1.5 pF adjustable.

Figure 1. Small capacitance does not necessarily equate to small size or small importance.
Here’s a showcase of rare-bird, vintage and DIY capacitors ranging from 0.2 to 1000 pF.

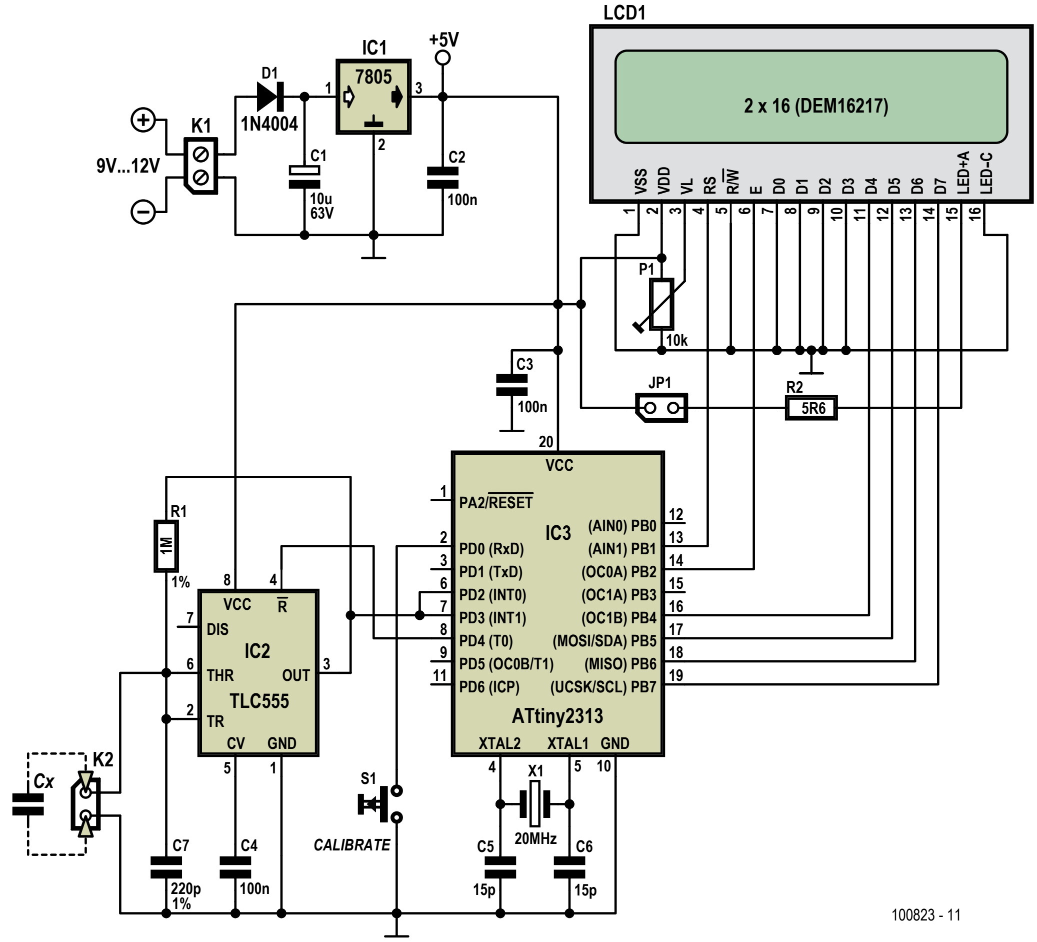


Figure 2. Smart and utterly efficient is one way of describing this circuit, fully realising of course that all the measuring is actually carried out by firmware running inside the ATtiny microcontroller.

filters, capacitor values really matter and specifications like 1% suddenly make sense. So, for all measurements below 1000 pF (1 nF) forget about your 3.5 digit DMM and use Pico C instead.

Devil in the details

The measurement principle applied in Pico C is well-known and widely used in other similar instruments: an unknown capacitance C_x determines the frequency of an oscillator. Next, a microcontroller goes about measuring the frequency and so determine the value of C_x. Fair enough, but if you want to measure very low capacitances, you're bound to be confronted with parasitic (or 'stray') capacitances in unexpected corners, as well as electrical disturbances and many other factors that may affect the measurement. And that's where commercial multimeters often fail miserably despite their apparent 1 pF resolution. By contrast, Pico C solves these problems with a simple but carefully designed bit of hardware and cleverly written software.

How it works

Let's take a tour of the circuit diagram in **Figure 2**. There's old cronies to be found: a TLC555, an ATtiny, a 7805 and an LCD so this should be fun. Together with R1 and C7, the CMOS type TLC555 timer (IC2) forms a 50% duty cycle oscillator generating a frequency of around 3.2 kHz. Do not attempt to use the bipolar (NE)555 here, you will shoot yourself in the foot. If you connect your unknown capacitor C_x to K2, effectively it's in parallel with C7 so the oscillator frequency will be lowered.

COMPONENT LIST

Resistors
R1 = 1MΩ 1%
R2 = 5.6Ω
P1 = 10kΩ trimpot, horizontal

Capacitors
C1 = 10µF 63V, axial, lead spacing 2.5mm
C2,C3,C4 = 100nF 50V ceramic, lead spacing 0.2 in (5.08mm)
C5,C6 = 15pF 100V ceramic, lead spacing 0.2 in. (5.08mm)
C7 = 220pF 63V 1%, polystyrene, lead spacing 7.18mm, e.g. LCR Components # EXFS/HR 220PF +/- 1%
Optional: 1000pF 1% reference capacitor, polystyrene or polypropylene

Semiconductors
D1 = 1N4004
IC1 = 7805
IC2 = TLC555 8-pin DIP, e.g. Texas Instruments TLC555CP
IC3 = ATtiny2313-20PU, programmed, Elektor Shop # 100823-41, see [1]

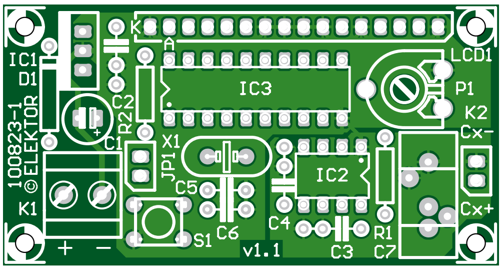


Figure 3. All the components except the LCD go on this simple, double-sided circuit board. The LCD is hooked up vertically or horizontally using the 16-pin connector set. Here, horizontal mounting is used to allow the two boards to be fitted in an Elektor Project Case.

Miscellaneous
K1 = 2-way PCB screw terminal block, lead spacing 5mm
K2 = 2-way pinheader and receptacle, lead spacing 0.1 in. (2.54mm)
JP1 = jumper, 0.1 in. (2.54mm)
S1 = pushbutton, SPNO, 6mm
X1 = 20MHz quartz crystal, C_L=18pF, 50ppm, solder wires
LCD = DEM16217, 2x16 characters with backlight, e.g. Elektor # 030451-72
LCD connector = 16-way (14+2) SIL pinheader and socket, right angled, lead spacing 0.1 in. (2.54mm). See text for connection of DEM16217 LCD.
20-pin DIP socket for IC3
8-pin DIP socket for IC2
PCB, Elektor # 100823-1
Kit of parts, including Project Case, PCB, LCD and programmed microcontroller; Elektor # 100823-71.

Arguably, to ensure this frequency change is substantial (i.e. measurable) even if C_x has just a few pFs to throw in, C7's capacitance should be kept low.

However, contrary to this reasoning a rather high value was chosen for C7 (220 pF, 1%) for the following reasons:

- parasitic capacitances around K2 and Cx now have less influence on the oscillator frequency;
- the relation between capacitance and oscillator duty-cycle is not linear for capacitances under 100 pF.

and form a unique 25-bit binary counter, which in turn ensures a high resolution.

The rest of the circuit is conventional. The ATtiny2313 micro ticks at 20 MHz thanks to quartz crystal X1 and loading capacitors C5 and C6 (see **inset)**. The ATtiny2313 micro directly drives an LCD with two lines of 16 characters and LED backlighting you can (optionally) turn on by fitting jumper JP1. R2 if necessary defines the brightness. Be sure to adapt its value to match the requirements of the LCD you're using. The Elektor supplied DEM16217 LCD module has an internal series resistor and

LCD backlight disabled — the instrument alone consuming about 20 mA. Diode D1 affords a degree of protection against polarity reversal of the DC input source. Replacing the diode with a wire link, and the 7805 with a low-drop regulator allows Pico C to be powered from four 1.5 V dry cells in series.

Assembly

The little instrument is built on a printed circuit board designed by Elektor Labs. The component mounting plan appears in **Figure 3** and the associated copper track artwork as usual is a free download from

Free 1000 pF 1% reference capacitor included with first 100 Pico C kits

In order to compensate for the disadvantage of C7's relatively high capacitance, several measures were taken at the microcontroller side:

- instead of only one, it measures the time period of 24 cycles;
- thanks to the ATtiny's high clock signal of 20 MHz, 680 counts are available to resolve a change of 1 pF, which is a solid basis for accurate measurements even in the case of a 0.1 pF capacitance change;
- by configuration Timer0 and Timer1 are linked via their common PD5 pin (Timer0 OC0B output; Timer1 input pin)

its backlight normally consumes 33 mA at 5 volts. The LCD contrast setting is adjustable on trimpot P1.
Pushbutton S1 when pressed pulls the PD0 line low triggering the start of the instrument's calibration mode — more about this further on.
A totally traditional power supply around IC1 completes the design. The instrument is powered from a DC source with an output voltage between 9 and 12 volts and capable of doing about 200 mA if a backlit LCD is used. A cheap wallwart will do the job admirably, but a 9 V battery may also be used for short measurement and with the

the project page on the Elektor website [1], where you will also find the ATtiny source code and hex files. Those of you with no access to an ATtiny programmer will like to hear that ready-programmed micros are available from the Elektor Shop [1]. Even better, a kit of parts is available, this includes the printed circuit board, an Elektor Project Case, LCD and the programmed micro.
All parts are through-hole and fitted at the component side of the board. A good quality 20-pin IC socket is recommended for position IC3 (note orientation). If you work neatly and copy-cat the lab prototype pictured here you stand the best chances of

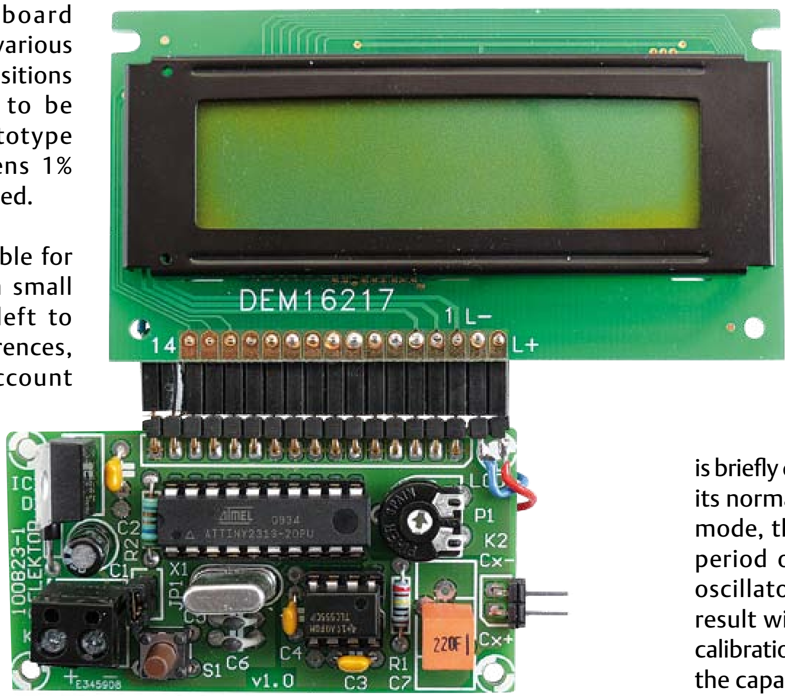
When a zero is not 0

C5 and C6, there you have them — tiny capacitors of just 15 picofarads! Small as they may be, if you get them wrong, the entire circuit won't work. These capacitors provide the required load on the quartz crystal. Let's eavesdrop on Elektor labs answering a tech phone call from a reader (a programmer, very likely) complaining his microcontroller-based circuit doesn't' work (because of a stalled CPU oscillator).

"No Sir, the print '151' on the ceramic capacitor from XYZ Corp. Inc. does not mean 151 pF but 15 with one zero behind it. That's 150 pF, which you may also find printed as 'n15' (0.15 nF). Whichever, whatever, it's not suitable for the Pico C circuit. And no, the print '150' does not mean 15 with zero zeroes behind it, it actually stands for 150 pF; 15 pF is normally printed as ... '15p'. Thank you, happy to assist."

A can of worms to the Youtube generation; a chuckle from the old hand at electronics from the radio days. Now try 'p82' and 'n12' (Figure 1b) and all of you should be forever happy to have Pico C handy on your workbench!

success.
Care should be taken to prevent the quartz crystal case from touching the solder pads underneath it. That's why the crystal is mounted either .1 of a millimetre above the board surface, or with a piece of thin plastic sheet or tape inserted.



Location C7 on the board allows capacitors with various lead pitches and lead positions (relative to the case) to be mounted. For the prototype a bright orange Siemens 1% polystyrene device was used.

Many options are available for housing the board in a small enclosure and this is left to the constructor's preferences, insights and PayPal account status. One prototype was fitted in an Elektor Project Case (# 100500-71), which is also included in the kit you can buy for the project. By now, it should be obvious that the stray capacitance at the TLC555's input must remain as small as possible. Consequently it is paramount that the board be mounted in such a way that the capacitors under test get connected with the shortest possible lead lengths. Remember, all wiring — also of the fixed type — represents a parasitic capacitance that adds to your measurements.
As compared to other 2x16 character LCDs on the market the DEM16217 has its L+ and L– connections at the 'wrong end' of the 14-way connector row, so a workaround was devised using two separate pin connections and wires shown in **Figure 4**. When in doubt, consult the LCD's datasheet.

Practical use and calibration

First off, always connect the capacitor under test **directly** to the Pico C test terminals, or, if that's not possible, using the **shortest possible leads**. Remember, you're dealing with tiny capacitances here and two test leads of say 30 cms easily represent 50 pF or more, especially if crossed or twisted.
Pico C requires calibration in order to work correctly and a 1000 pF (1 nF) 1% polystyrene, polypropylene, silver mica or other high precision capacitor is required for the job. The calibration routine in the ATtiny's firmware is called automatically when Pico C is switched on for the first time and can be repeated at will if you press pushbutton S1 and keep it pressed until the message "Cal:" appears on the LCD (this will take 2-3 seconds). The microcontroller will guide you through the calibration process.
As the first step, you will be prompted to remove any capacitor from K2 and only then briefly press S1:

```
Cal: C=0pF   (S1)
```

In the second step, you are prompted to connect the 1nF/1% reference capacitor and briefly press S1:

```
Cal: C=1nF   (S1)
```

This ends the calibration procedure. The message

```
Calibrated
```

is briefly displayed, whereupon Pico C enters its normal measuring mode. In measuring mode, the microcontroller measures the period of 24 consecutive cycles of the oscillator output signal, compares the result with the values memorised during calibration, and then calculates and displays the capacitance of the currently measured capacitor. For example, if the reference capacitor is still inserted, the display will show the message:

```
Cx= 1000.0pF
```

Or, if there is no capacitor inserted, the display will show

```
Cx=      0.0pF
```

You can measure capacitances up to 2,000pF or even a bit higher — the actual upper limit lies between 2400 and 3000 pF depending upon IC2's free running frequency. There are internal hardware and software controls that detect overflows produced by the counters and variables. Overflows may cause wrong calculation results or even a program lock-up. If you insert a capacitor with a too high value, an overflow will be detected at some level of calculation and the message

```
Error: C>>
```

will be displayed. If this happens in measuring mode, normal measurements will be restored as soon as the large capacitor is removed. If you use an inappropriate reference capacitor, the same message can appear during calibration, which will be interrupted for repeating with a proper reference capacitor.

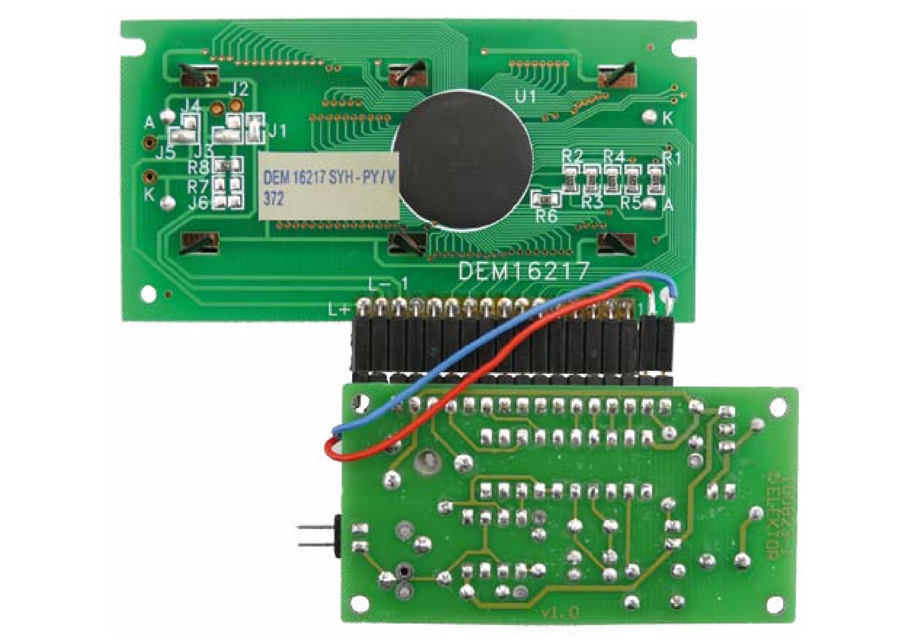


Figure 4. Inconveniently the DEM16217 LCD has its connections for the backlight LED(s) at the pin-1 side of the connector row, forcing the use of two wires and pin connectors to connect to the Pico C board.

Accuracy and stability

The accuracy of the little instrument depends primarily on the accuracy of your reference capacitor. Immediately after calibration you may expect 1%, ±1 digit accuracy or better, if you can get your hands on a more precise reference capacitor. Although the output frequency of the TLC555 timer is only slightly temperature and voltage dependent, even small fluctuations become visible due to the instrument's high resolution. For example, if you measure the same capacitor for several minutes, some change in the measurement results may be observed. In the Elektor labs, on testing the stability with a high-spec 1 nF polypropylene reference capacitor it was found that the measured value had a tendency to change a few tenths of a pF upwards in the first two minutes or so after calibration. After several hours, the measured value may be seen to change to 1001 pF or 999 pF. This might seem inaccurate, but actually represents a deviation of only 0.1%. During the same period, without a capacitor attached the readout was seen to vary between –0.1 pF and 0.1 pF.

If you notice persistent inaccuracies in your measurements, like a readout other than 0.0 pF without a test capacitor, or an error clearly exceeding 0.1% when measuring the reference capacitor, you may repeat the calibration as explained before. Calibration values are written in the EEPROM inside the microcontroller and will be reused the next time Pico C is switched on. If used at room conditions with no significant temperature changes, Pico C normally won't require calibration each time it is used. However, with the microcontroller's EEPROM allowing 100,000 write cycles (sez the Atmel sales rep), there should not be a problem if you calibrate Pico C whenever you think appropriate.

For all measurements below 1000 pF forget about your DMM and use Pico C instead

Software development

The 'EE_pico_C.bas' program was written in BascomAVR programming language [2], with several assembler routines. Interrupt and measuring routines are written in assembler, to have better control over timing. BascomAVR is pretty wasteful when it comes to arithmetic with long variables and it was a challenging task to fit the whole program into the ATtiny2313's 2 KB of flash memory. That's why some calculations and conditional branching are written in the assembler, too, as you will be able to discover for yourself in the source code file that's available free from the Elektor website [1].

(100823)

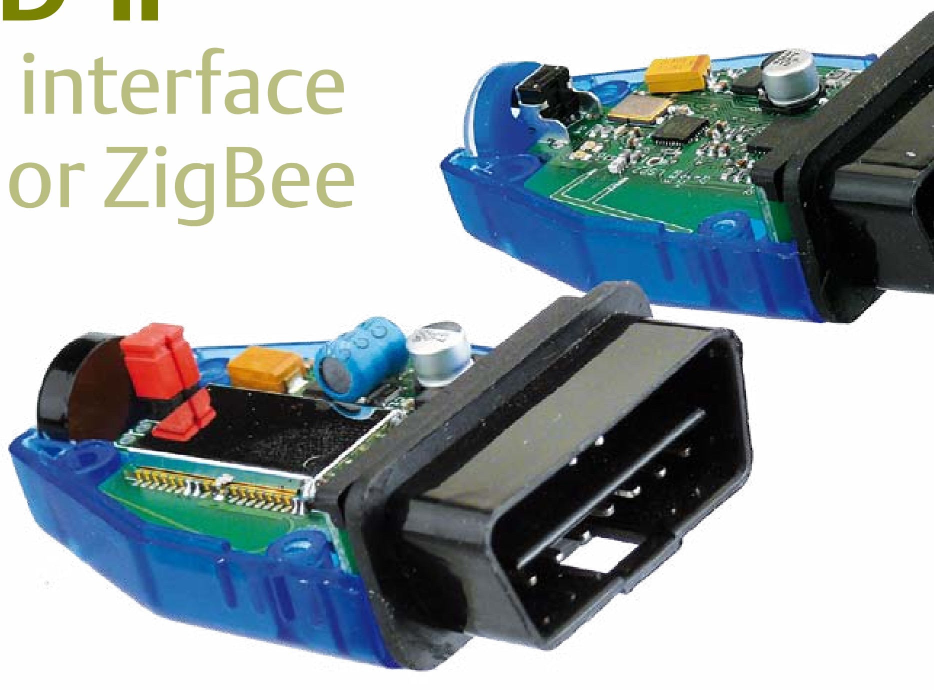
Internet Links

[1] www.elektor.com/100823

[2] Bascom AVR Course, parts 1–6, Elektor September 2008 through February 2009.

Wireless OBD-II

Car diagnostics interface with Bluetooth or ZigBee



by Folker Stange and Erwin Reuss (Germany)

The cheapest way to diagnose faults on a modern car is to connect its OBD-II interface to a (notebook) PC running suitable diagnostics software. However, a wired connection is not always the most suitable, and self-contained OBD testers are a rather expensive and less flexible alternative to using a PC. An interesting option is a wireless OBD interface with a radio interface to a PC: the homebrew solution described here allows the choice of using either Bluetooth or ZigBee.

Almost every car these days has a diagnostics connector hidden away somewhere in the passenger compartment. Although the distance from the steering wheel is, with some exceptions, standardised (at 0.61 m), this does not seem to have constrained manufacturers' creativity significantly: OBD-II connectors are found tucked away in the door pillar, in the driver's footwell, in the central console, in the glove box, behind ash trays and storage compartment flaps and in who knows what other nooks and crannies. It is probably best not to have to try to find the connector in a hurry when your car has conked out at the side of the road.

Make the connection

Assuming that you have managed to find your OBD-II connector, the next task is to get data from it to your PC. This requires special-purpose software along with, in the simplest case, a level shifter to convert the OBD-II signals to RS-232 voltage levels. Often a USB-to-RS-232 adaptor will be required as well, as few modern PCs have RS-232 ports.

In the most straightforward scenario just one pin (called the 'K' line) on the OBD-II socket is used. Then a MAX232 is all that is needed on the hardware side, with a bidirectional output stage to interface to the socket. Using software specific to the model of vehicle the car's electronics can then be interrogated.

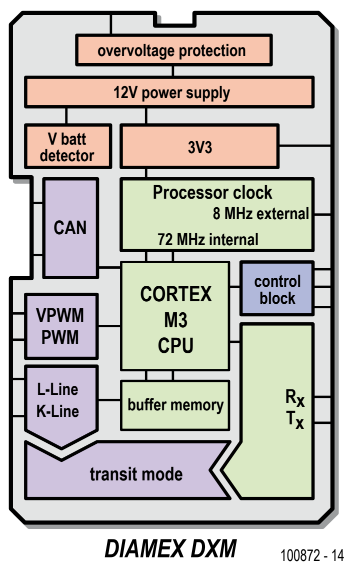


Figure 1. Block diagram of the DXM module with 32-bit ARM Cortex M3 processor for OBD applications.

In theory this remains valid with the standardisation of OBD-II. Indeed, the pinout of the diagnostics connector is standardised (for most pins at least), and there is a basic set of five permissible protocols (ISO, KWP2000, PWM, VPWM and CAN). A universal interface has to be able to recognise all these protocols and be able to adapt itself accordingly. This means that in practice the interface needs a microcontroller in addition to the level shifter so that a connection can be made automatically to the vehicle's electronics and the desired data transferred. In combination with suitable OBD-II software it is then possible to obtain diagnostics from any petrol-engined car built from 2000 onwards and any diesel-engined car built from 2003 onwards, regardless of manufacturer. Normally the interface is plugged directly into the OBD-II socket in the car and then linked to a notebook using a USB or RS-232 cable. It is more practical, however, to use a radio link between OBD interface and notebook,

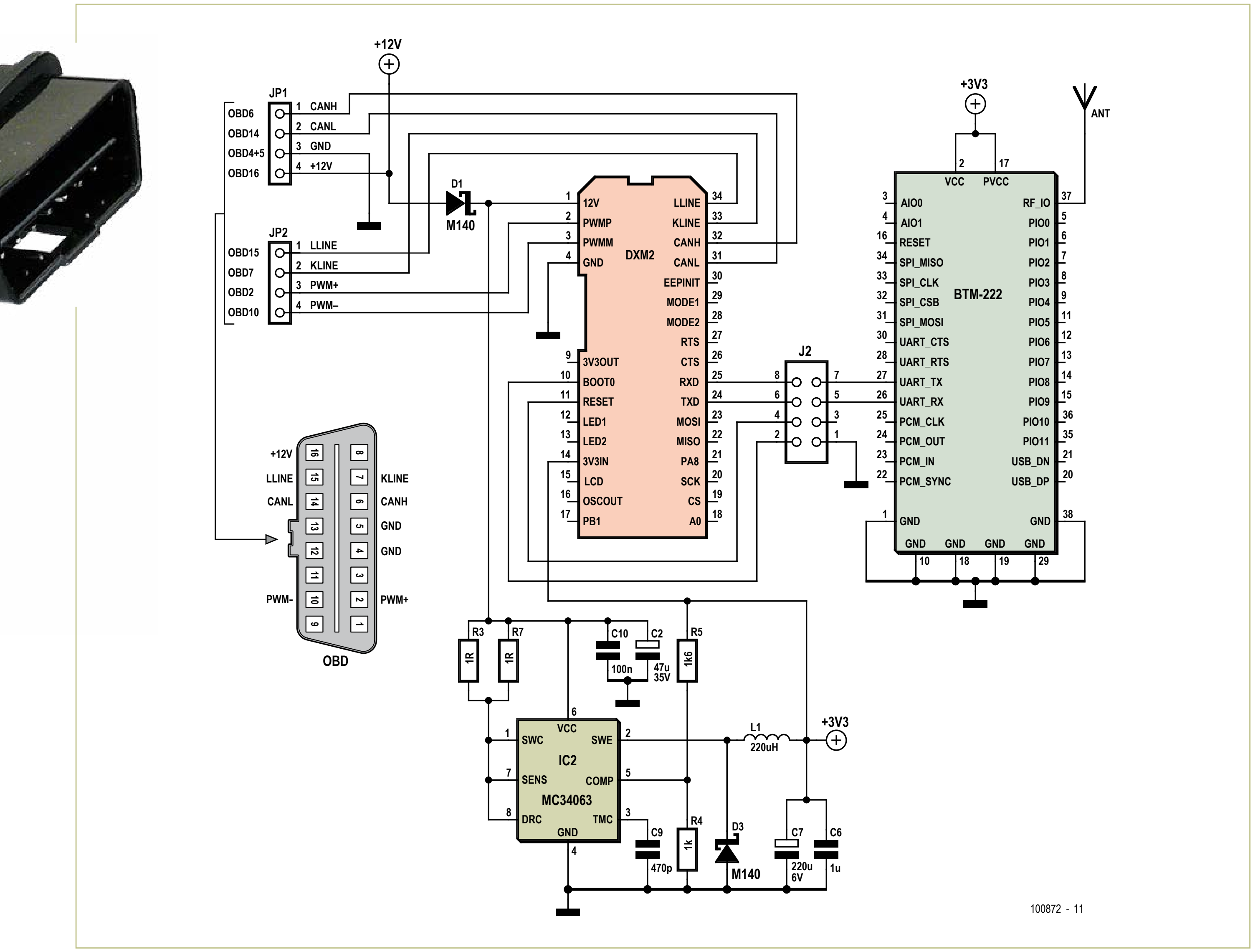


Figure 2. The OBD-II Bluetooth interface circuit consists of a DXM module and a Bluetooth module plus a 3.3 V switching regulator.

especially if diagnostics are to be obtained while driving. In this case it is possible for the OBD interface to derive power from the OBD socket itself. As many notebooks and netbooks already include a Bluetooth interface (and those that don't can be kitted out with a suitable dongle), this would seem to be the ideal standard to choose. If Bluetooth is not suitable, ZigBee is available as an alternative.

Build-it-yourself

In making a compact and powerful OBD interface it is impossible to avoid the use of fine-pitch SMD devices. However, the DIY approach is feasible if a ready-populated

Features

- compact size, fits inside an OBD-II plug
- integrated DXM module
- automatic protocol scan
- PWM, VPWM, ISO9141, KWP2000 and CAN interface standards
- software compatible with 'moDiag' and 'OBD-DIAG'
- suitable for use with all OBD-II-equipped cars

Bluetooth version

- compatible with Windows XP, Windows Vista and Windows 7
- Class 3 Bluetooth module with maximum range of 100 m

ZigBee version

- Cortex M3 and Atmel AT90USB162 host microcontroller
- Windows driver using INF file
- Frequency range 2405 MHz to 2480 MHz with automatic channel selection
- Receiver sensitivity –101 dBm
- IEEE 802.15.4-2003 (ZigBee-like protocol)
- automatic retry on failed transmission
- range approximately 10 m to 15 m (maximum approximately 30 m to 40 m)
- ZigBee USB stick compatible with Windows XP, Windows Vista and Windows 7

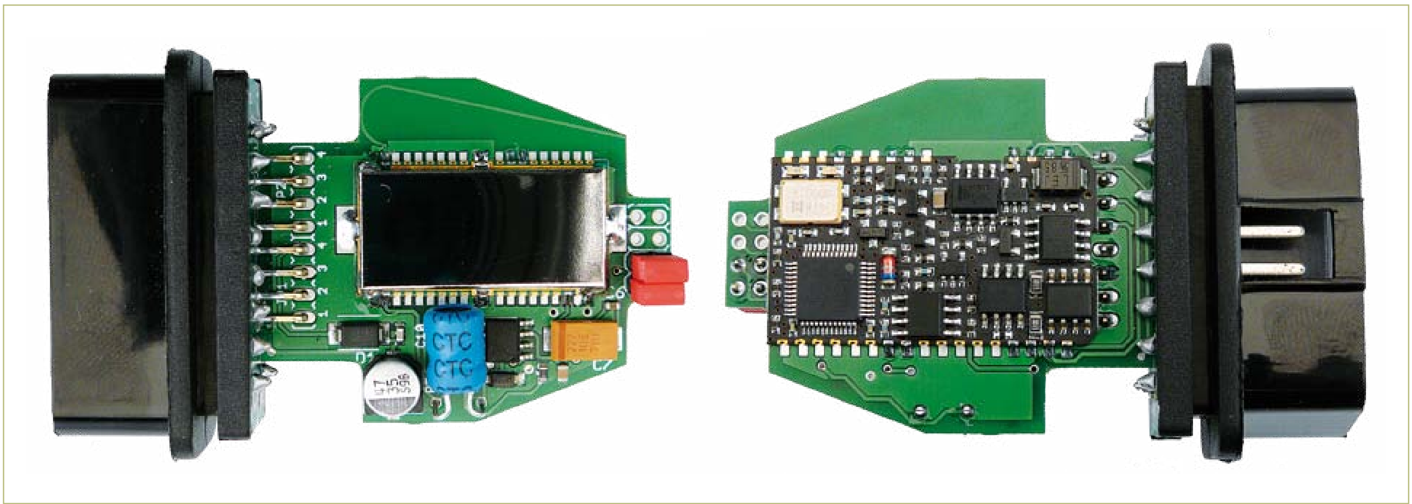


Figure 3. Top and bottom sides of the Bluetooth interface board with OBD plug soldered on.

SMD microcontroller module is used. The DXM module [1] used here was described in the September 2009 issue of *Elektor* [2]. As **Figure 1** shows, this unit comes with an ARM Cortex M3 processor and a panoply of peripherals. With firmware loaded it becomes a universal OBD-II diagnostics and control unit that can be connected directly to the vehicle's OBD-II connector. The module can be configured for various applications using AT commands (for further information see [1]), including as a diagnostics interface running at a suitable baud rate. On the output side it offers a serial interface at 3.3 V levels. This can be connected to a wireless transceiver, which might, for example, be a Bluetooth or ZigBee module. We will look at both options below.

Bluetooth

Figure 2 shows the Bluetooth version of the OBD-II interface circuit. The DXM module is connected to the OBD-II connector on the input side and to the compact Rayson BTM222 Bluetooth module on the output side. This module was described in the December 2009 issue of *Elektor* [3], and has already been used to provide a Bluetooth extension to the autonomous OBD-II Analyser NG [2]. The module comes completely preconfigured and transfers data at 19200 baud. We therefore also configure the DXM module to run at this speed.

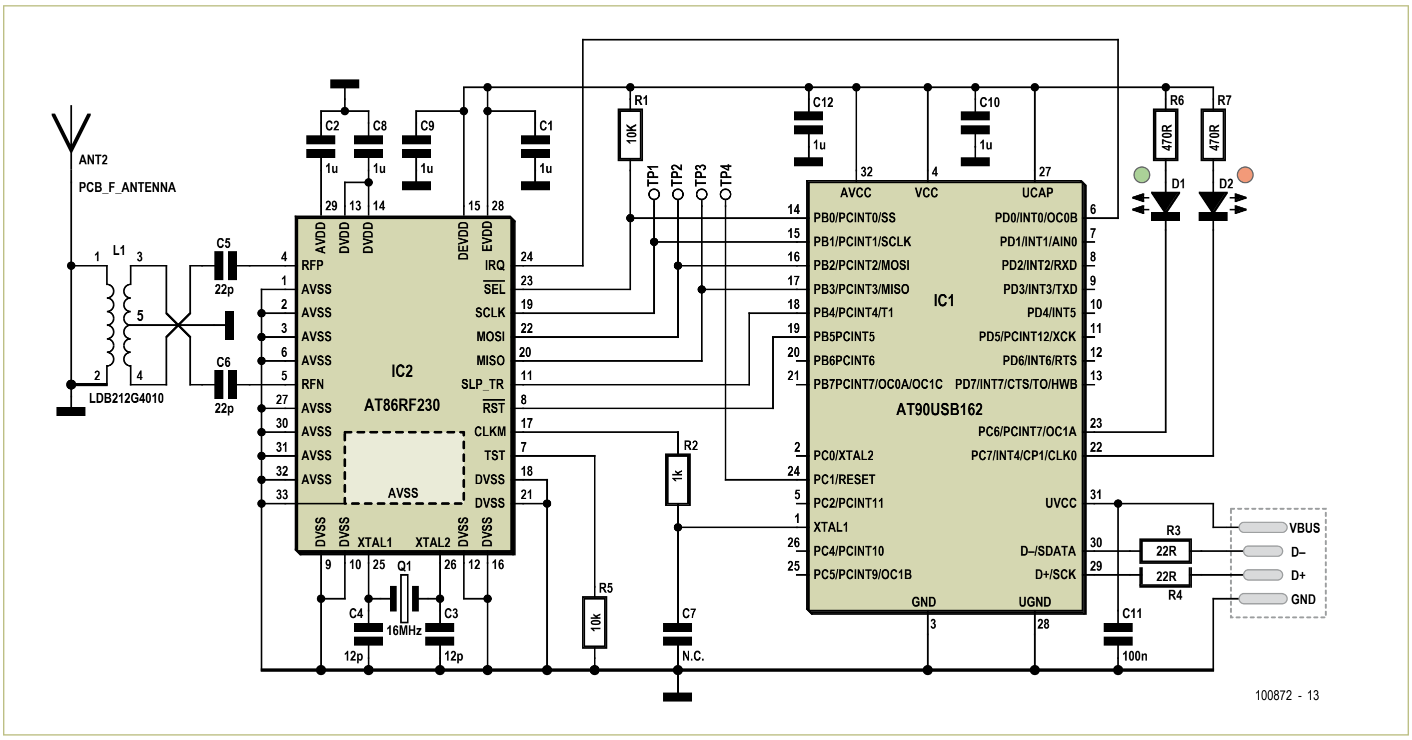


Figure 4. Circuit of the ZigBee USB stick, specially designed to work with the ZigBee OBD-II interface.

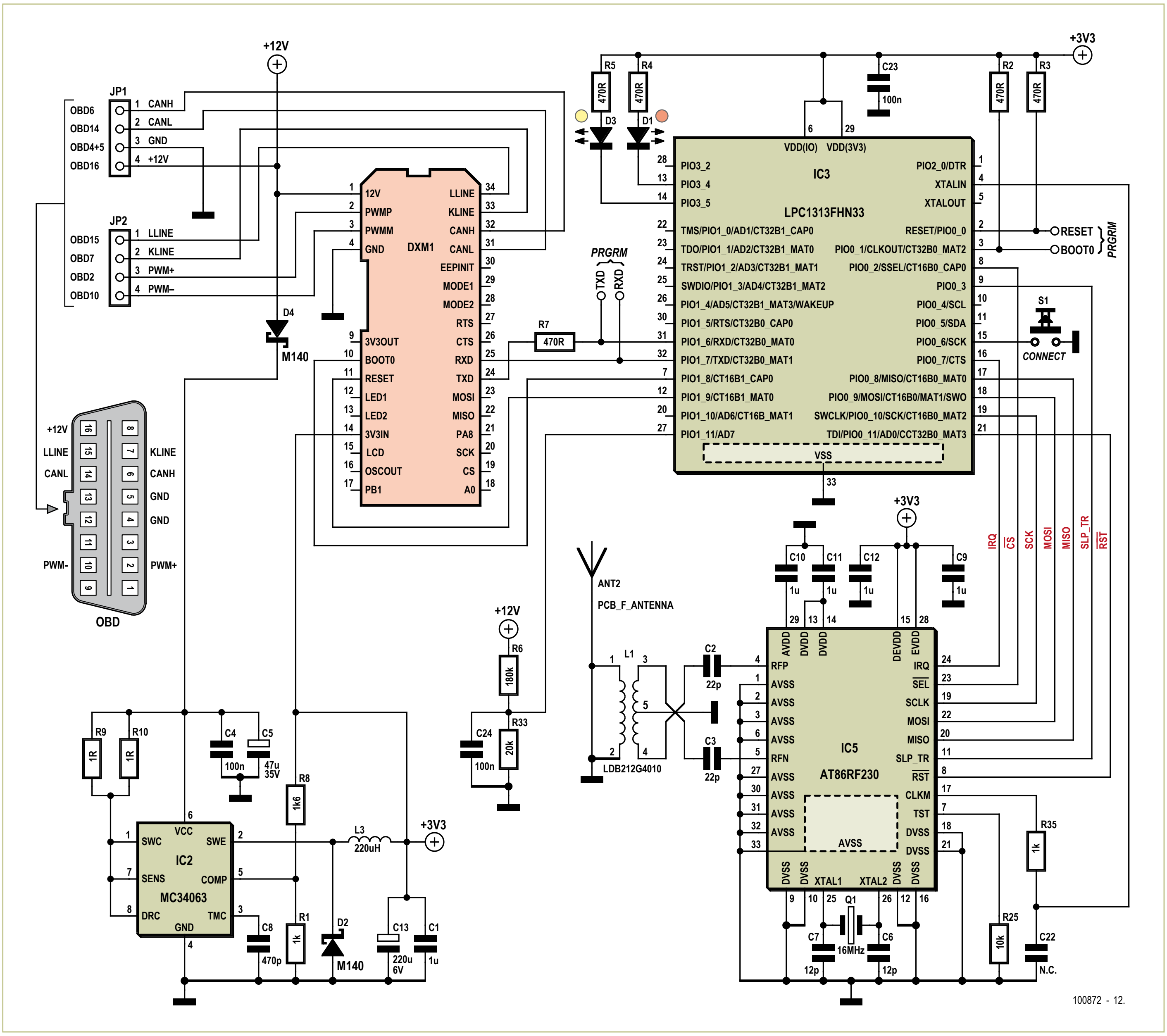


Figure 5. The ZigBee OBD-II interface includes two ARM Cortex processors: one handling OBD communications in the DXM module and one for communicating with the AT86RF230 ZigBee transceiver device.

Power for the circuit is obtained from the OBD-II socket, which provides the vehicle's on-board 12 V supply. Diode D1 provides reverse polarity protection, and a small switching regulator efficiently steps the voltage down to the 3.3 V required by the two modules.

The BTM222 is a 'class 3' Bluetooth module, with a specified range of up to 100 m. However, this range is achieved only under ideal circumstances, and requires the use of a class 3 Bluetooth receiver at the other end of the link: this is not provided by most Bluetooth-equipped notebooks. If maximum range is required, then a class 3 Bluetooth dongle can be used as the transceiver on the PC side. The circuit board, included in the kit of parts, has a printed quarter-wavelength antenna built in. This antenna works very well and should not be modified by the addition of extra lengths of wire. The board is ready populated with the SMD components, and only a few components remain to be soldered (the blue device in **Figure 3** is coil L1, not an electrolytic).

ZigBee

Whereas with Bluetooth data transfer is authorised by pairing devices using a password, ZigBee is a point-to-point protocol between two fixed stations. Since notebooks generally do not come with ZigBee interfaces, it is necessary to use a USB dongle plugged into the computer. A range of up to 40 m is possible, but the interface is designed for communications over a rather shorter range.

The circuit for the ZigBee USB stick designed for this project is shown in **Figure 4**. Here, as in the ZigBee version of the OBD-II interface circuit in **Figure 5**, the transceiver device used is the Atmel AT86RF230, which in

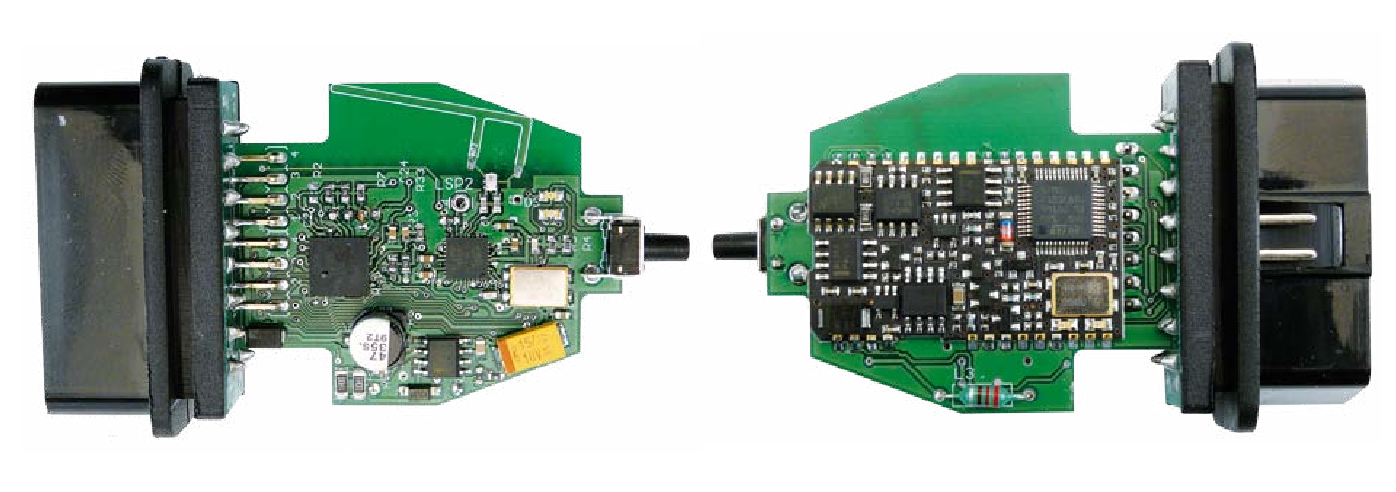


Figure 6. Top and bottom sides of the ZigBee interface board with OBD-II plug soldered on.

each case must be configured in software. For this reason both circuits include a host microcontroller: in the OBD interface circuit this is an NXP LPC1313 Cortex M3 device, while in the USB stick an Atmel AT90USB162 is used. In each case the microcontroller is responsible for initialisation and for optimising the data transfer for the requirements of OBD-II. All data transferred have to be specially treated for OBD-II, and so in the end we are looking at a proprietary data transfer format. Consequently the home made ZigBee USB stick is the only one that can be used here.

The LPC1313 has to make the data stream available very quickly, in order to add as little as possible to the overall latency. This is the reason for choosing a powerful 32-bit Cortex M3 device in the ZigBee OBD-II interface. The AT90USB162 is an ideal choice for the USB stick, as it includes a built-in USB interface.

The wiring of the AT86RF230 ZigBee transceiver follows Atmel's recommendations. A transformer (balun) matches the signal to the printed quarter-wavelength antenna. The firmware for the two microcontrollers can be downloaded from the *Elektor* website as a hex file [5]. There is scope to modify the code in the ZigBee interface, and the programming connections for both microcontrollers are available on the board. Interested constructors can therefore experiment using a suitable in-system programmer [6]. Button S1 in Figure 5 is only used when the system has to 'learn' a new USB stick.

The circuit around the OBD connector and power supply is not especially different from the Bluetooth version. A kit is also available for the ZigBee version, containing all the necessary components and with the SMDs already fitted. **Figure 6** shows the populated board with OBD plug soldered on. The companion ZigBee USB stick, corresponding to the circuit in Figure 4, is available ready assembled, although the board is still visible (see **Figure 7**).

Construction

In both versions the DXM module is soldered to the underside of the printed circuit board. A trick comes in handy to simplify desoldering the DXM module and BTM222 module in the Bluetooth version if necessary: cut a small piece of paper (10 mm by 25 mm) and place it between module and board (**Figure 8**), leaving a narrow gap. Then the module can be more easily removed from the board using desoldering braid.

Figure 7. The ZigBee USB stick showing the circuit board in its transparent enclosure.

When soldering the modules (the DXM module and the BTM222 module in the case of the Bluetooth interface) it is best to solder first just the pins that are actually used in the circuit. **Figures 9** and **10** indicate these pins with dots. A reasonably powerful iron is required to solder the ground pins on the modules. On the Bluetooth version the only components to be soldered are the coil L1 (the blue component in Figure 8), the headers for RXD and TXD, and the two jumpers (see Figures 8 and 9).

On the ZigBee version the coil is soldered on the same side of the board as the DXM module.

The OBD plug is mounted in the same way on the two versions of the interface. First solder the eight-way header and then remove the black plastic strip from the pins, using a knife or pliers to lift it away. This makes subsequent soldering of the OBD-II connector block (the right way around!) much easier. The *Elektor* web pages [5] accompanying this article include a series of photographs and brief guide to construction, which should help you orient yourself. Finally screw the two halves of the case together, fitting the perspex shim in the space provided for the cable strain relief. In the ZigBee interface two shims are provided (one with a hole and one transparent) to allow button S1 to be operated if necessary.

Testing

Those lucky readers who possess an *Elektor* OBD Simulator [7] will be able to test their device from the comfort of their own benches. Less lucky readers will have to make do with the real thing in their car. With the interface connected, the two LEDs on the DXM module should flash briefly, indicating a successful self-test.

If using the Bluetooth interface, start up the Bluetooth interface on the notebook, allow it to find the new device, and enter the master password ‘1234’.

Windows offers a wide range of virtual COM ports. The first port is used by our application software for communication. The interface can be used with the help of a terminal emulator such as AGV-Supertool [8]. It is essential to select the correct baud rate (19200) and COM port. Type ‘ATZ’ or ‘ATI’ into the terminal window, which should prompt a reply from the DXM module. With that, the Bluetooth connection has been successfully tested.

To test the ZigBee interface, a driver needs to be installed. Plug in the ZigBee USB stick, and the Windows Assistant will start up automatically and whisk you off to the *Elektor* website to download a driver. The connection will be established automatically without the need for a master password. The ‘ED Tester’ tool will assist with testing: both components, the host and the USB stick, should be recognised. The value indicated by the field strength bars should be between 30 and 50.

Software

Operation of the diagnostics software on the PC is independent of the standard used for radio communication, which means that both versions can be used with the ‘moDiag’ OBD software. This was described in the April 2010 issue of *Elektor* as part of the description of the Bluetooth expansion of the Analyser NG [4], and is available for download at [5]. The ‘OBD-DIAG’ program is also compatible with both interfaces. One interesting possibility would be to transfer the OBD data to a smartphone over Bluetooth.

This would require suitable (and yet-to-be-developed) diagnostics software running on the smartphone; however, the authors would be keen to assist any enthusiastic software developers with ambitions in this direction.

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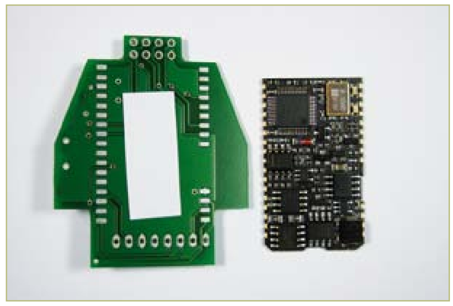


Figure 8. A strip of paper placed between board and module makes it easier to desolder it later.

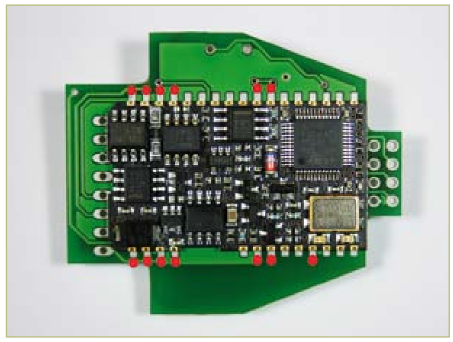


Figure 9. When fitting the DXM module only solder the indicated pins.

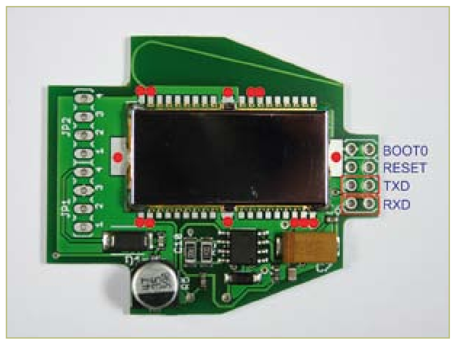


Figure 10. The pins to be soldered are marked here. None of the other pins is needed.

Internet Links

[1] www.dxm.obd-diag.net (DXM module)

[2] www.elektor.com/090451 (OBD-II Analyser NG)

[3] www.elektor.com/080948 (Bluetooth with the ATM18)

[4] www.elektor.com/090918 (Bluetooth expansion for the OBD-II Analyser NG)

[5] www.elektor.com/100872 (wireless OBD-II project pages)

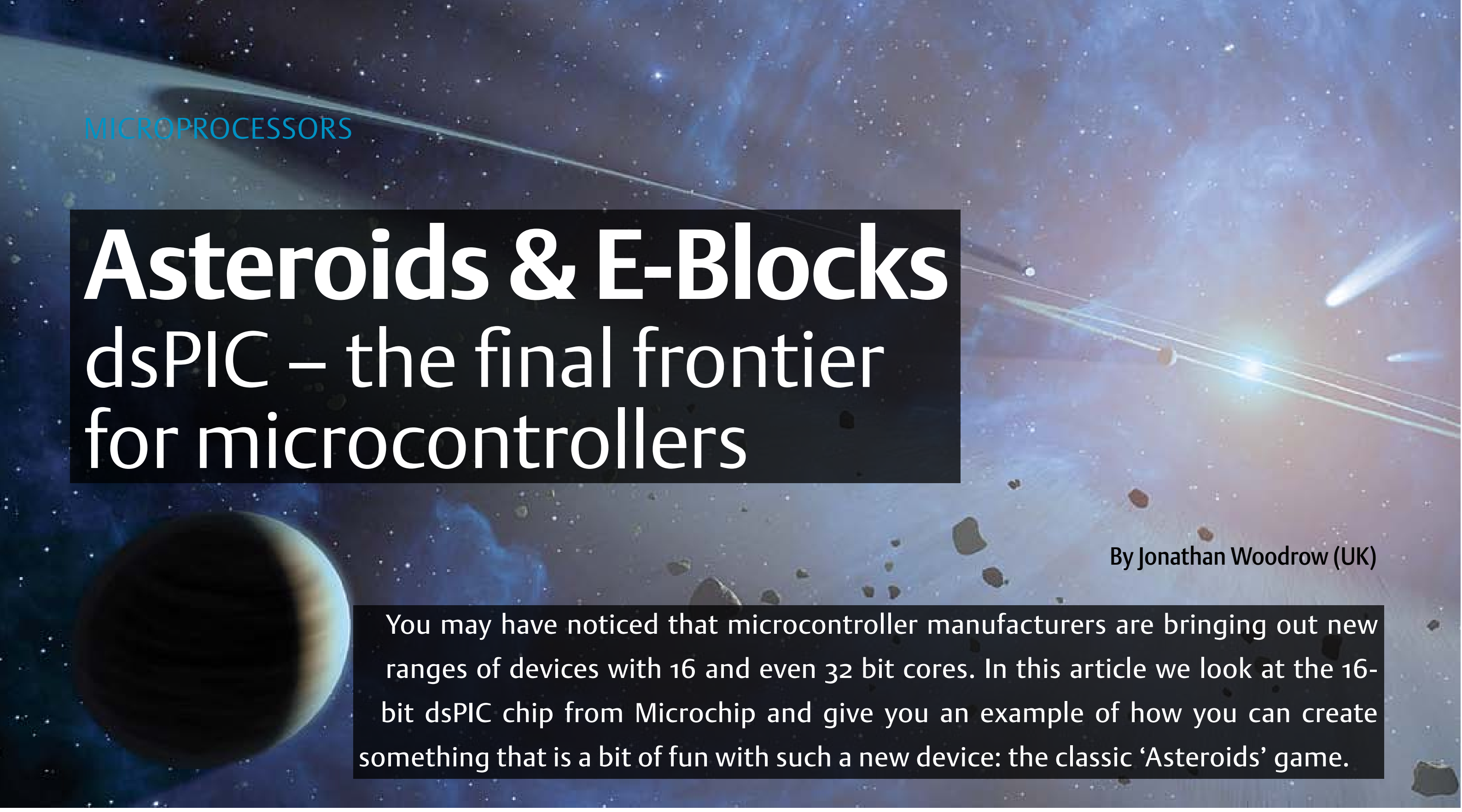
[6] www.obd-diag.de (ISP STM/NXP device programmer)

[7] www.elektor.com/080804 (OBD-II simulator)

[8] www.er-forum.de/odb-diag-dl (OBD-DIAG software)

Elektor Products & Services

- OBD-II Bluetooth interface, complete kit of parts including enclosure and printed circuit board with SMDs ready-fitted: order code 100872-72
- OBD-II ZigBee interface, complete kit of parts including enclosure and printed circuit board with SMDs ready-fitted: order code 100872-71
- ZigBee USB stick, suitable for use with OBD-II ZigBee interface, ready to use: order code 100872-91
- Items accessible through www.elektor.com/100872



Asteroids & E-Blocks

dsPIC – the final frontier for microcontrollers

By Jonathan Woodrow (UK)

You may have noticed that microcontroller manufacturers are bringing out new ranges of devices with 16 and even 32 bit cores. In this article we look at the 16-bit dsPIC chip from Microchip and give you an example of how you can create something that is a bit of fun with such a new device: the classic 'Asteroids' game.

You wouldn't know the difference just by looking at them: they look just like those 16-series chips we've been using for a couple of decades now. But inside, dsPICs are very different. Microchip have taken the microcontroller to the next level. Let's look at how.

Architecture: the dsPIC chips belong in the 16-bit family of microcontrollers which includes the dsPIC devices and the PIC24 series of devices. The key element here is that the processor is 16 bits wide rather than the more traditional eight bits.
This, other architectural features, and a single execution cycle, have lots of implications for programming and performance: no more bank swapping, handling larger numbers and calculations is easier, addressing larger chunks of memory is easier, and your program goes faster.

Power: reflecting the general trend to lower the power consumption of electronic devices these chips operate at supply voltages as low as 1.8 V although the one we used is operating at 3.3 V. Lower power means smaller transistors on the silicon, which means that you can cram more circuitry (up to 512 K Flash memory and up to 128 K RAM) on a given silicon chip.

Comms and internal peripherals: with effectively more silicon to play with Microchip have included more internal comms peripherals on the chips: custom I^2C and SPI blocks, (up to three of each!), up to four USARTs, USB and others. Specialised function blocks rather than a single USART you adapt to a particular use means that programming in is easier and the comms can go faster. The internal motor controls are also impressive with bags of features.

Play Asteroids on a single chip

Analogue capability: these chips have comparators and ADCs by the bucket load. On some dsPIC33s you can select 10 or 12-bit ADC operation and the 10-bit ADC samples at 1 MHZ. That's fast for a microcontroller and speech processing is surely possible with these little beauties.

Cost: It is hard to do a direct comparison as there are so many differences between the 8-bit and 16-bit variants. A quick search shows that the 28-pin dsPIC33FJ128GP202 we're using in a DIL package costs less than £3 (around € 4.70) from Farnell. That is actually less than a 40-pin, 8-bit PIC16F877.

Wow — all that speed!

It's not just that they clock faster, but it seems like Microchip have done everything they can to improve the speed of all parts of the device. How much faster depends on the application you are using. But if you want to do a floating point calculation consider this: 8-bit PICs clocks at, say, 20 MHz and perform at around at 5 MIPS. The daddy of the dsPICs — the dsPIC33 core — clocks at 80 MHz and performs at around 40 MIPS. Eight times as fast. But as the bit width of the dsPIC33 is twice as wide it performs floating point at least four times as fast as the 8-bit core. So even without invoking specialist hardware accumulators in the device, a quick calculation shows that the dsPIC performs at least 32 times as fast as their like 8-bit cousins where floating point numbers are concerned.

Elektor Products & Services

- E-Blocks dsPIC bundle: # EB655SI4
- E-Blocks graphic colour display: # EB058
- E-blocks keypad: # EB014
- Flowcode for dsPIC/PIC24: # TEDSSI4
- Flowcode program file: 100955-11.zip
- Hyperlinks in article

All items accessible through www.elektor.com/100955

So what?

So what do we do with this new 8 litre V6 hot rod of a chip? Well, to start with it is not that obvious. When you discuss this with Microchip, they talk about motor speed control with on-the-fly calculated feedback loops made with MatLab-derived blocksets embedded in the C code, switched mode power supply circuits, speech processing and more. However what struck the development teams at Matrix Multimedia and Elektor was the ability of the mathematical engine inside these devices for developing applications with the new generation of graphical displays. Manipulation of graphical displays requires relatively large amounts of memory and a capability of transferring that memory from a microcontroller to a display in super quick time. As well as this, the chip needs to run the main program and yet still have enough oomph left to do the number crunching on the graphical data itself. With the dsPIC33 we have all this; So, single chip computer games based on graphical displays have to be the way forward — our target had to be to recreate the vintage computer game 'Asteroids' on a single chip.

Wanted: Compiler

One of the difficulties you face when starting with a new series of devices is that you don't have a suitable compiler or assembler. Never fear: there is a new version of Flowcode that has just become available that is compatible with the dsPIC and PIC24 families of 16-bit microcontrollers (**Figure 1**). This has the same user interface as other Flowcode programs and existing programs should transfer across to this new version easily enough.

There is one major difference with this new version: Flowcode for dsPIC/PIC24 has a full mathematics library including all trigonometric functions and full floating point processing capability. Flowcode for dsPIC/PIC24 supports more than 200 types of chips in the 16-bit family, also has direct support for various Microchip development hardware boards and allows direct support with In Circuit Debug with the new E-blocks dsPIC/PIC24 E-blocks Multiprogrammer board.

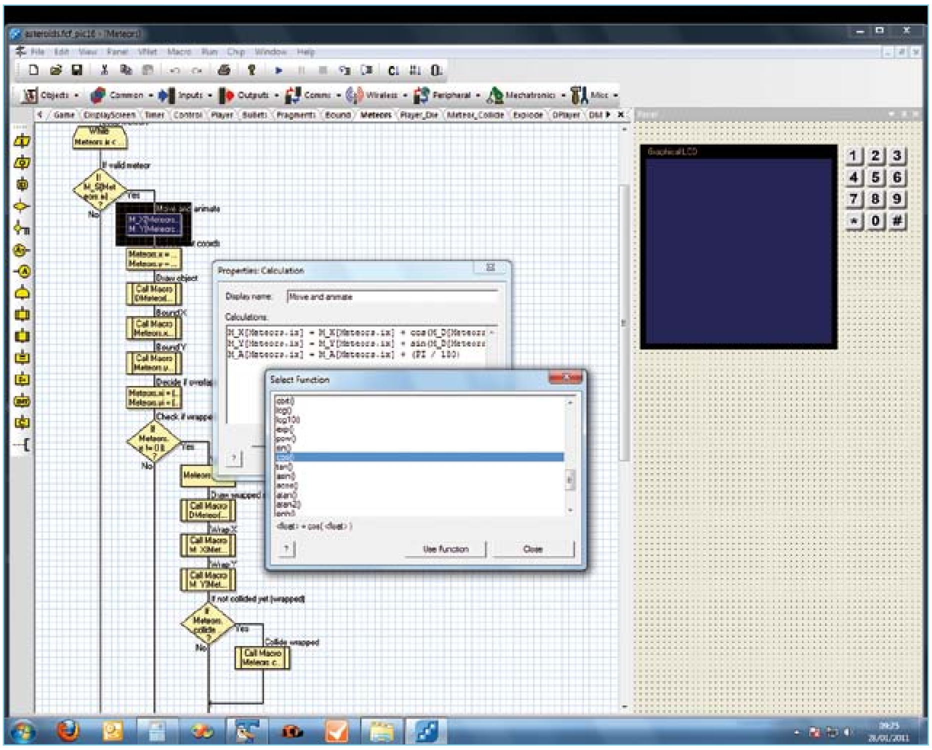


Figure 1. Flowcode for dsPIC & PIC24 showing mathematics functions.

Hardware configuration

Our design is based on a dsPIC33fj128 which can easily be fitted onto the board that comes with the *Flowcode for dsPIC bundle*. This device has 128 K ROM, 16 K RAM and runs at around 40 million instructions per second (MIPS). It is shipped in a standard 28-pin DIL package. To get the design up and running we are using the new E-blocks dsPIC Multiprogrammer which is compatible with the dsPIC and the PIC24 family of chips. To the Multiprogrammer we have connected a keypad and a 128 x 128-pixel colour graphical display. You can see

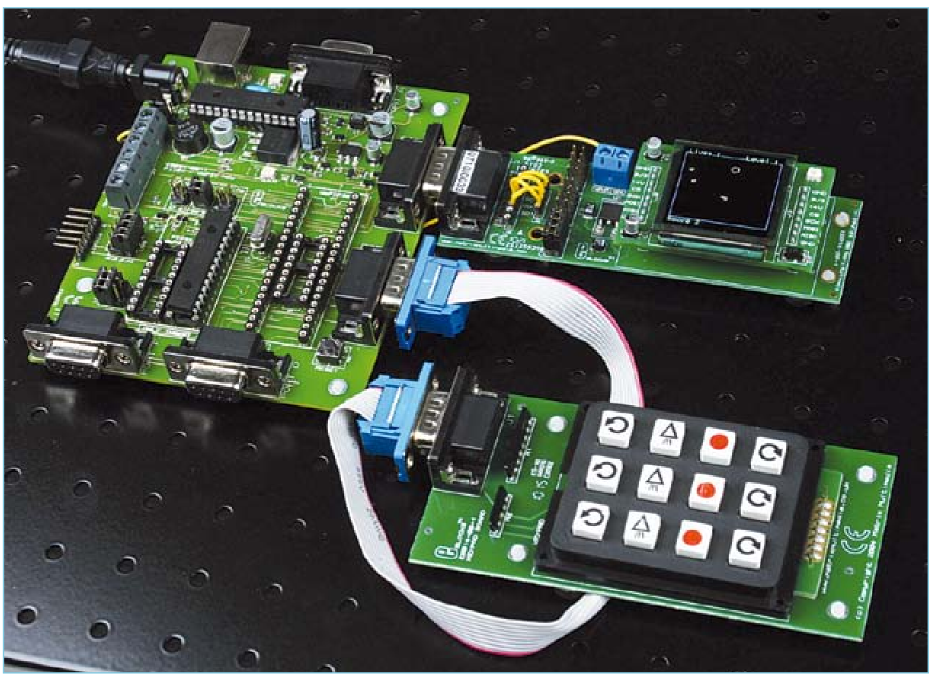


Figure 2. The E-blocks hardware set up.

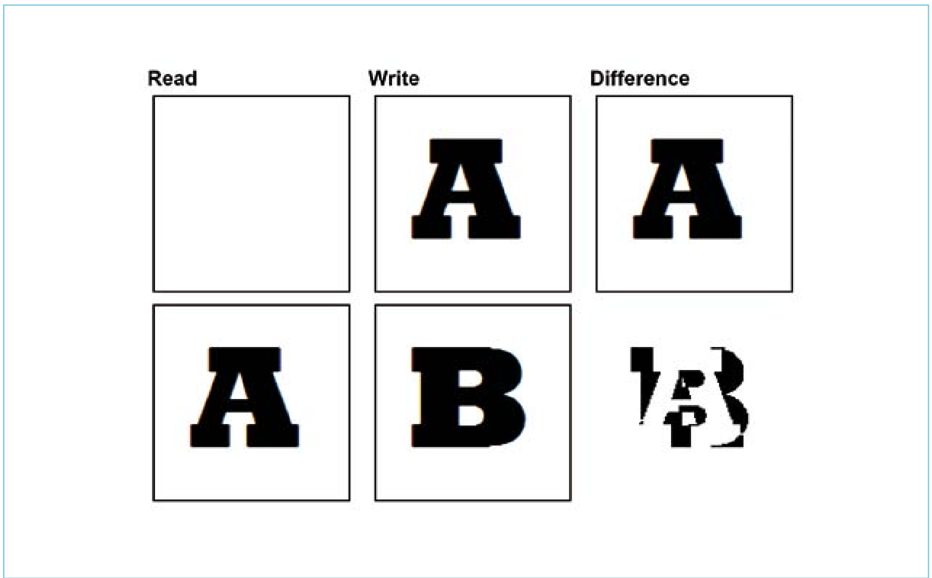


Figure 3. Speeding up the graphics by managing sequential differences.

the overall configuration in **Figure 2**. The dsPIC33 family runs at 3.3 V to save power. By contrast the colour graphical display operates off 14 V, which is required to run the powerful backlight.

Software description

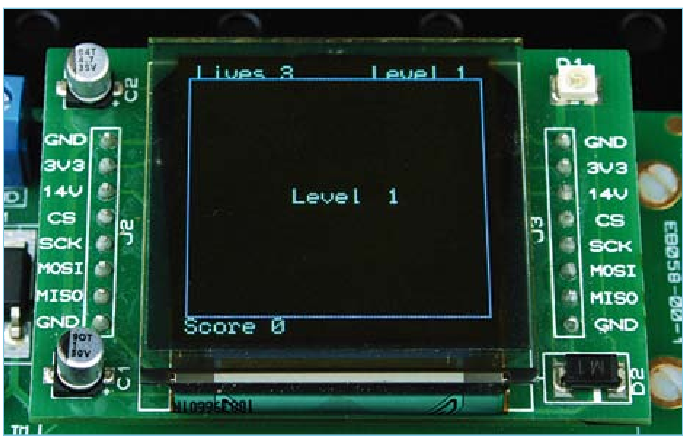
The software of course is the tricky bit. There are several problem areas: managing the graphics data, sending the data to the display, calculating the graphics data to display, tracking the objects in the game and their status, the user interface and the game play itself.

Managing the graphics data is the major task and the Flowcode program revolves around this. The key problem here is that you can not manipulate the data and display it at the same time or it will flicker To solve this, we reserved two blocks of 128 by 128 pixels for display memory with one bit per pixel — around 2 K in RAM per block. We developed a two phase program which allowed us to manipulate the contents of one memory block according to the game play, whilst the other block is being transferred to the display using the SPI protocol and the on-board SPI interface in the dsPIC chip. We found that around 20 frames per second was sufficient for this game (we could have made it go quicker). We also sped up the system by only changing the pixels in the display that had changed from the last time the display was sent. You can see this in **Figure 3**. When writing different letters to the screen, the whole block can be written again, or you can monitor which pixels go from black to white, and white to black and you can just process these.

Because we now have software-level access to the pixel data, we can perform tricks with the pixels. One trick we use, is to make the asteroids and other objects appear to 'wrap' around the screen. Instead of clipping and discarding pixels outside the playing area, 'wrapping' those pixels so they appear at the far side of the screen. This saves having to draw objects potentially four times in all separate corners of the game grid.

Those of you who are concentrating will notice that there is a colour border and scoring text (see **Figure 4**). The potential downside of this graphics technique is that we only have one colour. To get round this, we restrict the game to only the inside parts of the display and we 'window dress' the main game area with colour borders and text in full colour. Most of the routines for the display are embedded in Flowcode: the only exception were two routines we developed in C code to perform the double buffering, as this is a specialist and custom feature that is tweaked to the requirements of the game (wrapping the pixels is one example).

The in-game objects themselves are fairly simple graphical constructions: the spaceship is a three vertex object with a central position and vertices calculated by trigonometry. Each asteroid has up to five vertices. As they move across the screen they rotate. The positions of their vertices are represented in the chip by floating point co-ordinates whose values are all calculated by trigonometric calculations each frame. With up to seven asteroids in the frame, fly-



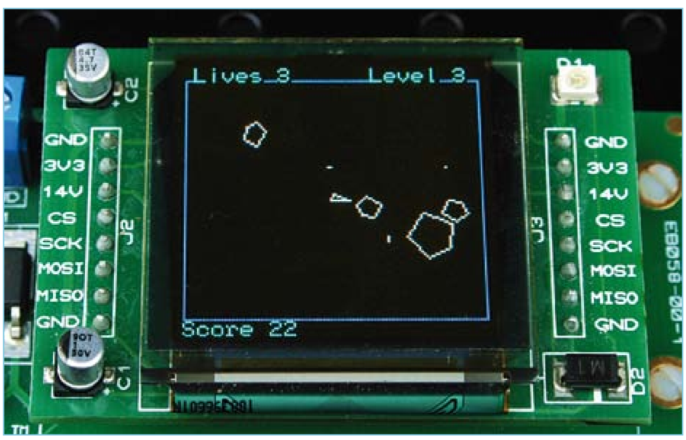


Figure 4. Some screen images from the final Asteroids game

ing rockets from the space ship and exploding asteroids, the number of floating point trigonometric calculations per frame needs to be between 100 and 200.
We also made certain sections of the code quicker with a few other tricks: for example on collision detection. We assumed that all objects on the game were circular as detecting collisions on circles is much faster than on other objects. The section on the panel shows how this is done and gives a nice example of how the maths library can help in writing a program like this.

Clever collision detection calculations

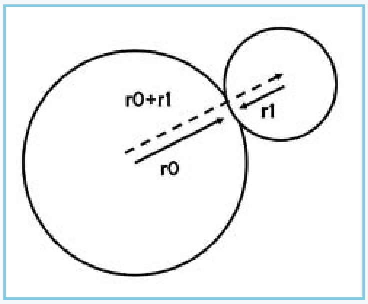
If two circles (radius r0 and r1) touch, they form a larger circle whose radius is (r0 + r1).

The distance from the centre of one circle to the centre of the other is:

$r = \mathrm{sqrt}((x1 - x0)^2 + (y1 - y0)^2)$

Therefore if this is less than (r0 + r1) then the objects collide:

$r < (r0 + r1)$



Luckily we can therefore remove the square-root as it is more efficient to calculate the square of (r0 + r1). So to calculate the collision detection we need to do:

$rsq = (x1 - x0)^2 + (y1 - y0)^2$

$result = rsq < (r0 + r1)^2$

This is only 3 multiplies, and no divides or anything more complex.

One issue is that the best apparatus to-hand for controlling the ship is the keypad. However this works on a matrix of 4x3 bits, so it is possible to find if a single key has been pressed, but not if multiple keys have been held. This is a drawback as you might want to fire missiles and move at the same time. We worked around this by treating each 3-element row as a single key, therefore splitting the keypad into four independent rows.
Each row can then be tested to see if any key is pressed or held, allowing the player to hold down the keys, improving the game no end. So 1, 2, 3 rotate the ship left, 4, 5, 6 accelerate the ship, 7, 8, 9 fire the missiles, #, 0, * rotate the ship right.
The game play is based on several arrays which track the positions of the relative objects in the game and simple algorithms to dictate their motion. There is also a simple scoring and level mechanism.

Conclusion

The dsPIC33 we have used is a great little device. We are impressed by the power and the versatility and the trouble Microchip has taken to make this easier to use — and faster! Being able to fit this game into one little chip is quite impressive. We have an urge to do PACMAN next.
A YouTube video of this project is available at [3]. So far no one has beaten the game at level five. Let us know!

About this project

The program is written in Flowcode for dsPIC. A copy of the Flowcode program can be downloaded this project´s web page [1].
The hardware consists of the new *Flowcode for dsPIC bundle* (EB655SI4) to which for this occasion is added the dsPIC33FJ128GP202, the optional add-on *Graphical Colour Display* (EB058) and the *Keypad* (EB014). *Flowcode 4 for dsPIC* and is available from the Elektor Shop.

(100955)

Note: You will have to use Flowcode 4 for dsPIC/PIC24 Professional as it relies on the Graphical LCD component. The Home/Student version does not have this component.

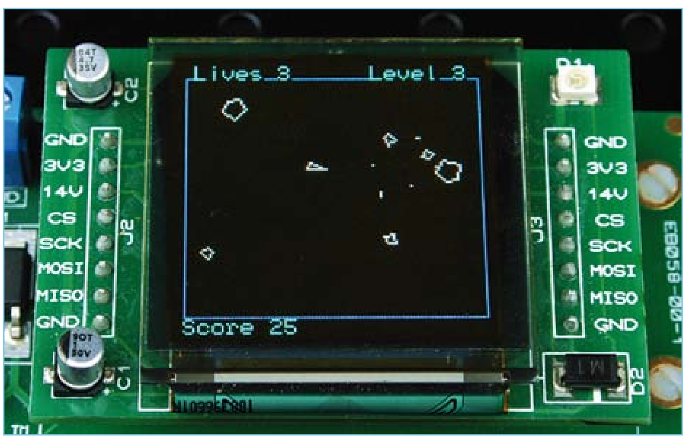
Internet Links

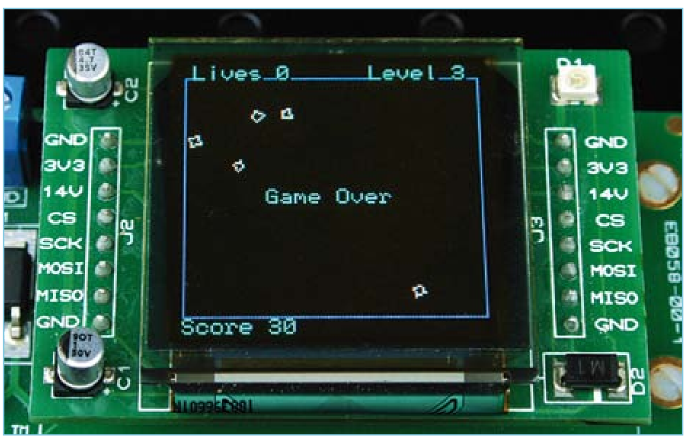
[1] www.elektor.com/100955

[2] www.elektor.com/eblocksoverview

[3] www.youtube.com/user/MatrixMultimediaLtd#p/u/5/jgsM4mSzbPg

[4] www.matrixmultimedia.com





Guitar Input for Multi-Effects Unit

Preamp based on Ibanez TS9

By Thijs Beckers (Elektor Labs)

In September 2010 we published a digital multi-effects unit. This circuit can only be used with line level signals, such as those used by keyboards and the effects loops of mixing panels. To make that circuit suitable for use with electric guitar signal levels we now present a simple but effective amplifier circuit.

The Elektor Digital Multi-Effects Unit published in the September 2010 edition [1] contains a number of nice effects that would not be out of place in conjunction with an electric guitar. Here we publish a preamplifier, which makes the input of that circuit suitable for connecting to an electric guitar. This preamplifier, which in addition to a high-impedance input, also has the option of adding an effect commonly used with electric guitars, namely distortion.

Circuit

For this very simple circuit we took inspiration from a very popular overdrive-pedal from Ibanez. To be more precise: the TS9 Tube Screamer. You could say that our 'preamplifier' is a slimmed-down TS9, but still

Characteristics

- Easy to solder
- Powered from a 9-V battery or suitable adapter
- The character of the sound is easily changed
- Bypass-switch option for the distortion
- Adjustments for Drive, Tone and Level

having the same characteristic sound of one of those.

The schematic of the circuit can be seen in **Figure 1**. The input impedance is mainly determined by R1 (470 kΩ), since the input impedance of an opamp generally amounts to several megohms. Input capacitor C1 ensures that the guitar pickup elements are not subjected to the offset voltage that is generated by R1 at the non-inverting input of IC1A. You don't have to worry about the corner frequency of the high-pass filter that is formed by R1 and C1. This amounts to only 7 Hz. For guitar signals, that value of C1 could easily have been selected to be smaller by a factor of nearly 10.

IC1A operates simultaneously as a buffer and as a 'drive' amplifier. Together with anti-parallel connected diodes D1 and D2, IC1A determines, to a large degree, the 'sound' of the distortion effect (see 'Modifications'). The gain — i.e. the degree of distortion — is determined by R2 and the potentiometer connected to JP3. The following applies: the larger the value of the resistance in the feedback loop of IC1A, the higher the distortion.

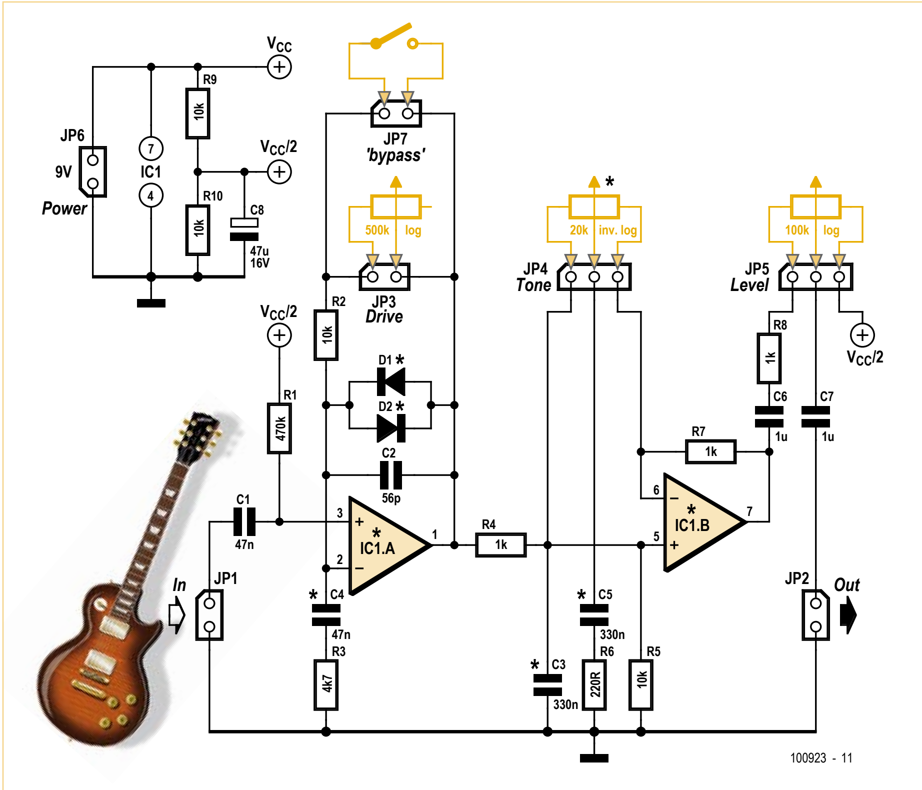


Figure 1. The schematic is based on the TS9 Tube Screamer from Ibanez.

A switch can be added via JP7 to turn the distortion on and off (just as with a guitar effects pedal). When the switch is closed, the gain-potentiometer is short-circuited and the gain is entirely determined by R2 alone. By selecting an appropriate value for R2, the volume level of the undistorted sound can be matched to the volume of the distorted sound. The optimum value depends a little on the pickup elements that are used in the guitar. It was found that a value of 10 kΩ gave the most balanced result. Note: The 'bypass'-switch only turns off the distortion, not the tone-control section. It is therefore not a real bypass...

Via a simple tone-filter, which mainly influences the higher frequencies, the signal then arrives at the output buffer IC1B. The potentiometer for the tone control is connected via JP4. For the best feel when adjusting the tone control it would be preferable to use an inverse-logarithmic potentiometer here. These are, however, difficult to obtain. You could, of course, use a normal logarithmic potentiometer and wire it the other way around, but this will probably feel a little strange, because the highest gain then occurs when turning the potentiometer to the left.

After the output buffer stage there follows a simple volume control with a potentiometer that is connected via JP5. A logarithmic potentiometer with a value of 100 kΩ will suffice here.

The output impedance is quite large, but with a short connection between this output and the input of the next stage (the multi-effects unit, for instance) this will not result in any problems.

Power supply

The circuit has to be powered from a regulated voltage of 9 V. If we are using a regulated mains adapter with a 9 V output as the power supply for the Digital Multi-Effects

Elektor Products & Services

- PCB: # 100923-1
- PCB artwork (free download): # 100923-1.pdf
- Demo movie at www.youtube.com/user/ElektorIM
- Elektor Digital Multi-Effects Unit: September 2010 (www.elektor.com/090835)

COMPONENT LIST

Resistors
R1 = 470kΩ
R2,R5,R9,R10 = 10kΩ
R3 = 4.7kΩ
R4,R7,R8 = 1kΩ
R6 = 220Ω

Capacitors
C1,C4 = 47nF
C2 = 56pF
C3,C5 = 330nF
C6,C7 = 1µF
C8 = 47µF 16V

Semiconductors
D1,D2 = e.g. 1N4148*
IC1 = e.g. OPA2134*

Miscellaneous
JP1,JP2,JP3,JP6,JP7 = 2-pin pinheader, lead pitch 0.1 in. (2.54mm)
JP4,JP5 = 3-pin pinheader, lead pitch 0.1 in. (2.54mm)
8-pin IC socket for opamp*
2 pcs 2-pin socket for diodes*
2-pin socket for connecting drive pots
2 pcs 3-pin header for connecting tone and level pots
Potentiometers: 500kΩ logarithmic (drive), 20kΩ anti logarithmic (tone)*, 100kΩ logarithmic (level)
Wires for potentiometers
PCB # 100923-1, see [2]

* please refer to text

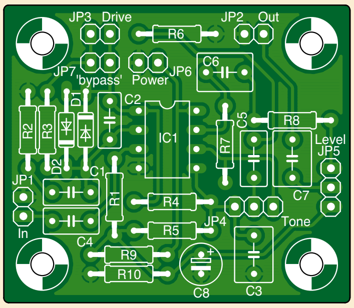


Figure 2. The circuit board is single-sided and designed to be very compact.

Unit, then all three boards (this preamp and the user interface and main boards of the Multi-Effects Unit) can all be powered from the one power supply. The power consumption is very minimal, so practically any standard adapter will suffice.

In the circuit of the preamp, R9 and R10 are used to generate a symmetrical power supply voltage, where ground is replaced by $V_{CC}/2$. The signal from the guitar is offset by $V_{CC}/2$, after which it passes through the circuit. Before the signal reaches the output of the circuit this offset is removed again by C7, so that any of the following stages, such as the input of the multi-effects unit, will not be damaged.

Modifications

Every guitarist has his or her own preference as far as the sound goes. You are therefore welcome to experiment to your heart's content with the sound of this preamp. R3 and C4 act as a high-pass filter, so that lower frequencies are overdriven less by the diodes. With the component values as indicated, the corner frequency of this filter is about 720 Hz. By taking a larger value for C4, the gain at lower frequencies is increased. A smaller value results in a thinner sound. Incidentally, a smaller value for R3 results in more drive.

The diodes have by far the greatest influence on the sound. In our prototype we used two standard 1N4148 diodes, which generate a very pleasant sound. A 1N4007 results in a somewhat 'hulking' sound, while germanium diodes, such as the 1N34, provide a softer sound. The 1N914 is also a good candidate. Combinations of diodes are also possible, for example a 1N4148 connected in anti-parallel with two germanium diodes connected in series. Each of these results in a sound that is slightly different, which may appeal to one person but perhaps not another. So we strongly recommend that you experiment. It is therefore a good idea not to mount the diodes directly onto the circuit board, but to fit a couple of sockets instead. In this way it is very easy to try out different diode combinations by simply plugging them in.

The type of opamp used has a lesser effect. But the differences are definitely audible and can make the difference between a sound that is just right or one that is just not right. Our preference is the OPA2134, which gives a somewhat 'smoother' sound than, for example, a TL072, which sounds a lot coarser. Other opamps which are also used by guitarists in Ibanez TS-9 pedals are, among others, the LM358, the LM833, the LT1124, the OP227 and the JRC4558D. Each of these bestows its own effect on the sound and it is only possible to pick the 'best' one by simply trying them all.

Finally it is also possible to experiment with the tone control. R4 and C3 form a high-pass filter (with the component values as indicated, the corner frequency is at about 480 Hz). By varying C3 between 100 nF (more treble) and 470 nF (more bass) there is yet another opportunity to polish the sound some more. With C5 and R6 and the potentiometer the sound can be fine-tuned externally. With C5 the same is true as for C3: 100 nF gives more treble; 470 nF gives more bass.

Construction

The assembly of this simple circuit is relatively easy since only standard, leaded components are used. The component overlay is printed in **Figure 2**. As always, begin with the low profile components such as resistors and fit the taller components such as capacitors last. This generally makes assembly the most straightforward. A small piece of soft foam can be pressed against the PCB to help the components stay in place when the board is turned upside down to solder the leads.

To make it easy to try several different opamps it is a good idea to use an IC socket for this. You can then simply plug in the opamp of your choice and it is also very easy to swap it for another type. The same is true for the diodes, but you will perhaps have to improvise a little here; you could cut two sockets from a female header/connector and plug the diodes into these.

The potentiometers are connected to the board with headers. This is mainly done to keep the printed circuit board as small as possible, but this way also allows them to be mounted on a front panel in whatever way you like best.

It is recommended that you use a mono jack for the bypass switch. You can then easily connect a simple foot switch from the music store. The printed circuit board layout can be downloaded from the Elektor website [2], as well as the Eagle PCB design files (Eagle version 5.6).

(100923-I)

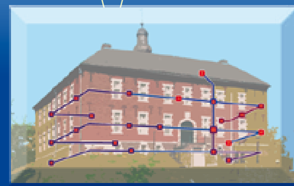
Internet Links

[1] www.elektor.nl/090835

[2] www.elektor.nl/100923

[3] www.youtube.com/user/ElektorIM

Here comes the bus! (4)



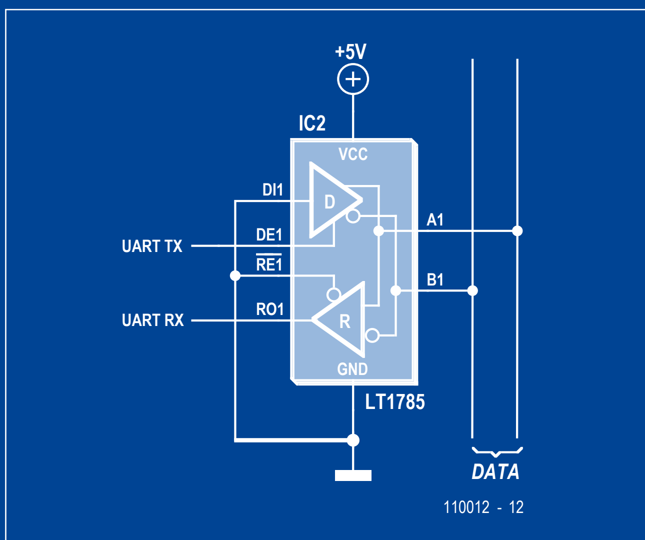
by Jens Nickel (Elektor Germany Editorial)

Our bus doesn't stop for anyone! Even after the copy deadline for the previous edition we received many new e-mails from interested readers. Many thanks for these: I have tried to comment on all of your ideas, which have sometimes turned into mini-discussions. It is a pity that readers were not aware of the most recent developments in the design of the bus: producing a magazine takes a little time and there is inevitably a delay between the writing of an article and its appearance in print. Many of the e-mails contained valuable thoughts and ideas, and so we decided to institute a mailing list for interested readers. I wanted to be able to share feedback on this fourth article in the series 'live' with other developers, and members of the list can also add their comments immediately.

A core group of readers took up the idea of working together on an *Elektor* project in a new way like this rather, shall we say, enthusiastically. After the initial invitation ideas for the *ElektorBus* protocol started to flood in to my inbox: seven e-mails on the first day, thirty-odd on the next, all full of suggestions and advice as well as more fully worked-out ideas. And when I tell you that even experts in the field such as John Dammeyer were chiming in (he was one of the people behind the biggest CAN bus installation in the world, controlling the illumination of the Olympic rings at the winter games in Vancouver), you will see that we were really getting down to business!

It was clear that some seasoned engineers had already started work on getting the test node circuit we gave in the last issue up and running on the bench. *Elektor* author and professional engineer Günter Gerold suggested a capacitor in parallel with the reset button: consider it done. And surely the 7805 regulator was last seen in the stone age? We received many e-mails suggesting alternatives for this and for other components. There is no shortage of microcontrollers, perhaps only a little dearer than the Atmega88, but featuring useful built-in bus interface peripherals: CAN transceivers are mentioned especially frequently. Several substitutes were also suggested for the LT1785. I would like to stress again, however, that the test node circuit is not intended as a 'reference implementation'. A bus node can be made using completely different components, and we want to avoid a dependence on special-purpose devices.

Several readers alerted us to the fact that although connecting the RE and DE pins on the LT1785 together is a practical approach to achieving half-duplex operation, it is not the most flexible. If DE is taken high and RE low, the microcontroller can read back its own transmissions. This can be useful in detecting bus collisions. John sent us a (to me) highly novel variation on the RS-485 transceiver circuit using just two pins on the microcontroller: see the small circuit diagram. This idea seemed so useful that I decided to modify the circuit of our first test node as shown in the figure. All the relevant transceiver pins are now connected to pins on the microcontroller, and we can test the different variants of the circuit simply by changing the software.



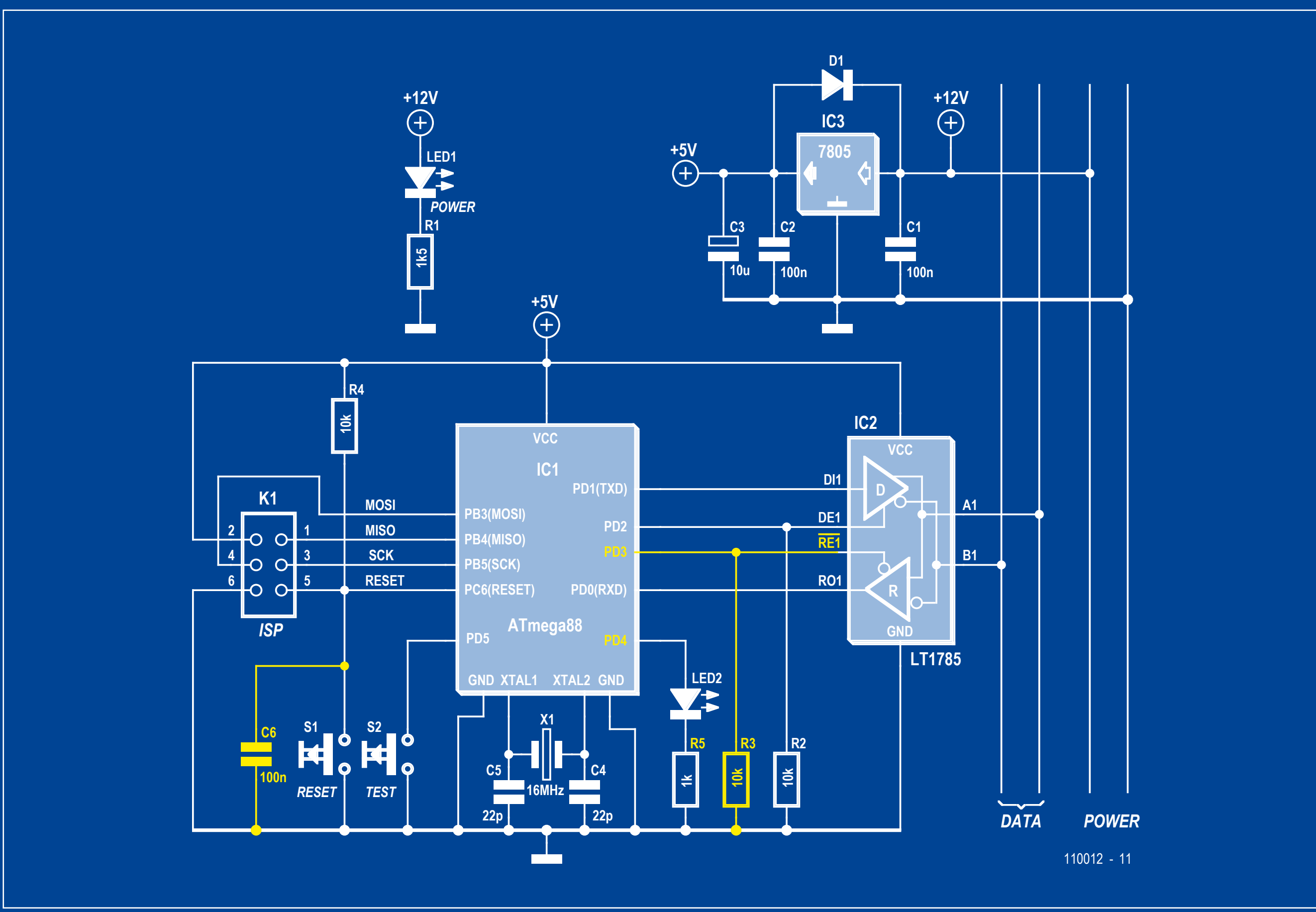
Many of the ideas are certainly worth looking at in the longer term. The internet was a recurring topic: an internet connection for the bus is certainly right at the top of our wishlist. John, along with *Elektor* reader Eric Huiban from France, suggested modularising the hardware: make a small *ElektorBus* printed circuit board with processor, crystal, RS-485 driver and one or two LEDs, and then, just as with the Ethernet modules we often use in *Elektor* projects, use this to equip other devices with *ElektorBus* functionality. Such a module could be replaced by a wireless version at a later date. An excellent idea, and one we will surely return to later in this series.

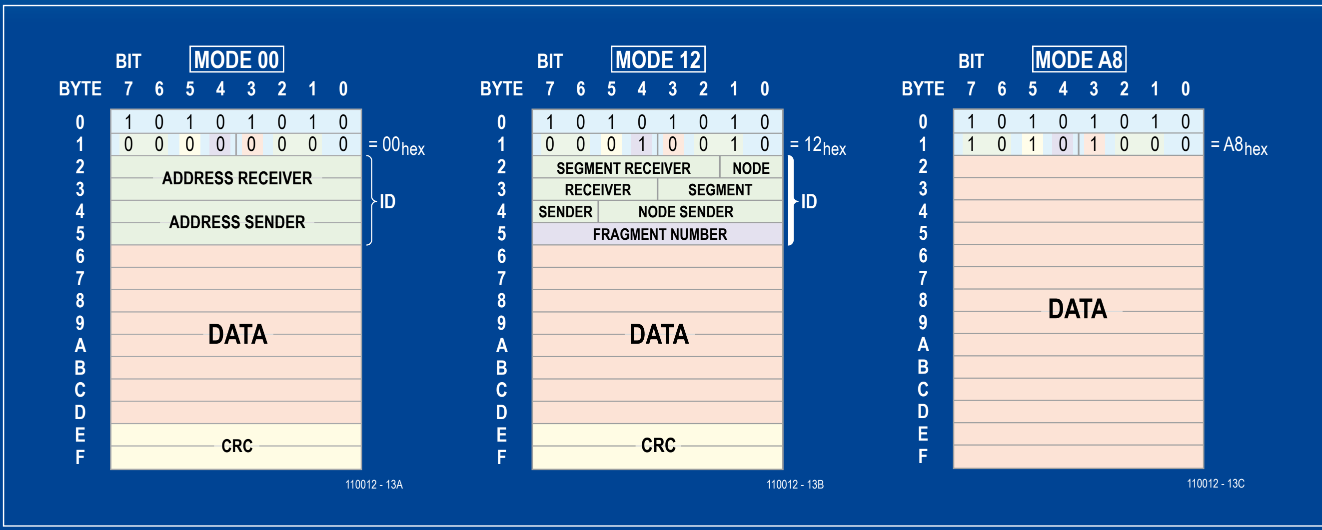
Another popular point of discussion revolved around how to connect a PC to the bus. Writing Windows applications that can be controlled by external events is not always straightforward. *Elektor* author Walter Trojan suggested that it should be possible to make a USB gateway with its own microcontroller to replace the USB-to-RS-485 converter. This would help decouple the PC from the microcontroller-based bus. We soon came to the conclusion that using a PC as a bus master was at best an interim solution, even given that frameworks such as .NET directly support (virtual) COM ports [1]. Our goal should always be to create a bus architecture that can run independently of a PC, with central control coming from a more humble microprocessor.

The small team had big plans when it came to the question of the maximum permitted number of bus nodes. *Elektor* reader Bertrand Duvivier, a product manager at Cisco, proposed a hierarchical bus topology. Since RS-485 was designed for a maximum of somewhere between 32 and 256 bus participants (and in a home automation application we could easily exceed even the greater of those numbers), Bertrand felt that it would be necessary to divide the bus into segments. The various segments would then be joined using a kind of router or controller, which would orchestrate the flow of messages between segments. A node address would then be divided into a segment identifier and an identifier of the node within the segment, much as IP addresses are divided. However, as we have said before, we want our bus to be as simple as possible so that understanding the hardware and software can easily be within the grasp even of beginners. However, it was becoming clear to me that we would have to allow for the possibility of joining bus segments at some point, and in our protocol (see below) we have expressly provided for addresses divided into two parts.

Finally: the protocol. Let us start with the question of how a bus node can detect when a message starts. Günter's idea was that the transmitter could force an artificial UART framing error. I wasn't keen on this, since it would create a dependency between the higher protocol layers in the stack and the lower physical layer (RS-485 and UART). My preference was to use a more traditional 'start byte': but what value to use? 0X02 or 0x03? Perhaps 0x7E? I felt that 0b10101010 would be best, since that would also allow for synchronisation. (A similar idea is used in Ethernet, where the bits are written 'backwards', the start byte thus appearing as 0x55.)
In his first e-mail Bertrand had put forward the possibility of using message packets of a fixed length, and even though almost all other protocols use a variable payload size, the idea did have some appeal. Indeed, for our round-robin mode, where the nodes transmit in turn, it seemed ideal. It also makes synchronisation easy: every so many bytes on the bus we must see the value 0xAA.
After our small community had exchanged a few links, such as [1] and [2], and a few more suggestions for simple protocols, I made my proposal for a protocol with a fixed message length. We would need about eight bytes for the header (start byte, addresses, error detection and so on) and so it seemed that a total length of 16 bytes would be ideal. Eight payload bytes would be plenty for most applications and the overall structure had a pleasing symmetry.
Some of the ideas that were bandied about concerned the use of different function control bytes and the possibilities of handshake between master and slave, but these (highly valuable) discussions became so voluminous and in places so application specific, that it was necessary to defer looking further into the ideas until a later date.
As in the OSI model, the second layer of our protocol is concerned with getting the data packets to the right receiver without damage, and, if necessary, reassembling them in the right order. Thus any message longer than eight bytes will have to be fragmented.

There then followed several e-mails discussing the number of bits that should be used to form an address. Four bytes (allocated between transmitter and receiver addresses) at first





seemed far too many: would we ever want to have as many as 65,536 participants on a bus?

For error detection we decided to use a CRC (a full description of which would be an article in itself, but you can read all about it on the internet [4], [5]). Two bytes would be enough for that. But perhaps there are applications, such as transmitting audio, where error detection is not so important? Also, in point-to-point connections, for example, we would not make use of the full range of addresses, and in any case the transmitter address would often not be necessary. All these are potential overheads in the protocol that we would like to reduce. On the other hand, we would like to keep open the option of splitting an address into a segment identifier and a node identifier (see above). And finally, I wanted to keep the option of numbering the fragments of a message from 0 to 255. If the transmitter numbers the fragments counting downwards to zero, the receiver will know how many more packets to expect until the message is complete.

So we would have configurable addressing, whereby more or fewer bytes can be used for addresses depending on whether it is needed to specify both transmitter address and receiver address or just the receiver address, and on whether grouping into segments is required, with optional fragment numbering and optional two-byte CRC error detection. These various options are flagged using bits of a single byte, called the 'mode byte', sent immediately after the start byte (see text box). *Et*, ladies and gentlemen, *voilà*, the *Elektor* Message Protocol (EMP)! When John the CAN expert saw my proposal, he could not resist a chuckle: 'just like CAN', he wrote. 'If you had restricted the addresses to just 12 bits each, you would practically have reinvented it.' Quickly I looked up the details of CAN on the computer. I had to admit that we was to some extent right: CAN also uses a payload length of eight bytes (although this is a maximum, rather than a minimum as in our case). The flexible allocation of bits to identifiers and addresses, and of course the CRC, were also a little reminiscent of CAN.

However, I couldn't help feeling that coming from a CAN-fan like John, I should perhaps take his words as something of a compliment...

(110012)

Internet Links

[1] http://msdn.microsoft.com/library/system.io.ports.serialport.aspx

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

[3] www.vscp.org/wiki/doku.php?id=vscp_specification_-_vscp_level_i_over_rs-485

[4] http://en.wikipedia.org/wiki/Cyclic_redundancy_check

[5] www.lammertbies.nl/comm/info/crc-calculation.html

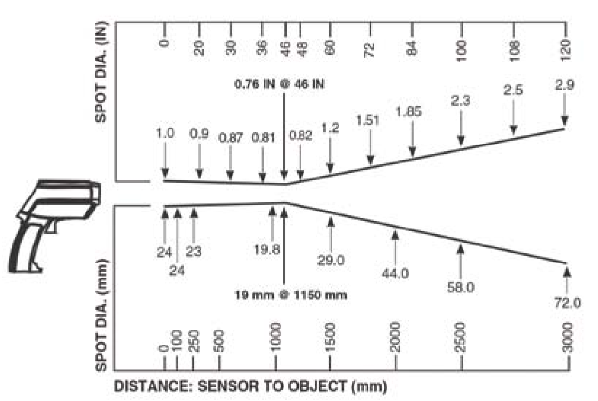
ElektorMessageProtocol: mode byte

Bit	1	0
7	no ID bytes, data from byte 2	ID bytes from byte 2
6	bytes 2 and 3 are ID bytes	bytes 2 to 5 are ID bytes
5	no CRC	bytes E and F form a 16-bit CRC
4	last ID byte is a fragment number	all ID bytes are used for addressing
3	next fragment follows immediately	no fragment follows immediately
2	address bits for receiver only	address bits for both transmitter and receiver
1	top six address bits give bus segment	no segment address
0	reserved: may be used as a flag indicating a high-priority message	

If bit 3 of the mode byte is set fragments can follow one another immediately in sequence (think of the carriages of a train), giving the same effect as a larger packet size.

A quick temperature measurement...

By Thijs Beckers (Elektor Netherlands Editorial)



1

“Know what you measure” is obviously derived from the phrase “know what you eat”, but that doesn’t make it less true. During our IR thermometer test published this month, this was confirmed once again. Our plan was to test a number of reasonably affordable IR thermometers. A list of potential candidates was made and the suppliers are approached with the question whether they would be prepared to make a device available. Now Elektor is not the Consumer Federation, so it does sometimes take a considerable amount of persuasion to convince suppliers, who are not operating in the electronics sector, to send us an instrument, but anyway: in front of us there are 15+ IR thermometers in all shapes and sizes. Now it starts for real.
What would we like to know about these thermometers and how can we test them? And we need a reference thermometer of course, to compare the measurements. Fortunately, the people at Fluke were generous enough to send us a model 572. With specifications such as an measuring angle of 60:1, a triple laser and a calibrated accuracy of 1% to 900 °C this thermometer is eminently suitable as a reference. With these thermometers we especially would like to know how accurate they are at measuring the temperature. Another important aspect is the measuring angle or size of the surface area that is measured.
Measuring the temperature accuracy is not a major problem. Take a surface at a certain temperature, measure it with the different IR thermometers and the reference thermometer, and compare the results. A simple cooking element was perfectly suitable for generating some higher temperatures.
In addition, we checked the laser indication. Why do that, you think? With a number of the thermometers there was already a clearly visible deviation of the laser(s) compared to the ‘centre-line’ of the instrument, where you would have expected the measurement to take place. Further measurements (unfortunately) confirmed this (refer to the test report article elsewhere in this issue). The so-called accuracy of the built-in laser beam is therefore sometimes deceptive, in reality you are measuring something else instead of what the red laser dot is pointing to.
Incidentally, the measuring itself is also a subject on itself. It can be quite hard to estimate what the exact surface as that you are measuring, despite for, example, the double laser indication that three of the instruments have built in.
In any case, the thermometers need a certain minimal surface area to be able to measure properly. This surface is too large to measure the temperature of ‘normal’ chips, which is a little disappointing for us as electronics engineers. With those thermometers that have a very small measuring angle, you would think that you could measure very close up for a very small surface area. This is not the case however — over the first 10 to 15 cm these instruments have a kind of ‘measuring bundle’, which has a certain minimum dimension. Incidentally, with the Fluke 572 this is clearly indicated in the documentation (see **Figure 1)**. Other instruments don’t make any mention of this at all. These assume a complete cone-shape from the front of the instrument, the correctness of which we have our doubts. But it is also very difficult to check. Our advice when using an IR-thermometer is to always measure as close as is possible, but nevertheless always assume a measuring spot of at least 1 to 2 cm diameter.
Since we were also warned from several quarters that there are large deviations when measuring reflecting objects we put that to the test by taking a small, black anodised aluminium heatsink and file down one side of it so that the bare aluminium became visible. This heatsink when subsequently heated to a practical value of about 65 °C, a temperature that this type of heatsink can easily reach when mounted on a circuit board in a small enclosure. Now using the Fluke 572 and one of the other thermometers with a small measuring angle of 30:1, we measured at a close distance first the black side and then the bare side. The difference was enormous with 65 °C on the black side and 40 °C on the bare side. If you then take into consideration that the ambient temperature is about 20 °C, then the difference between the two sides, caused by the so-called coefficient of emissivity, is more than 50%. The maxim ‘Know what you measure’ is certainly appropriate! It even should be: ‘Know what you measure and how you measure’.

(110140-I)

3 GHz Frequency and Signal Level Meter

Built around a CPLD and a dsPIC microcontroller

This handy instrument measures frequencies from 50 MHz to 3 GHz with an accuracy of 10 ppm and provides an indication of the signal level over a range of –40 dBm to +10 dBm. Readings are displayed on a three-line LCD module, and the instrument is powered by three standard AA cells.

By Martin Bachmann and Daniel Schär (Switzerland)

A convenient battery-powered instrument is very practical for quickly measuring the frequency and level of HF signals. The instrument described here also features very high accuracy for frequency measurement. It has a 50-Ω HF input with a female SMA connector, suitable for connection to a cable or directly to an antenna. Of course, if you connect an antenna to the instrument you need to ensure that the level of the signal you wish to measure is sufficiently high relative to other signals that are also picked up by the antenna.

Basic architecture

The block diagram in **Figure 1** shows the general layout of the meter, with the HF portion and the digital portion distinguished from each other by different shading. The input signal is fed via a passive (resistive) splitter to the input stages of the two branches of the HF circuit: one for frequency measurement and the other for signal level measurement. The signal level measurement circuit essentially consists of a logarithmic

Features

- Frequency measuring range: 10 MHz to 3 GHz
- Frequency measurement error less than 10 ppm (0.001%)
- Signal level measuring range: –40 dBm to +10 dBm (0.1 µW to 10 mW into 50 Ω) over the range of 300 MHz to 2.8 GHz
- 146 readings per minute
- Power source: three 1.5 V AA cells or a 5 V AC mains adapter (min. 180 mA)
- Maximum current consumption at 5 V input: 170 mA
- Battery life with three 2000 mAh NiMH cells: 18 hours continuous operation without LCD backlighting or 11 hours with backlighting

detector IC made by Linear Technology.
Frequency measurement requires a more complex circuit. It basically consists of a frequency counter implemented in an Altera CPLD, along with a frequency divider and a reference oscillator. Signal processing, control and display functions are provided by a Microchip dsPIC microcontroller.

Signal level measurement

An LT5538 logarithmic signal detector IC [1] from Linear Technologies is used to measure the signal level. Along with a frequency range of 50 MHz to 3 GHz, the selection criteria for this device were a dynamic range of at least 50 dB, an input sensitivity of –46 dBm, operation over the industrial temperature range of –40 to +85 °C, operation from a 3.3-V supply voltage, and the lowest possible price. Only three ICs meet the dynamic range requirements: the ADL5513, the LT5534 and the LT5538. We chose the LT5538 because it has the largest dynamic range of the three (75 dB).
This IC detects the power of the HF signal and outputs a voltage proportional to the power. This voltage is fed to an A/D converter in the microcontroller, and the digitised value is further processed by the microcontroller.
Unfortunately, the signal level output voltage from the LT5538 is highly frequency dependent. For this reason, we implemented a digital correction function using polynomial approximation. The signal level measurement function can be calibrated using a routine in the microcontroller firmware that is accessed from the display menu.

Frequency measurement

Frequency measurement is essentially based on a counting method implemented in the Altera Max-2 CPLD [2]. During the measurement cycle, one counter counts zero crossings of the signal being measured, while another counter counts zero crossings of the signal from the reference oscillator. The frequency can then be calculated from the counts accumulated by the two counters by using the formula:

frequency = (reference frequency) × (signal count) ÷ (reference count)

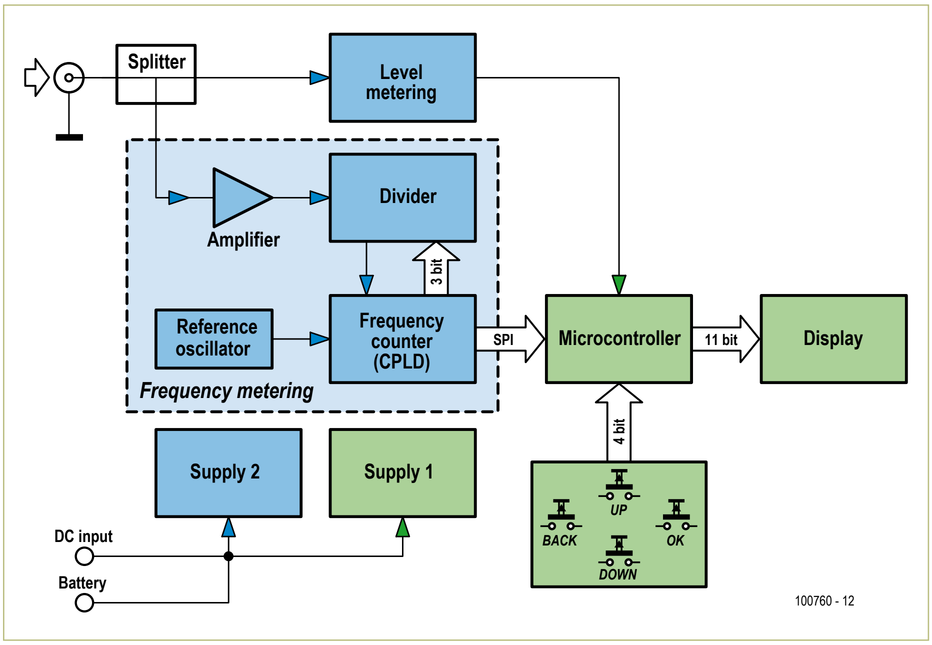


Figure 1. Block diagram of the frequency and signal level meter, with the HF portion shaded blue and the digital portion shaded green.

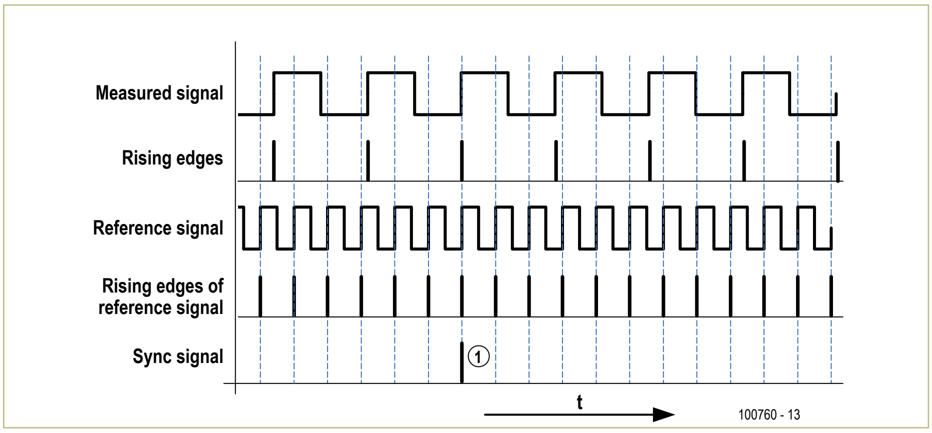


Figure 2. Timing diagram of the synchronisation logic in the CPLD. Frequency measurement using two counters starts and stops when the reference signal and the input signal both have rising edges at the same time.

Elektor Products & Services

- PCB: # 100760-1
- PCB layout files (free PDF download): # 100760-1.zip
- CPLD and dsPIC software (including source code): free download file # 100760-11.zip
- Items accessible through www.elektor.com/100760

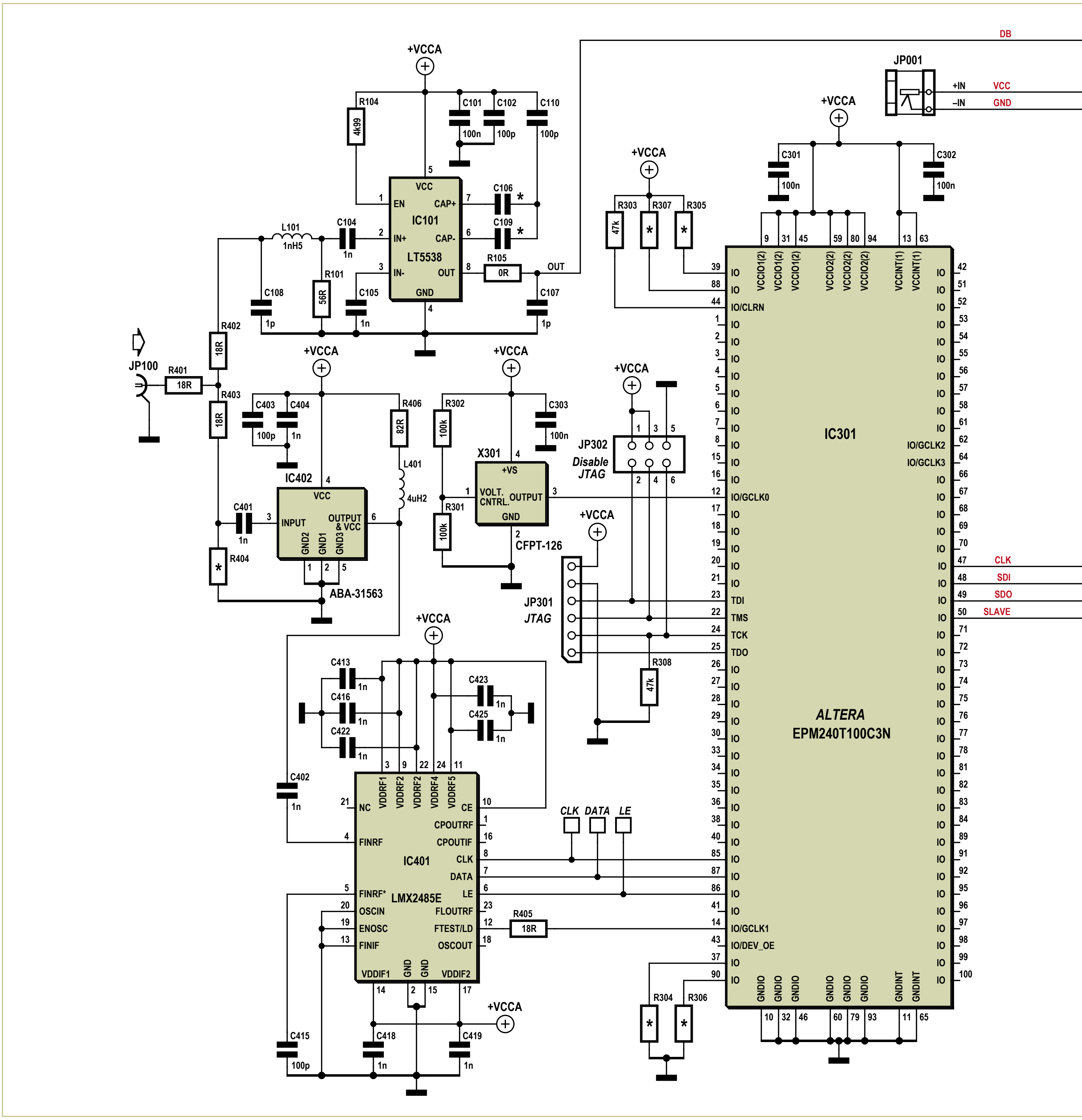
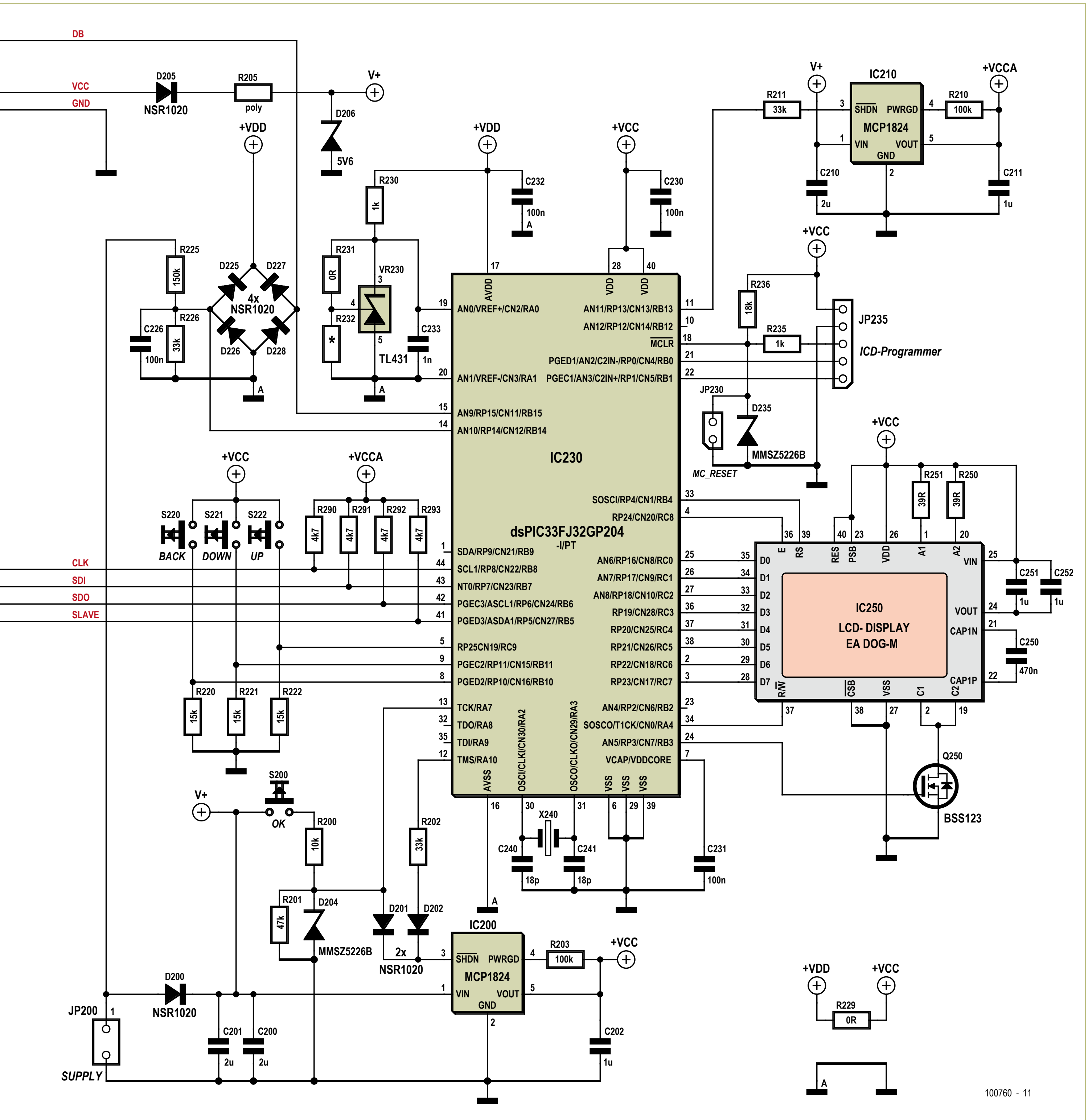


Figure 3. In the actual circuit, the HF portion on the left and the digital portion on the right

Synchronisation logic is programmed in the CPLD to increase the accuracy of frequency measurements. This logic ensures that the two counters used for frequency measurement are both started and stopped when the reference signal and the signal being measured have rising edges at the same time (see **Figure 2**). The counts accumulated by the two counters are sent to the microcontroller over an SPI bus.

The CPLD can process input signals up to approximately 200 MHz. A frequency divider is required to allow higher frequencies to be measured. Naturally, the division factor (in this case 32) is included in the calculation of the frequency. An LMX2485E PLL IC [3] from Linear Technologies is used here as the frequency divider. Only the inte-



are independent functional units with separate supply voltages.

grated frequency divider of this IC is actually used; the PLL function is not utilised. The advantage of this seemingly wasteful approach is that PLL ICs are manufactured in very large volumes and are therefore cheaper than pure HF divider ICs.

The internal settings of the PLL IC (including the division factor) must be configured every time the instrument is powered up. We were able to implement this directly in the CPLD, so the microcontroller is not needed for this function. This allows the frequency measurement portion of the circuit to operate as an independent, self-contained module that simply outputs data from its SPI port and can easily be used for other applications.

To improve the input sensitivity of the instru-

COMPONENT LIST

Resistors
(SMD0603)
R101 = 56Ω
R104 = 4.99kΩ
R105,R229,R231 = 0Ω
R200 = 10kΩ
R201,R303,R308 = 47kΩ
R202,R211,R226 = 33kΩ
R203,R210,R301,R302 = 100kΩ
R220,R221,R222 = 15kΩ
R225 = 150kΩ
R230,R235 = 1kΩ
R232,R293 = not fitted
R236 = 18kΩ
R250,R25 = 39Ω
R290,R291,R292 = 4.7kΩ
R304,R305,R306,R307,R404 = not fitted
R401,R402,R403,R405 = 18Ω
R406 = 82Ω

Capacitors
(SMD0603)
C101,C226,C230,C231,C232,C301,C302,C303 = 100nF
C102,C110,C403,C415 = 100pF
C104,C105,C233,C401,C402,C404,C413,C416,C418,C419,C422,C423,C425 = 1nF
C106,C109 = not fitted
C107,C108 = 1pF
C200,C201,C210 = 2µF
C202,C211,C251,C252 = 1µF
C240,C241 = 18pF
C250 = 470nF

Inductors
(SMD0603)
L101 = 1.5nH
L401 = 4.2µH

Semiconductors
D200,D201,D202,D205,D225,D226,D227,D228 = NSR1020 (SOD323-W)
D204,D235 = 3.3V zener diode (SOD123)
D206 = 5.6V zener diode (SOD123)
IC101 = LT5538
IC200,IC210 = MCP1824 (SOT23-5L)
IC230 = DSPIC33FJ32GP204-I/PT (TQFP44), programmed
IC301 = EPM240T100C3N (TQFP100), CPLD (Altera)
IC401 = LMX2485E (LLP24), PLL (National Semiconductor)
IC402 = ABA-31563 (SOT363), wideband amplifier (Avago)
Q250 = BSS123 or SN7002W (SOT23)
VR230 = TL431 (SOT23-5), voltage reference (TI)

Miscellaneous
IC250 = EA DOGM163W-A, 3.3V-LC-Display, 3x16 characters (Electronic Assembly)
JP001 = DC adaptor socket, PCB mount
JP100 = SMA socket, 142-0711-881 (Emerson/Johnson)
JP200 = (optional) 2-pin pinheader (battery connection)
JP230 = 2-pin pinheader with jumper (if required)
JP235 = 5-pin pinheader, right angled
JP301 = 6-pin pinheader, right angled
JP302 = 6-pin pinheader, 2-row (if required)
R205 = self healing fuse 30V/0.2A (SMD1210), Littlefuse 1210L020WR (e.g. Farnell 1596997)
S200,S220,S221,S222 = pushbutton, 1 make contact, PCB mount
X240 = 18MHz quartz crystal (HC49/SMD)
X301 = CFPT-126 (LF TVXO009920) from IQD, temperature compensated 40MHz SMD quartz oscillator (Farnell #1100757)
Enclosure: Bopla Type BS404 F-7035
PCB # 100760-1 (see www.elekor.com/100760)

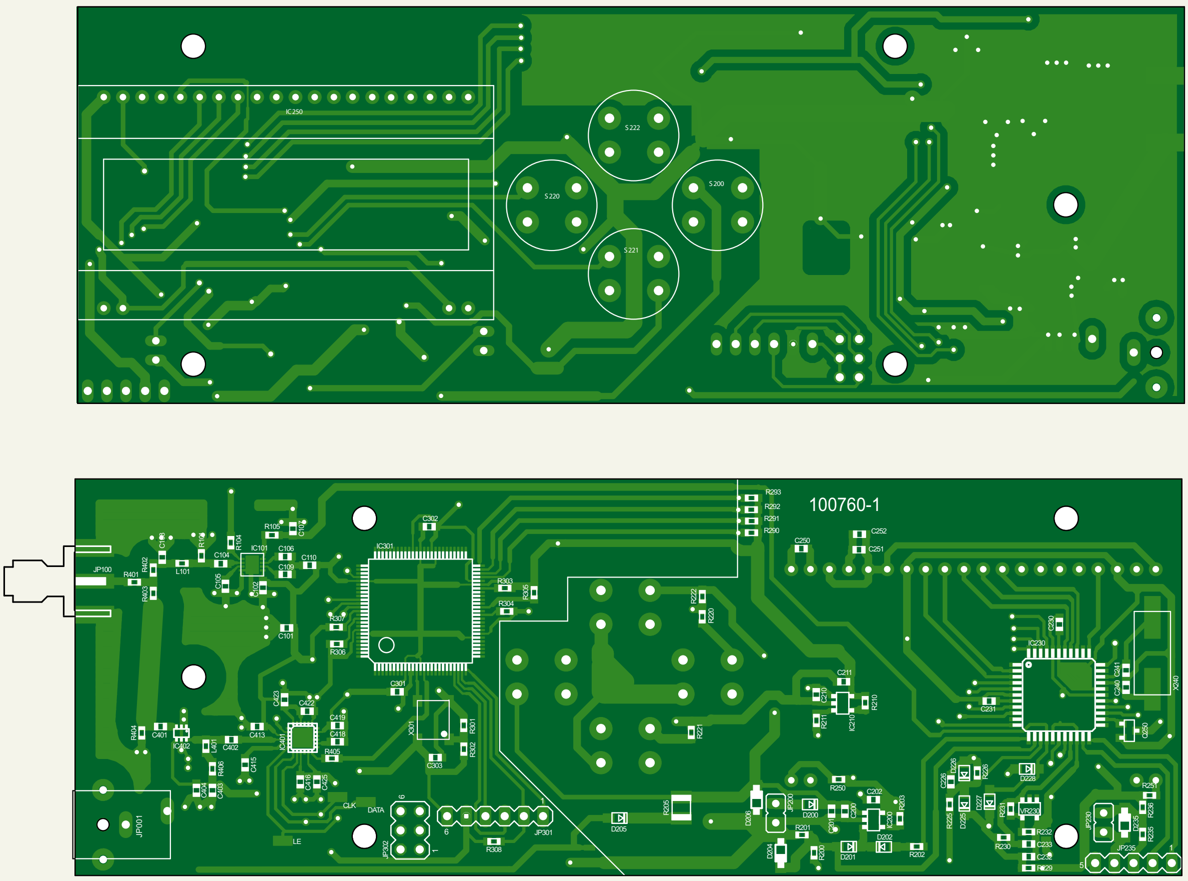


Figure 4. The PCB layout with exclusively SMD components on the bottom side. Only the buttons and the display module are located on the top side.

Table 1. Measurement accuracy		
Quantity	**Accuracy**	**Range**
Frequency	< 10 ppm (< 0.01 %)	50 MHz to 3 GHz –20 dBm to 0 dBm
	< 10 ppm (< 0.01 %)	700 MHz to 2700 MHz –35 dBm to +10 dBm
	< 1000 ppm (< 1 %)	300 MHz to 2700 MHz –40 dBm to +10 dBm
Signal level (calibrated)	4.3 dB	50 MHz to 3 GHz –40 dBm to +10 dBm

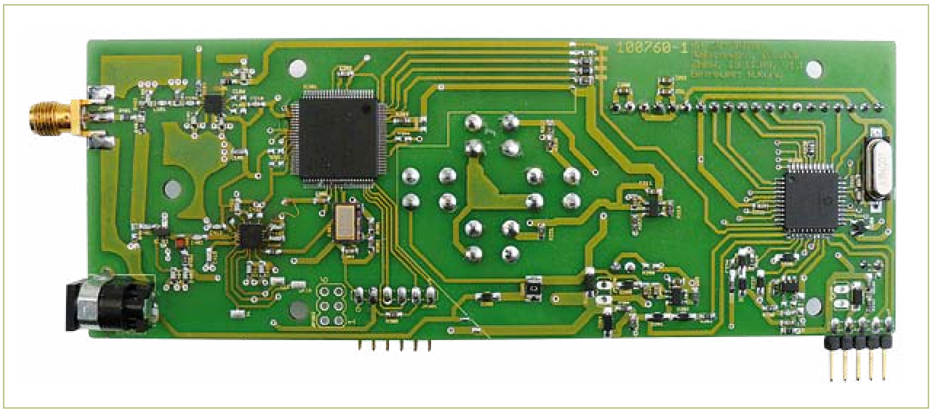


Figure 5. SMD side of the manually assembled Elektor lab prototype board.

Figure 6. Top side of the Elektor lab prototype board.

ment and compensate for the attenuation of the passive splitter (–6 dB for each leg), a broadband HF amplifier is included ahead of the divider. The Avago ABA-31563 [4] device used for this purpose has 50 Ω input and output impedances and a frequency bandwidth extending from DC to 3.5 GHz, and it provides approximately 20 dB of gain. The HF amplifier operates in the saturation region in the presence of strong input signals.

Accuracy

The frequency measurement accuracy essentially depends on the accuracy of the reference signal. The readings cannot be more accurate than the oscillator frequency. In addition, the accuracy of the frequency measurement depends on the signal level and the frequency being measured. Fundamentally, the accuracy increases with increasing input signal level.

Despite signal level calibration, the signal level measurement can never match the accuracy of the frequency measurement (see the section 'Signal level calibration').

The achievable results are summarised in **Table 1**. From tests, we determined that the frequency measurement accuracy of our prototype unit was 1 ppm at room temperature.

Circuit description

The portions of the circuit shown with different shading in the block diagram (HF portion and digital portion) were originally built and tested on separate PCBs. In the course of device development, these two portions were merged on a single board. The corresponding full circuit diagram is shown in **Figure 3**.

Here again the HF portion on the left and the digital portion on the right are separate functional units that can be used independently of each other. To improve supply decoupling, the two portions of the circuit are powered by separate supply rails and voltage regulators, with IC200 for the digital portion and IC210 for the HF portion. Both voltage regulators provide a supply voltage of 3.3 V. The two voltage regulators receive their input voltage either from a battery pack connected to JP200 (three AA cells; voltage 3.6 to 4.8 V) or from a 5-V AC mains adapter connected to JP001. Voltage source selection is automatic: if the voltage on the AC adapter input is higher than the voltage from the battery pack connected to JP200, diode D200 is reverse biased and isolates the battery pack. This diode also provides protection against reverse-polarity battery connection. A series diode in the AC adapter input circuit provides similar reverse polarity protection and prevents reverse current flow. A Polyfuse (self-healing thermal fuse) and Zener diode are connected after this diode. This combination protects the circuit against excessive voltage and limits the current in case of a fault.

The HF and digital portions are connected only by the four SPI bus lines and the signal detector output line (and of course by a common ground point). The CPLD sends the counts from the frequency measurement counters to the dsPIC over the SPI bus, and the dsPIC uses this data to generate the frequency reading shown on the LCD module and to apply frequency correction to the

Figure 7. The authors' prototype device.

signal level data. The output voltage from the level detector (IC101) in the HF portion is fed via the DB line to the A/D converter input of the dsPIC, which digitises it with 12-bit resolution and processes the resulting values with the previously mentioned frequency-dependent correction to obtain the readings shown on the LCD module. Diodes D225–D228 limit the voltage on the dsPIC A/D converter input (pin 15) to prevent overdriving. The dsPIC monitors the battery voltage on a separate analogue input (pin 13); this voltage is reduced to a suitable level by a voltage divider (R225/R226). The TL431 reference voltage source (VR230) provides a 2.5-V reference voltage for the A/D converter in the dsPIC.

The user interface consists of four pushbutton switches (S200 and S220–S222) and the three-line LCD module, with the backlight switched via Q250. The LCD module operates from a supply voltage of 3.3 V and features high contrast with automatic adjustment and very low current consumption (just 250 µA without backlighting).

In the HF portion, it's easy to recognise the elements of the block diagram. The signal splitter after the 50-Ω SMA connector consists of just three resistors (R401–R403). Passive splitting of the input signal into two signals for input to the level detection circuit and the frequency measurement circuit results in a loss of 6 dB for each path, which is why an amplifier (IC402) is placed ahead of the input to the PLL IC (IC401), which as already mentioned is used solely as a prescaler (frequency divider). This prescaler must be configured by the CPLD each time the instrument starts up, for which reason the PLL IC's Microwire interface port (which is compatible with SPI) is connected to the CPLD (IC301).

The CPLD receives the reference clock signal for frequency measurement from reference oscillator X301, which effectively determines the measurement accuracy. The type LF TVXO009920 specified in the components list, which is a member of the CFPT 126 family from IQD Frequency Products, is a temperature compensated 40-MHz crystal oscillator with an operating temperature range of -40 °C to 85 °C. It is compatible with 3-V logic and has a frequency stability of ±0.5 ppm, which is equivalent to just 20 Hz at 50 MHz. Of course, this accuracy comes at a price, and if you do not need such high accuracy you can use a more economical oscillator instead.

If you have access to a high-accuracy frequency counter for comparative measurement, you can improve the accuracy of the LF TVXO009920 by trimming the values of resistors R301 and R302. In the second prototype built by the authors, the measured frequency error at 40 MHz was -15 Hz (0.38 ppm) with the standard resistance value of 100 kΩ for R301 and R302. The authors were able to reduce the error to +5 Hz (0.125 ppm) by lowering the value of R302 (with R301 = 94.68 kΩ, R302 = 100 kΩ).

The CPLD is programmed via the JTAG port (JP301). Jumpers on the pin header labelled 'JTAG Disable' are used to select either programming mode or operating mode for the CPLD. If desired, after the CPLD has been programmed you can replace the pin header and jumpers by solder bridges.

JP25 in the digital portion of the circuit is an ICD programming and debugging port for the dsPIC microcontroller. Jumper JP230 can be used to manually reset the microcontroller if necessary.

PCB

All SMD components are fitted on the bottom of the double-sided, through-hole plated PCB (**Figure 4**). Only the four buttons and the display module are located on the top of the board. **Figures 5** and **6** show the fully assembled prototype developed in the Elektor lab, while **Figure 7** gives an impression of the authors' prototype.

In both cases the SMD components were placed and soldered by hand, which is not easy (especially with the PLL IC). However, the advantage of using manual assembly instead of reflow assembly is higher accuracy of the SMD reference oscillator frequency. This means that only electronics enthusiasts who are truly experienced in handling SMD devices should attempt this demanding project.

After the board has been assembled correctly, you need a Byteblaster or USB Blaster programming interface and the Quartus programming environment to program the CPLD. For the dsPIC, you need MPLAB from Microchip and an ICD programmer. Everything else (VHDL code, source code, hex files and programming instructions) are available in the software download package on the Elektor website [5].

Display

The readings are shown on the LCD module in a very straightforward manner. The first line displays the text 'Frequency / Level', the second line displays the frequency in MHz, and the third line displays the signal level in dBm. The display menu also supports calibration of the instrument and viewing status information, such as the battery voltage. The four buttons, whose functions are described in **Table 2**, are used for menu selection and parameter configuration.

The menu scheme is designed to always

Table 2. Menu functions of the pushbutton switches

S200	OK (confirmation) and switching on the instrument
S220	Back (return to previous menu level)
S222	Increase value or move up in menu
S221	Decrease value or move down in menu

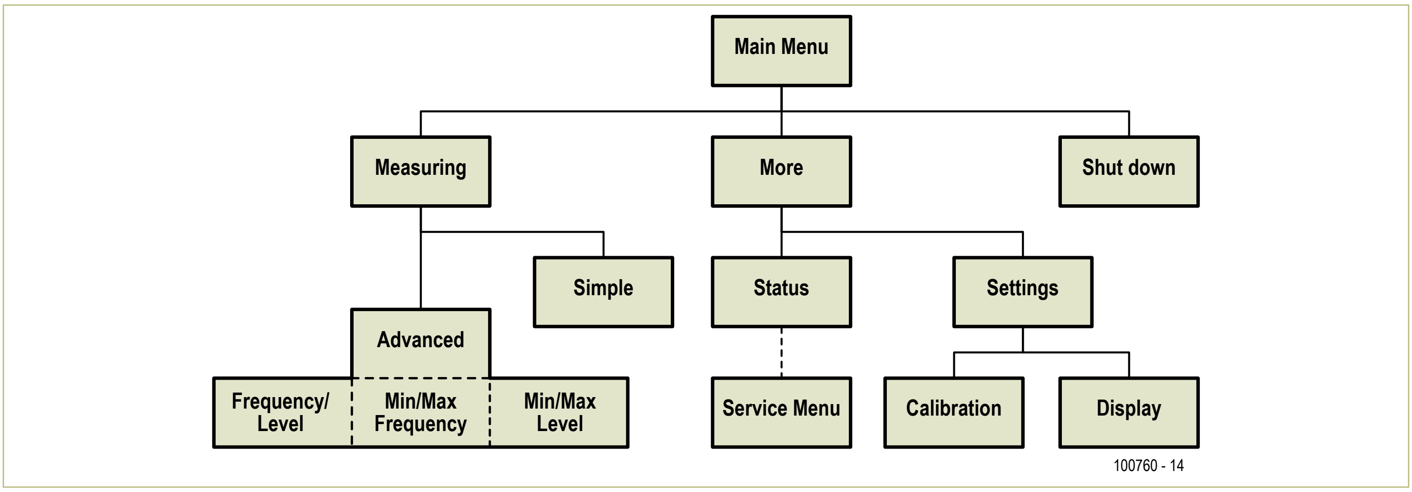


Figure 8. Menu structure of the microcontroller software.

show the name of the currently selected menu in the top line of the display The menu structure of the software is illustrated in **Figure 8**. Here it should be noted that in the 'Measuring / Advanced' menu, switches T3 and T4 can be used to select either 'Frequency / Level', 'Min/Max Frequen.' or 'Min/Max Level'. The 'Service' menu can be selected in the 'Status' menu by pressing buttons T3 and T4 at the same time. In the 'Service' menu you can display the raw signal level data (A/D value) and switch power to the HF portion on or off via IC210, thereby either enabling or disabling the frequency and signal level measurement functions.

Signal level calibration

The LT5538 used for signal level detection has a very large dynamic range, but it has the drawback that the output voltage is highly frequency dependent. Although signal level measurement can be calibrated very precisely within a narrow frequency band, it is rather inaccurate over the desired broad frequency range. Fortunately, the frequency dependence of the detector output can be corrected, at least partially, by taking advantage of the fact that the frequency of the measured signal is known. Using the measured frequency value, the microcontroller can convert the detected signal level to the correct value. For this purpose, the firmware provides a separate 'Calibration' menu. To perform the calibration, which is based on the least squares method, you need a frequency generator with an adjustable frequency range of 100 MHz to 3 GHz and an adjustable signal level range of –40 dBm to +10 dBm.

Use the following procedure to calibrate signal level measurement:
1. Select the 'Calibration' menu.
2. Enter the indicated frequency and signal level.
3. Confirm the entered values.
4. Enter the next set of indicated frequency and signal level values.
5. Repeat this for all of the indicated values
6. After a short computation time, the calibration process is completed and the data is stored permanently in the flash memory of the microcontroller.

Even with this calibration, the signal level readings are less accurate than the frequency readings. The largest measured error was 4.3 dB.

Development potential

In addition to many stimuli for developing your own devices in the domain of truly high frequencies (including PCB layout aspects), this project provides an introduction to CPLD programming. Thanks to the open source software (VHDL code and dsPIC source code in C), you can easily adapt the instrument to meet your specific needs or use it for other applications. The authors used MPLAB IDE v8.30 and the MPLAB C30 C compiler to develop the microcontroller firmware. They also used Quartus II v7.0 to develop and download the CPLD logic.

Expanding the functionality would require a CPLD with more macrocells. Additional pads for a CPLD with more memory are already present on the PCB. If such a device is fitted, 0-Ω resistors must be fitted in positions R304, R305, R306 and R307.

There is also room for improvement in the signal level measurement function, assuming you have access to good test equipment. With regard to the hardware, you could try to minimise reflections at the amplifier input by using an impedance matching network. Possible software modifications include the ability to select different calibration points or more calibration points, and you might want to try using higher-order polynomials for correction of the signal level reading.

(100760-I)

Internet Links

[1] http://cds.linear.com/docs/Datasheet/5538f.pdf (LT5538-1 data sheet)

[2] www.altera.com/literature/hb/max2/max2_mii5v1_01.pdf (MAX II CPLD data sheet)

[3] www.national.com/ds/LM/LMX2485.pdf (LMX2485 data sheet)

[4] www.avagotech.com/docs/AV02-1782EN (ABA-31563 data sheet)

[5] www.elektor.com/10076

About the authors

Martin Bachmann and Daniel Schär studied Electrical Engineering at the Zurich University of Applied Sciences Winterthur in Switzerland. They developed the instrument described in this article as part of a project carried out during their studies.

Altimeter for Micro-Rockets

Higher and higher!

By Anthony le Cren (France)

When dealing with micro-rockets or scale models, it's often difficult to find out the altitude. The main problem is really the weight of the on-board electronics system, which needs to be as light as possible. This altimeter using SMD components is as light as a letter (16 g) and has a data recorder that lets you record atmospheric pressure every 25 ms up to 16,384 stored values. Once the flight is over, the data are recovered via a serial connection to a computer and displayed in a spreadsheet. This then converts the pressure to altitude and plots the rocket's behaviour.

Technical specifications

- SMD throughout
- PIC16F88, programmed in Flowcode V4
- Uses Tiny PIC Bootloader [2]
- ADS1110 16-bit I^{2}C A/D converter
- 32 kB I^{2}C EEPROM memory for around 5 minutes recording time
- MPXH6115A6U pressure sensor
- Powered by a 12 V battery
- Weight: 16–20 g

The whole thing revolves around an MPXH6115A6U pressure sensor from Freescale. The sensor's analogue output voltage is converted into a 16-bit digital value by the ADS1110 sigma delta analogue-to-digital converter (ADC) from Texas Instruments. This 6-pin device has an I^{2}C bus, making it possible to considerably reduce the PCB space needed. A PIC16F88 microcontroller manages the acquisition of the digital pressure values and saves them into a 24LC256 I^{2}C EEPROM memory. The circuit is shown in **Figure 1**. The four LEDs are used to check the altimeter is working properly in the acquisition and computer data recovery phases.

Power is provided by a compact P23GA 12 V/50 mAh battery. The average consumption of the altimeter is 12 mA, giving it a battery life of around four hours. Since the duration of a flight is only a few minutes, that's no problem at all. In the event of an extended flight, two batteries could be used in parallel. The 78L05 regulator IC2 in an SOT89 package is vital, as it provides the regulation down to 5 V needed for powering all the ICs. Don't overlook the decoupling with capacitors C1 and C2 around the regulator. There isn't a switch — a jumper is all that is needed, once again, to save weight.

The MPXH6115A6U absolute pressure sensor (**Figure 2**) has a sensitivity of 45.9 mV/kPa. The curve in **Figure 3** shows

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The use of Elektor style schematics and other illustrations in this article does not imply the project having passed Elektor Labs for replication to verify claimed operation.

the mathematical relationship between the pressure and the sensor's output voltage. We can see that it is linear between 15 and 115 kPa.
The expression for the pressure (kilopascal, kPa) as a function of the voltage becomes:

$$P_{kPa} = \frac{V_{out} + V_s \times 0.095}{V_s \times 0.009}$$

The ADC (**Figure 4a**) already has everything we need built-in: clock, programmable amplifier, voltage reference, I²C interface. No external components are needed. There are just the I²C bus pull-up resistors R2 and R3, along with a decoupling capacitor. Here, the extension A0 in the device part number (ADS1110-A0) corresponds to the three LSBs of the I²C address, which in this case is 1001000. The default configuration is going to be used for the internal registers: Gain = 1, 15SPS (samples per second, **Table 1**) which offers a 15-bit conversion — given that the voltage being converted is always positive.
The formula to find out the input voltage as a function of the digital value N is:

$$V_{out} = \frac{N}{32768} \times V_s$$

From the two preceding formulas, we can derive the equation for the pressure as a function of the digital value:

$$P_{kPa} = \frac{N \times V_s + V_s \times 0.095 \times 32768}{V_s \times 0.009 \times 32768}$$

By measuring the supply voltage accurately, V_S = 4.93 V, the equation becomes, for a pressure expressed in decipascals (dPa):

$$P_{dPa} = \frac{N + 3113}{295} \times 100$$

This is the equation that is going to be used in the altimeter's microcontroller software. No calibration has been done, since what

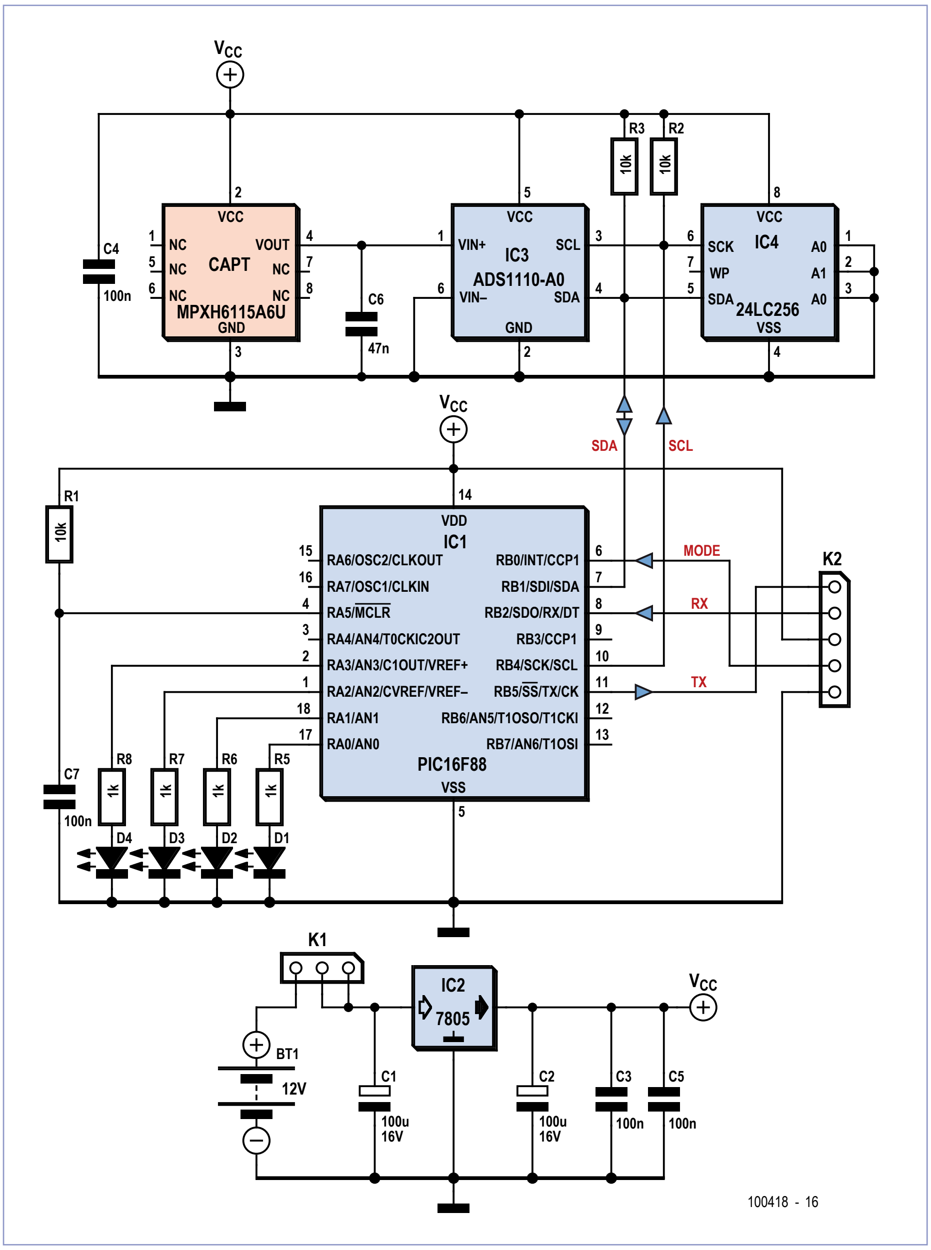


Figure 1. Circuit of the altimeter.

we're interested in is the change in pressure, not the absolute pressure. However, it is possible to modify the equation if you have access to a reference barometer.
The PIC16F88 microcontroller IC1 is clocked by its 8 MHz internal clock, so doesn't need an external crystal. It is mainly used to manage the I²C bus between the pressure value reader and the writing into the EEPROM IC4. You'll note the serial link on connectors K2 and K3, to let us recover the data stored in the memory, along with the configuration jumper (Mode).
When power is applied, a logic test is carried out on RB0 to find out the operating mode for the program:
– RB0 pulled up to 5 V: 'Run' mode, acquisition of the pressures and storage

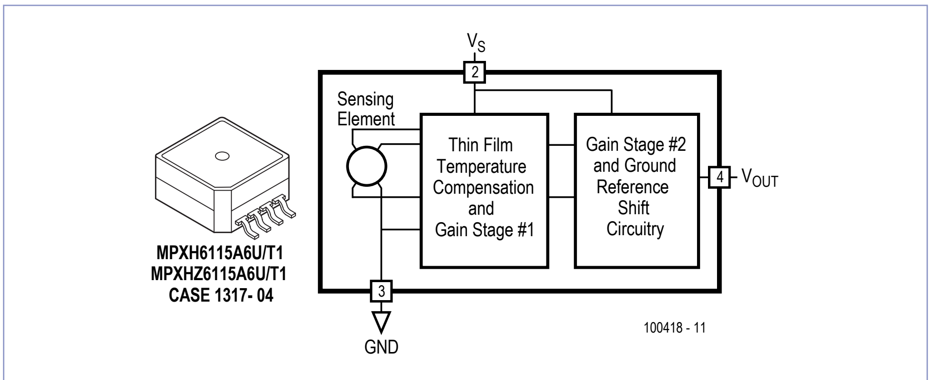


Figure 2. Block diagram of the pressure sensor and orientation.

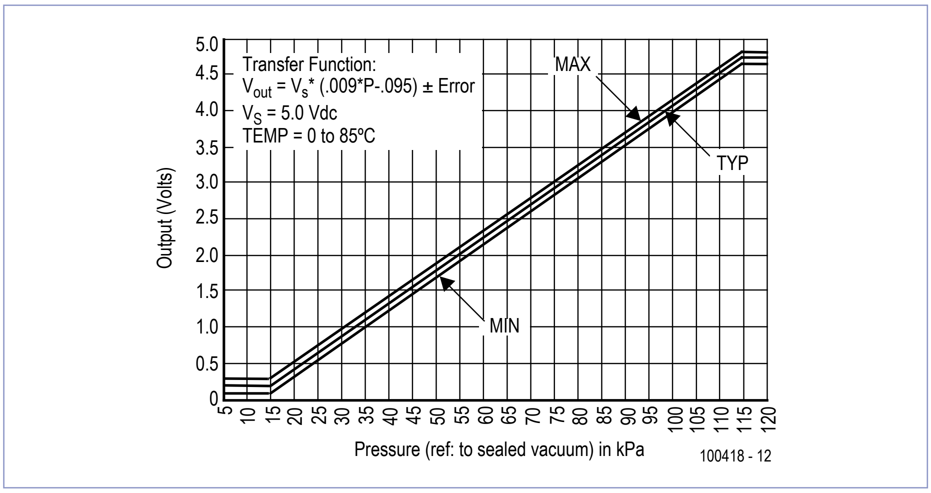


Figure 3. Relationship between sensor output voltage and atmospheric pressure.

into memory.

– RB0 pulled down to ground: 'Read' mode, for reading the recorded pressures and configuration (the computer and the altimeter dialogue via the RS-232 serial link).

To minimize the weight of the unit, the computer interface (consisting of an ICL232, IC5) that performs the RS-232 level adaptation for the computer is connected to the altimeter only when the data stored in the I²C memory is being recovered or for reprogramming the microcontroller (**Figure 5**). This board is powered from the altimeter battery.

Table 1. Configuration of the ADS1110 A/D converter.			
Samples/s (SPS)	**Number of bits**	**Minimum code**	**Maximum code**
15	16	-32 768	32 767
30	15	-16 384	16 383
60	14	-8 192	8 191
240	12	-2 048	2 047

Construction

Warning: You must program the PIC16F88 with its firmware **before** soldering it on to the board! (file 'firmware_altimetre.hex' available from this article's web page [1]). Use a DIL/SOIC adaptor for your programmer.

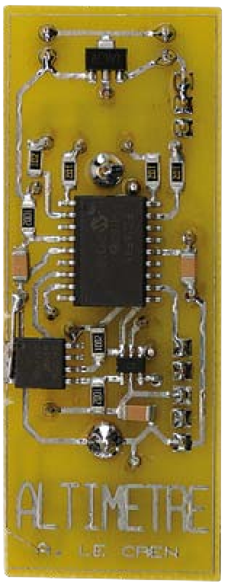
Use a soldering iron with a very fine tip. You have components to solder on both sides of the PCB. You should start by fitting all the components on the track side, starting with IC3 (the ADC), as it's the trickiest to solder. To avoid getting it the wrong way round, it's best to use a magnifying glass to identify the dot on the device that indicates pin 1 (**Figure 4b**). To minimize the need for troubleshooting later, it's a good idea check for the absence of continuity between each of the pins, and above all to check frequently that there is no short between 5 V and ground. Then come the other two ICs (make sure you get these the right way round too), the regulator, the 1 kΩ (marked 102) and 10 kΩ (marked 1002 or 103) SMD resistors, and to complete the first side, the SMD capacitors.

As for the other side (the component side), start by soldering in the microcontroller, the four LEDs, and the two capacitors. It's tricky to spot the orientation of the pressure sensor. If you look at it carefully, there is a chamfer at the bottom left that indicates pin 1 (**Figure 2**).

There now remain the two regulator decoupling capacitors and the pin header. There's no holder for the 12 V battery, all you have to do is solder like a standard resistor in the middle of the PCB. Fitting the components on the RS-232 board should present no problem. However, you should take care to solder the female connector onto the track side in order to facilitate the connection between the two boards.

Firmware

The program is produced using Flowcode V4. The hex file contains the Tiny PIC Bootloader [2] bootloader. This will be very handy for reprogramming the microcontroller after your own fashion.
To do this, run the 'tinybldWin.exe' application. Select the file 'Altimetre.hex', 19200 baud for the speed, and the COM port you're using.



Power up the RS232 interface board and click on WriteFlash. The program should immediately be written to the PIC (**Figure 6**).
After ignition and the rocket has blasted off, the altitude increases (if everything's going according to plan...) and the atmospheric pressure reduces. As soon as the software detects a large enough pressure change, it automatically launches the acquisition for a period that will be a multiple of 3.2 s.
You can set the pressure threshold that will trigger recording and the duration of acquisition using HyperTerminal (**Figure 7**). In configuration mode, LED D4 stays lit. Press the space bar to display the menu. Select the configuration menu, then enter three figures for the duration of acquisition (here 010, i.e. 10 × 3.2 = 32 s). Then set the trigger threshold between 1 and 9 dPa; the 5 shown in the figure corresponds to an elevation of around 4 m (1 dPa = 0.83 m).

Launch and making use of the data

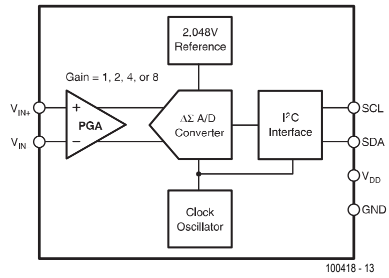


Figure 4a. Block diagram of the analogue-to-digital converter.

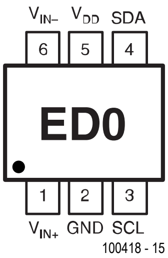


Figure 4b. Use a magnifying glass to identify pin 1.

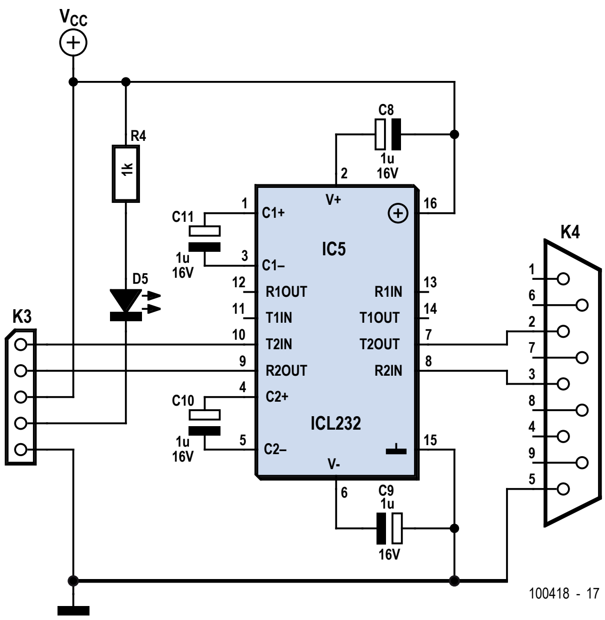
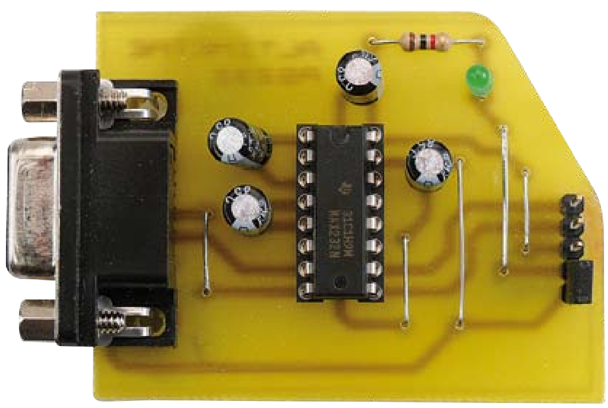


Figure 5. The RS-232 interface stays on the ground, so it has a PCB all to itself.



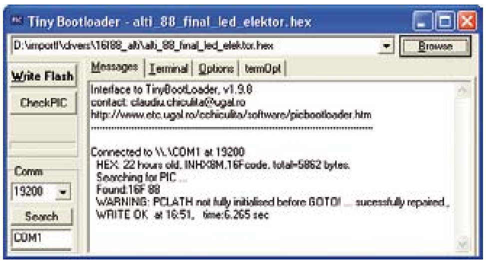


Figure 6. Reprogramming the microcontroller is easy thanks to Tiny PIC Bootloader.

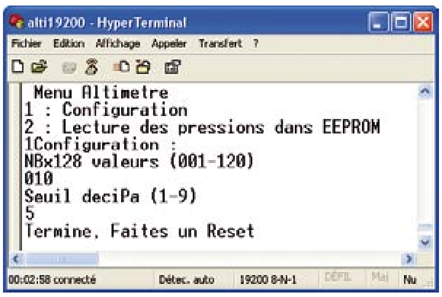


Figure 7. Configuring the altimeter with the help of HyperTerminal.

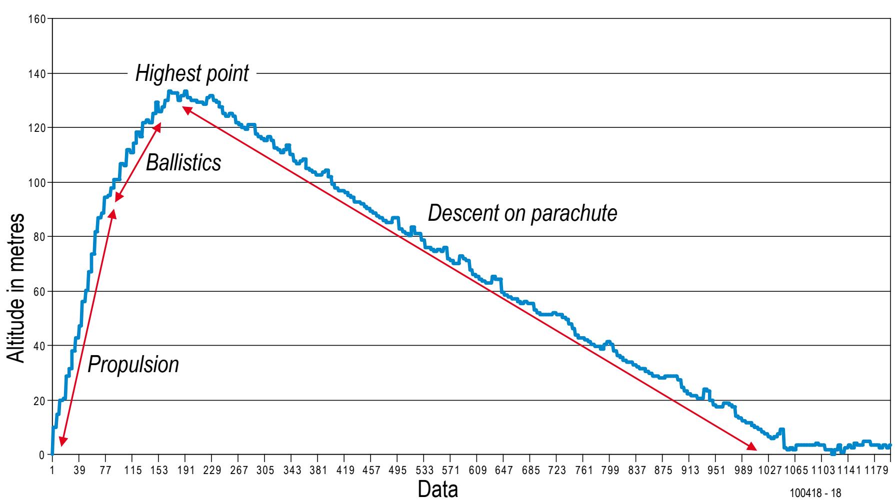


Figure 8. The pressure values recorded during the flight converted into altitudes. It's easy to make out the different phases of the flight.

For testing, it's perfectly possible to use this altimeter in a volley boll, on a kite, in a model aircraft, etc. The only difficulty will be adjusting the trigger threshold depending on the weather conditions. If the sensor is open to the air, the wind may very well trigger the acquisition without any elevation in the altitude. The trick is to protect the sensor like you would a microphone, with foam, or else to protect the whole thing inside a case — but that will increase the overall weight.

Once the altimeter has been configured and installed in/on your flying machine or object, apply the power using jumper K1. LED D1 will light for 3 s as the pressure at ground-level is measured, to be used as the reference for the spreadsheet plot. Then LED D2 will light to indicate that the altimeter is ready to start acquisition. Tapping lightly on the sensor will simulate an abrupt pressure variation, and you'll see that LEDs D1 and D2 both light for the duration of the acquisition phase.

To recover the data using HyperTerminal, go into the Transfer menu in order to capture the text displayed on the screen, before reading the pressures out of the EEPROM.

Using your favourite spreadsheet program, open a new spreadsheet, then paste into it the previously-recovered text data. All that now remains to be done is to calculate the altitude using the formula below and plot the graph (**Figure 8**). An example calculation can be found in the file 'trace.ods' [1].

$$Altitude = \frac{288.15}{0.0065} \times \left(1 - \left(\frac{P_{alt}}{P_{ref}}\right)^{0.19}\right)$$

where:

– P_{alt} = pressure at the altitude

– P_{ref} = reference pressure measured at ground level (first measurement)

– 288.15 = air temperature in Kelvin

(100418)

Internet Links

[1] www.elektor.com/100418

[2] www.etc.ugal.ro/cchiculita/software/picbootloader.htm

GPIB-to-USB Converter

Industry standard measurement bus gets a USB interface

by Rainer Schuster (Germany)

The 'General Purpose Instrumentation Bus' (also termed IEEE-488 and IEC-625) is probably the oldest bus system currently in use — and with more than 5,000 different GPIB devices available, it remains the foundation stone for controlling professional test & measurement equipment. PCs are not normally equipped with a GPIB interface, however, forcing users to buy a plug-in card or an expensive external USB-GPIB converter. Fortunately our DIY solution using a USB-equipped R8C/13 board is both straightforward and affordable.

It's barely credible that a bus system originally developed by HP in the 1960s under the designation HP-IB (Hewlett Packard interface bus) is today still a widely used industry standard. In the seventies the HP-IB was standardised as IEEE-488 (also known as IEC-625) and adopted by many manufacturers under the title GPIB. Its wide distribution, long-renowned reliability and ease of use have all meant that even now the GPIB is not threatened by any new bus standard. And since many users are unable or unwilling to abandon this interface, there is no shortage today of new T&M gear (such as oscilloscopes and signal generators) that are equipped not just with USB and Ethernet interfaces but also with GPIB, mainly to IEEE488.2 (IEC-60488-2) standards.
Its 8-bit parallel interface means that GPIB resembles the obsolescent Centronics printer interface, although up to 30 devices can be addressed with up to 15 device connected simultaneously to the bus cable, either in cascade (daisy-chained) or radially (or a combination of both). There's no need to go into more detail now, as we'll come to this later in the article. As usual there is a Wikipedia page [1] providing a good introduction as well as links to further information sources.

Because PCs do not by and large offer a GPIB interface, it's necessary to provide your own plug-in card or an external GPIB-to-USB converter, the price of which can in extreme cases exceed the value of the test gear that requires it. It's not all bad news, however, as this article shows. All the hardware you need for a GPIB-to-USB converter is a microcontroller with a USB interface equipped with at least two bidirectional I/O ports and a 24-pin Centronics connector...

R8C recycling

It does not take long to find a microcontroller with a USB interface equipped with at least two bidirectional I/O ports; one was already described in Elektor February 2009. For this transistor characteristics tracer project the author developed a small R8C board with a USB interface, which you can find as a built and tested PCB in the Elektor Shop under the order code 080068-91. This handy controller board (80 x 35 mm) is programmable via the USB interface. The schematic in Figure 1 shows it built around an R8C/13 microcontroller hooked up to a PL2303 USB-to-serial converter. The component list and the PCB layout can be found in the article describing the transistor characteristics tracer, which you can read gratis on the Elektor web page [2] for this project.
The connections of the R8C/13 correspond to the legendary "Tom Thumb" R8C/13 board [3], retailed by Elektor at extremely low cost in 2006 and the software CD that is also available from the Elektor Shop.
The current combination of PL2302 USB controller and microcontroller is recycled from the January 2006 issue of Elektor, in which the author described the application board [4] for the R8C/13.
Power for the project is taken through its USB connection. Various port pins, +V and ground are provided on a 20-pin connection strip (K1), allowing this PCB to be used also for other purposes if desired. The pinout roster is given in Table 1.
Pushbutton S1 lets you reset the microcontroller at any time. Eighteen 470 Ω resistors limit the output current of the port pins to around 10 mA and prevent the entire controller board being destroyed under fault conditions.
Setting jumper JP1 enables programs to be loaded into the micro-

Characteristics

- Low-cost GPIB-TO-USB converter
- Simple hardware (R8C/13 USB board with Centronics connector)
- Assembled and tested R8C/13 USB board available
- Free firmware with source code
- Free flash program
- Free development environment
- Free PC sample program with source code

controller through the USB port (for examples using the Flash Development Toolkit from Renesas, which can be found on the R8C software CD [5]. The R8C software package for this CD can also be downloaded from location [6].

As regards creating R8C software, downloading hex files into the controller and installing the USB driver for the PC there is plenty of information in the Elektor articles discussed above and on the R8C page of the Elektor website [8].

As already mentioned, the hardware for the GPIB-to-USB–converter consists purely of the combination shown in Figure 2 of a 24-pin Centronics connector and the R8C/13 USB board (080068-91). The cable connections are shown in Table 2. Everything else is handled by the firmware in the R8C/13.

Firmware

The firmware for the microcontroller was written in C for the Renesas High Performance Workshop (version 4.08) and is available as free download on the Elektor web page for this project [7]. Detailed information on programming the R8C/13 is at Elektor's R8C Digest web pages [8].

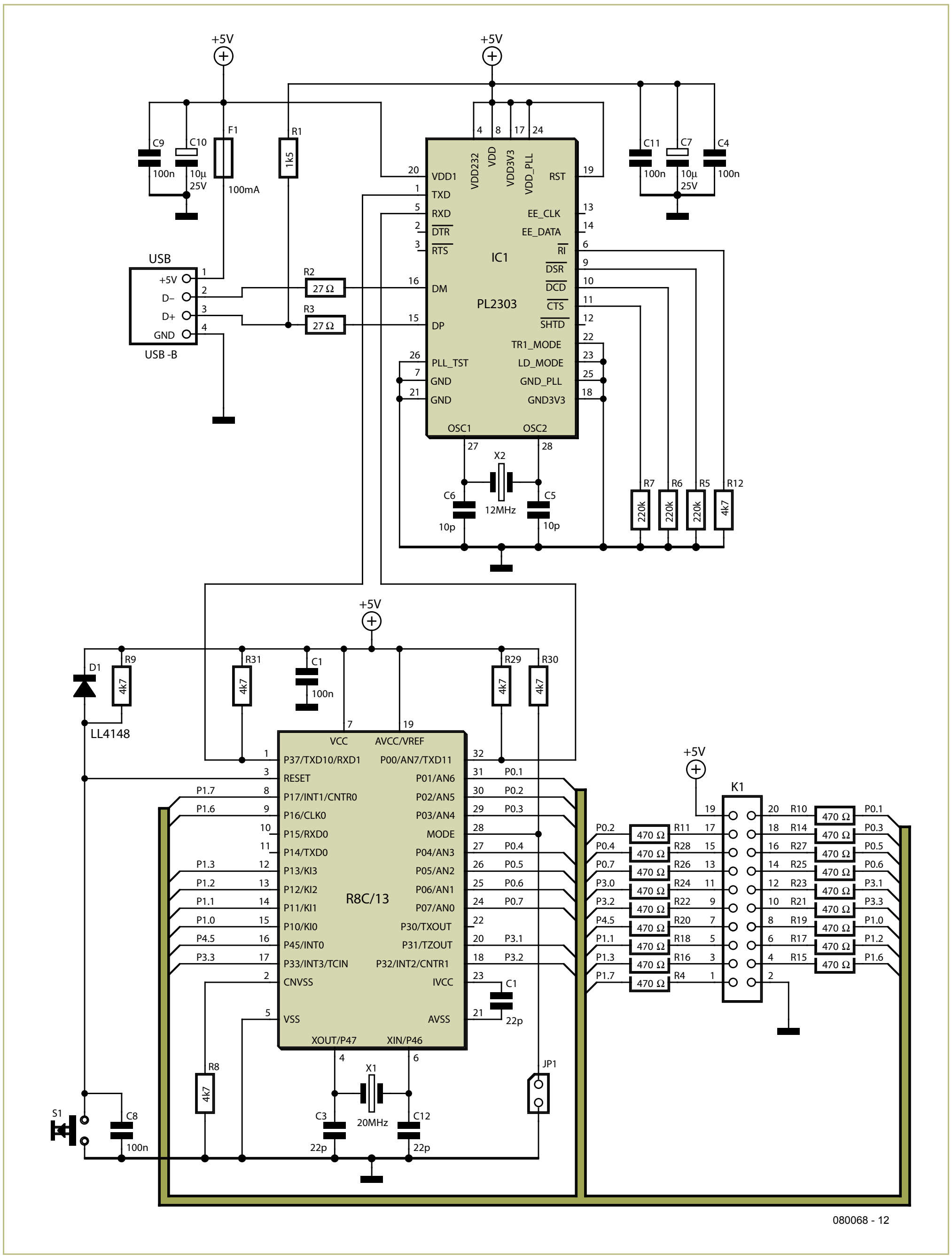


Figure 1. The circuit of the controller board with R8C/13 and USB-to-serial converter PL2303.

Communication between the USB interface and GPIB device is initialised using the serial interface UART1 of the R8C/13 (the settings are 38400 baud, 8 data bits, 1 stop bit and no parity). Next we activate the GPIB bus wire REN (remote enable) and after this the IFC (interface clear) wire for 10 ms, to reset any devices that may be connected. Simultaneously this resets the R8C/13 into its 'controller in charge' (CIC) state.

Elektor Products & Services

- Controller board (R8C/13 USB board, assembled and tested): # 080068-91
- PCB layout (PDF download) and component list for the controller board, available free at www.elektor.com/080068
- Firmware, source code and PC software: free download # 100756-11.zip
- Hyperlinks in article
- All items accessible through www.elektor.com/100756

Table 1: Pin assignments for K1

Pin	Meaning	Pin	Meaning
1	P1.7	11	P3.0
2	GND	12	P3.1
3	P1.3	13	P0.7
4	P1.6	14	P0.6
5	P1.1	15	P0.4
6	P1.2	16	P0.5
7	P4.5	17	P0.2
8	P1.0	18	P0.3
9	P3.2	19	+5V
10	P3.3	20	P0.1

Following this nothing happens initially, because by definition all connected GPIB devices can speak only when they have been instructed to in advance by the controller. In order to relay commands and data to the GPIB devices connected the program now waits for incoming commands from the serial interface to then carry them out. To this end a small protocol is implemented:

<command>[<device address><,>] [GPIB string] <CR><LF>

This example shows how it works. R1,*IDN? <CR><LF> represents the command 'Read'. This sends the string '*IDN?' to the GPIB device with the address 1 and waits for an answer. The reply string of the device is sent back to the PC via the USB interface.
Table 3 sets out the commands implemented, which are the so-called 'universal' commands to which all connected devices react. Next come the so-called 'addressed' commands, which are valid only for devices that have already been addressed (see Table 4).

In order to address a device (as listener) we must first send the command (before any others) 'Listen (0x20)' along with the ('ORed') device address. After the actual command 'Unlisten' must be sent. All the commands mentioned are so-to-speak 'low-level' commands. As a rule the only commands needed for communication with devices are R = Read, W = Write and if applicable S for polling the Service Request wire.

Any errors in the data transmission will cause the R8C/13 to send 'Error X' to the PC.
X=1 indicates that the addressed device is unavailable. X=2 flags a timeout problem in sending or receiving data

Table 2: Connections for the Centronics connector at K1 of the R8C/13 USB board

Signal name	Port pin	K1 assignment	24-pin Centronics connector assignment
DIO1	P0.1	20	1
DIO2	P0.2	17	2
DIO3	P0.3	18	3
DIO4	P0.4	15	4
EOI	P3.0	11	5
DAV	P1.3	3	6
NRFD	P1.6	4	7
NDAC	P1.7	1	8
IFC	P1.0	8	9
SRQ	P4.5	7	10
ATN	P1.2	6	11
Shield	-	2	12
DIO5	P0.5	16	13
DIO6	P0.6	14	14
DIO7	P0.7	13	15
DIO8	P3.1	12	16
REN	P1.1	5	17
GND	-	2	18-24

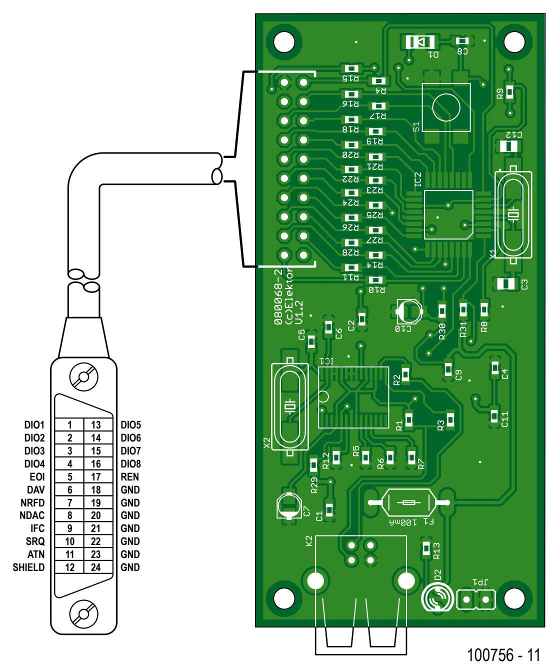


Figure 2. The hardware of the GPIB-to-USB converter combines a 24-pin Centronics connector with the R8C/13 USB board.

Programming

The High Performance Embedded Workshop from Renesas produces a Motorola hex file (GPIB_USB.mot) that can be loaded via the USB interface with the 'Flash Development Toolkit 3.4 Basic' available from [5] or [6]. For this the jumper JP1 on the controller board must be set and the reset button pressed briefly. After programming don't forget to remove the jumper and press the reset button once more. After this our GPIB-to-USB converter is ready to put to real work.

The converter in action

A practical application for the converter can be seen in this program written in VB6 for transferring traces from a Tektronix TDS210 oscilloscope to a PC. If you know the commands for your own 'scope it's simple to adapt the program, which you can download from location [7].

First install the program on your PC by running 'Setup.Exe'. After installation start the program by clicking on GPIP_USB.exe.

The program then opens all available COM ports sequentially and sends the identification polling string of the GPIB-to-USB converter (I<CR><LF>) until the matching port is found and the reply string is received. Directly after this the identification string of the oscilloscope is polled by sending the command 'R1,*IDN?<CR><LF>'. The

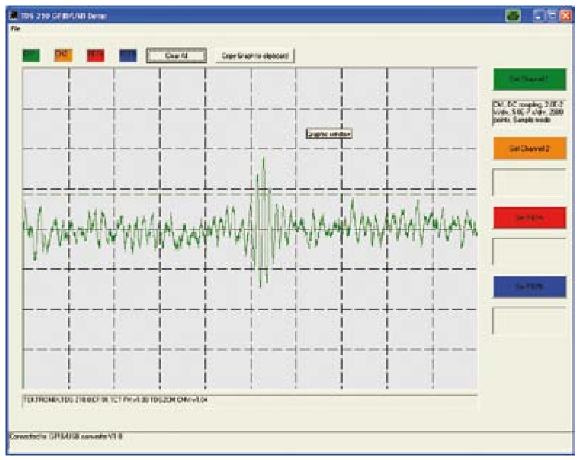


Figure 3. Sample oscilloscope trace delivered via the GPIB-to-USB converter from the 'scope to the PC.

Table 3: GPIB universal commands available		
Command	**Parameter**	**Meaning**
C	-	Send IFC and reset all connected devices
G	GPIB command	Activates the ATN wire and sends the received command as Parameter over the GPIB Bus
I	-	Interrogates the identification string of the USB converters Reply: GPIB-TO-USB converter V1.0
R	Device address, String to the device addressed	The string given in the parameter is passed on to the device addressed and the reply string from the device is passed back
S	-	Interrogates the SRQ (Service Request) wire Reply 0: No devices require a service request 1: A service request is required
T	Timeout period in us	Alters the timeout period while sending and receiving date on the GPIB Bus. Default = 200,000[us] = 200ms
W	Device address, String	The string received in the parameter is sent forward to the device addressed in the parameter (no reply expected)
LLO	0x11	Local Lockout: Local control of all connected devices is disabled
DCL	0x14	Device Clear: reset all devices on the GPIB Bus
PPU	0x15	Parallel Poll Unconfigure: block the parallel poll function
SPE	0x18	Serial Poll Enable: following a service request trigger serial polling of the devices
SPD	0x19	Serial Poll Disable: block the serial polling function
UNL	0x3F	Unlisten: Release all devices from listening
UNT	0x5F	Untalk: Instruct the device speaking to cease

Table 4: Addressed GPIB commands		
Command	**Value in Hex**	**Meaning**
GTL	0x01	Goto Local: switch the devices addressed to local operation
SDC	0x04	Selected Device Clear: reset the devices addressed previously
PPC	0x05	Parallel Poll Configure: carry out parallel polling for the devices addressed previously
GET	0x08	Group Execute Trigger: carry out a defined event simultaneously on the devices addressed previously
TCT	0x09	Take Control: hand over control to another device

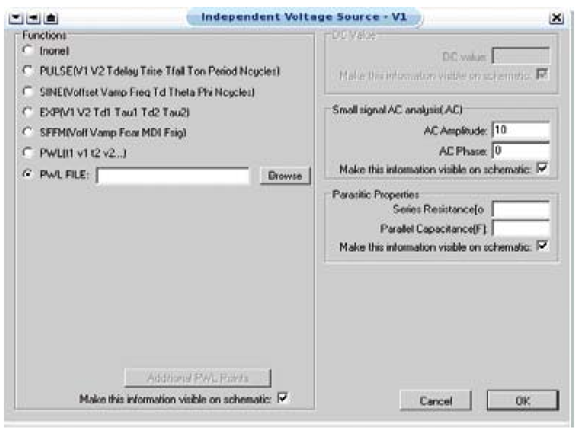


Figure 4. Using the LTspice simulation program we can import signals measured with an oscilloscope as .pwl files.

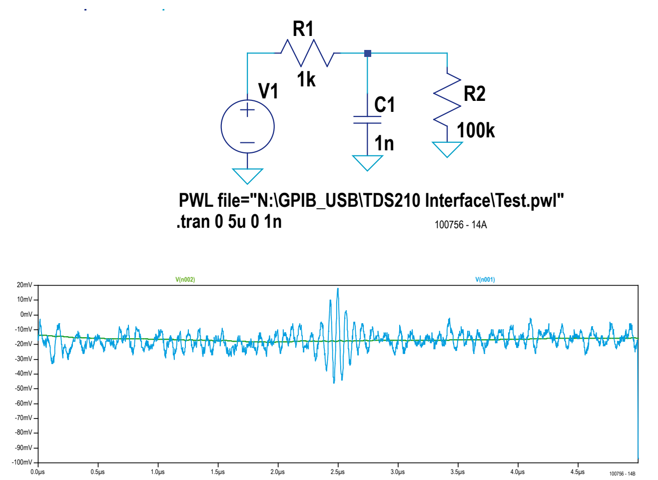


Figure 5. In this example an actual signal measurement is used in an LTspice simulation.

device address is set by the global constant ‘ADDR’ to 1. For other device addresses this value must be changed of course. If the reply string of the oscilloscope is received, the program is ready to transfer waveforms and display these on the PC screen. Figure 3 shows a sample transfer from channel 1 of the ‘scope.

Waveforms 2 Ref A and Ref B from channel 1 are available for transfer. The dashed line represents the Y-offset. Functions Y-offset, Y-DIV and X-Div are all extracted from the curve data. In turn they are transposed into ASCII format from –128 to +127, the visible array ranging from –100 to +100. The ‘Clear All’ control allows all waveforms to be erased, whilst ‘Copy to Clipboard’ sends the curve data to the clipboard for further processing, e.g. for copying into Word.

Menu options ‘File → Export csv’ and ‘Export pwl’ export the curve data into Excel or store it as a ‘.pwl’ file. The ‘.pwl’ stands for ‘Piece-wise Linear Function’ and a file of this kind contains curve data that can be incorporated in the simulation program LTspice. You can read a report [9] in Elektor for September 2010 that provides an insight into what you can achieve with this simulation program.

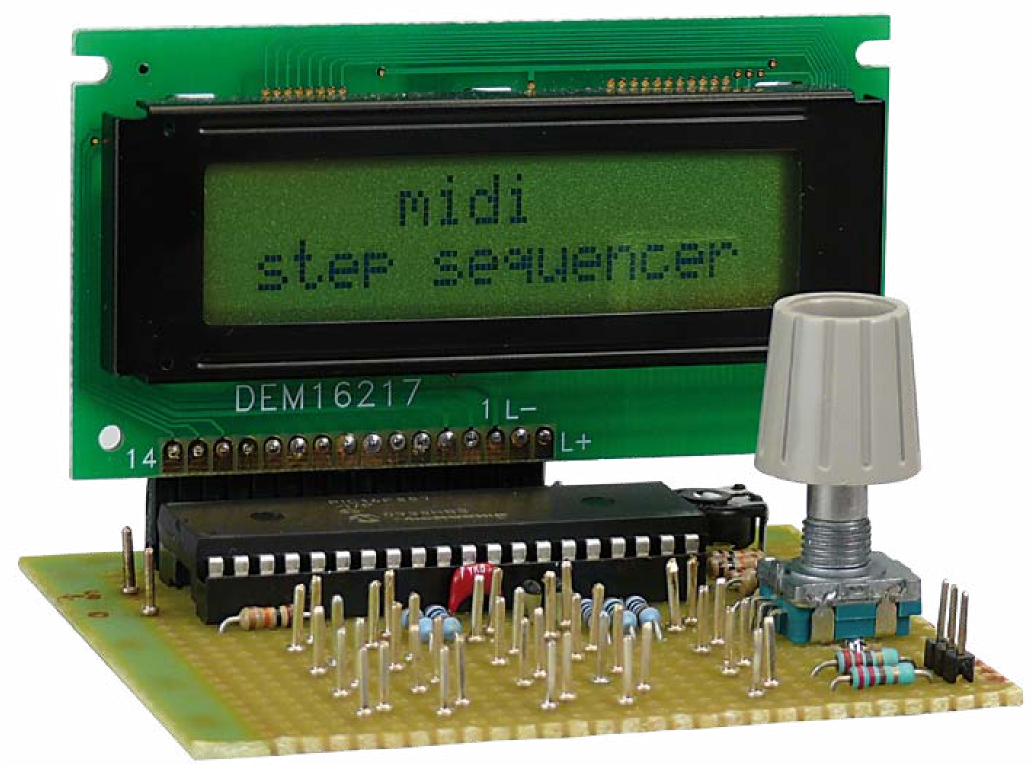
One of the features of this program is the ability to select not only signal sources with predefined curve shapes (sine wave, square wave, triangular, etc.) but also to import external signal flows in the form of a .pwl file (see Figure 4). The example in Figure 5 shows a noisy signal, transferred from the oscilloscope in Figure 3 to the PC, integrated as a .pwl file into the simulation program and taken through a simple low-pass (R-C combination). The result of simulated filtering of the signal taken from the real world can be seen at the bottom of Figure 5: the blue curve represents the input signal (from the .pwl file) whilst the green curve is the signal after smoothing by the low-pass filter.

(100756)

Internet Links

[1] http://en.wikipedia.org/wiki/IEEE-488
[2] www.elektor.com/080068
[3] www.elektor.com/r8cstart
[4] www.elektor.com/050179-3
[5] www.elektor.com/050179-2
[6] www.blafusel.de/files/r8c
[7] www.elektor.com/100756
[8] www.elektor.com/r8c
[9] www.elektor.com/081006

MIDI Step Sequencer
Low budget back beat generator



By Pim van het Hof
(The Netherlands)

Some projects just ask for small, simple solutions. This MIDI Step sequencer falls into this category. When you're playing a piece of music and you need a simple 'backbeat' this circuit will come to the rescue.

Specifications:

- - Maximum of 16 steps
- - 3 memory banks
- - CC1 and CC2 can be set for each note
- - Very easy to use

The MIDI Step sequencer drives a synthesizer or a (music) program on the PC via MIDI. A maximum of 16 notes can have their MIDI properties configured via 20 keys; 16 of them for the notes and four for loading, saving, mode-selection and start/stop. With this device it becomes child's play to create background rhythms or repeating melodies, for example.

The Step sequencer uses only a very small number of components. In the circuit we find a PIC microcontroller, a number of resistors and capacitors, a 2x16 character LCD, a crystal and 20 keys. The majority of the work is carried out by the microcontroller. The sequencer can produce a maximum of 16 steps. For each of those steps the sequencer sends the associated MIDI information to the connected synthesizer or PC. The pitch, velocity (or volume) and the values for CC1 and CC2 can be set for each step. The note, CC1 and CC2 values can be turned on or off. The reason for turning off the note value is to make it possible to create certain rhythms. The CC values are only entered when they are required. The length of all notes and the pitch of the base-note can also be varied. With the latter all notes are transposed by the same value. The number of steps can be set up to a maximum of 16. The MIDI channel and program number (instrument) can also be individually configured.

Keys galore

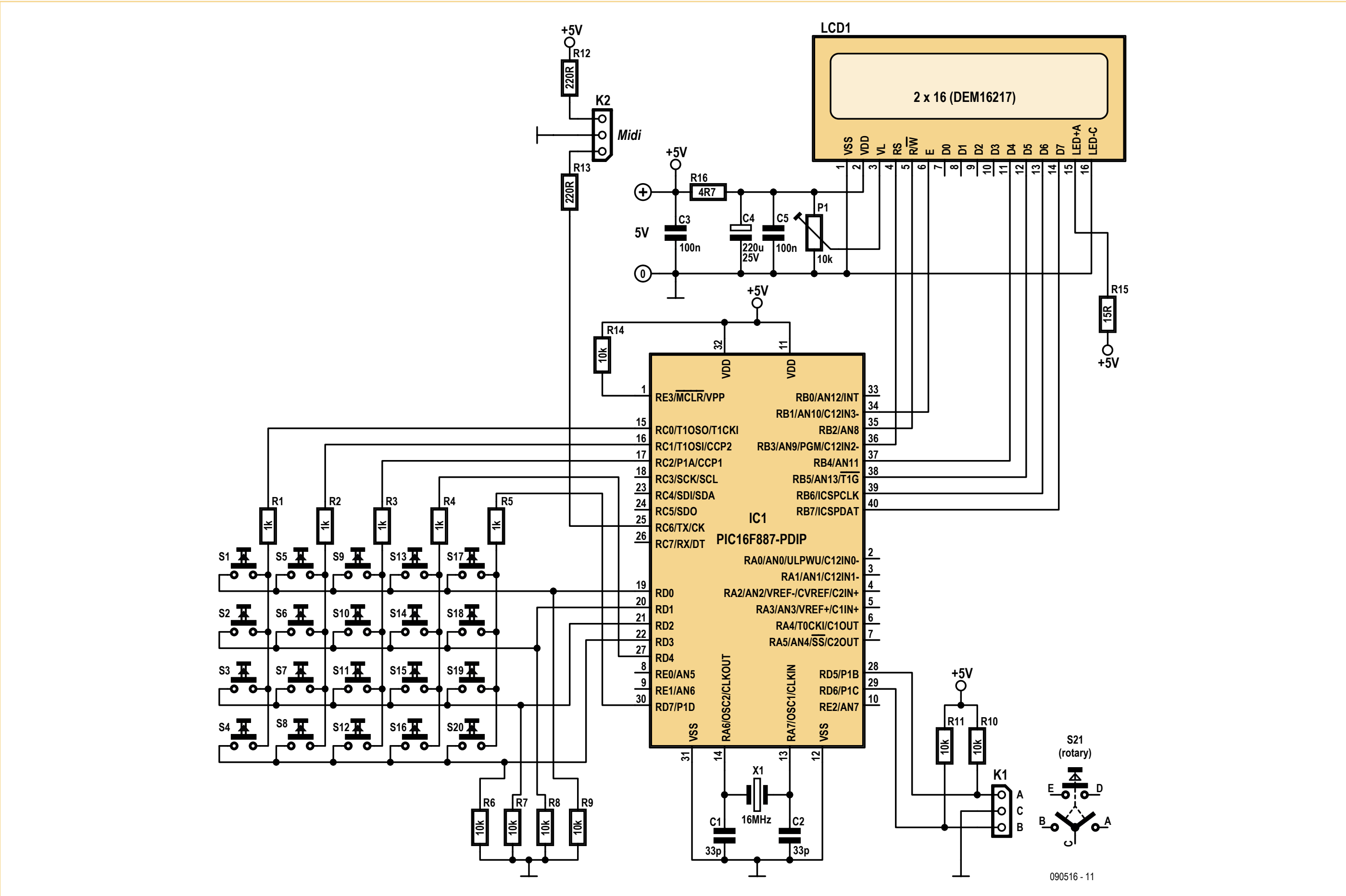
The 20 keys on the sequencer have the following functions:

- Keys 1 to 16 → 'normal' keys
- Key 17 → load
- Key 18 → save
- Key 19 → mode-select
- Key 20 → start / stop

The modes that can be selected with key 19 are (in order):

- Note (default)
- Velocity
- Skip
- CC1
- CC2
- Control 1 = Speed (default 100)
  2 = Length
  3 = Base-note
  4 = Steps
  5 = MIDI channel
  6 = Program no.
  7 = CC1 no.
  8 = CC2 no.

The function of keys 1 to 16 depends on the mode selected. In the note and velocity modes the key selects the relevant step. The rotary encoder is then used to set the value for that key. In skip mode pressing the relevant key will toggle a step on or off. In CC1 or CC2 mode pressing a key will toggle the CC mode on or off. When it's on, the focus goes to the rotary controller,



The circuit diagram is dominated by the microcontroller and the large number of keys.

which is then used to set the CC value.
In control mode the keys have a very different function. Key 1 then controls the speed: with the help of the rotary encoder you can set up the tempo. Key 2 is for setting up the note-length. With this the length of all the notes can be configured, again using the rotary encoder. If, due to the tempo, the length cannot be achieved, the notes will stop prematurely. The base-note is set using Key 3. All other notes are then tuned relative to this one and increased by this value if required. Key 4 selects the number of steps that the sequencer carries out and Key 5 is used to set the number for the MIDI channel.

Then there is Key 6, which selects the program number or instrument (dependent on the equipment that is connected). Keys 7 and 8 are used to configure the CC1 and CC2 controllers respectively.

Space has been reserved in the microcontroller for three 'songs'. Of course they need to be programmed first using the keys and the instructions shown above. After a press of the 'save' key the microcontroller asks in which memory bank you want to store the song. This number can be selected using the rotary encoder. Another press of the 'save' key will then store the sequence in the memory bank you selected. Loading a sequence is done in a similar way, but of course you must then use the 'load' key.

Construction

We constructed the prototype using a piece of experimenter's board. For the display we used a type that is sold by us (Elektor Shop # 030451-72), but any HD44780 compatible display should be suitable. Potmeter P1 is used to set the contrast level. During the testing phase we used pinheaders instead of keys, where we put a screwdriver across two pins to simulate a key-press. For day-to-day use this isn't very practical, so we would suggest that these are replaced with real keys. The quartz crystal was mounted under the microcontroller. This isn't vital, but it made the construction easier.

The MIDI output has been connected directly to the microcontroller via a 220 Ω resister, rather than via an optocoupler that is normally used. We never experienced any problems when the sequencer was connected to pin 15 of the (old) joystick socket on a PC in this way. However, if you want to do things properly you should add an optocoupler to the output. A good source of information about MIDI can be found at www.midi.org [1].

The hex-file for the microcontroller can be downloaded via the web page for this project [2]. As part of the download you'll also get the Basic code for the firmware, which was made using the PIC Simulator IDE from Oshonsoft.

(090516)

Internet Links

[1] www.midi.org/

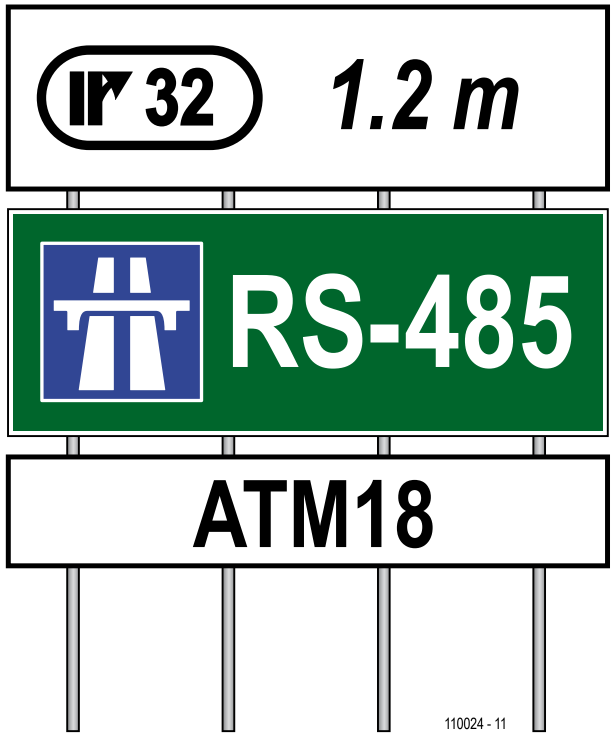
[2] www.elektor.com/090516

ATM18 Catches the RS-485 Bus

Next stop for driving relays...

By Grégory Ester (France)

If you're looking to establish communications between two electronic boards via a wired link over a distance of over 1 km, with no intermediate active elements, then there's really only one solution: an RS-422 link. And if you want to link three boards, then the point-to-point link becomes a multi-point link, and you'll need an RS-485 bus.



In fact, we're going take things a bit further still, since here we're setting up a communicating system involving four modules. Three ATM18 boards are going to have to get along with the latest newcomer: MuIn LCD, a display that's directly compatible with the RS-485 standard.

Physically, the data will be travelling over just two wires, and consequently the transmission mode will be semi-duplex: everybody can express themselves, but everyone has to take their turn. The EIA (Electronic Industries Association) and TIA (Telecommunications Industry Association) standard imposes on us how to physically link the communicating elements, but there's no imposed standard concerning the communication protocol. So the data, the characters are going to be carried over a twisted pair. As for the language to enable everyone to understand each other — we're going to have to invent that. My appetite whetted by Elektor's E-Labs Inside pages, I couldn't resist 'sticking my nose in'...

The players in the project

To make it easier to identify 'who's who' throughout this article, we've adopted the following convention: the two ATM18s fitted with a two-wire LCD display will be called ATM01 and ATM02, while the third, connected to the 'eight-relay module', will be called ATM05. See also **Figure 4**.

So ATM05 is connected to the 8-relay board, with the expansion port [1] to enable us to economize our ATM18's port lines, so we can drive the relays elegantly using just two wires in addition to the power rails. This project was the subject of an article in the 'ATM18 Relay Board and Port Expander' article in the October 2008 edition, and the hardware is available from Elektor with part numbers 071035-72 and 071035-95.

The MuIn LCD [2] is a module consisting of a standard LCD display with its built-in HD44780 chipset, coupled to a driver board that's directly compatible with our RS-485 bus. There's a whole section about this a bit further on.

ATM01 will be able to control relays 1 and 2 on the Elektor relay board, while ATM02 will drive relays 3 and 4. It's also worth noting that it is possible, without modifying the firmware, to rename the ATM01 and ATM02

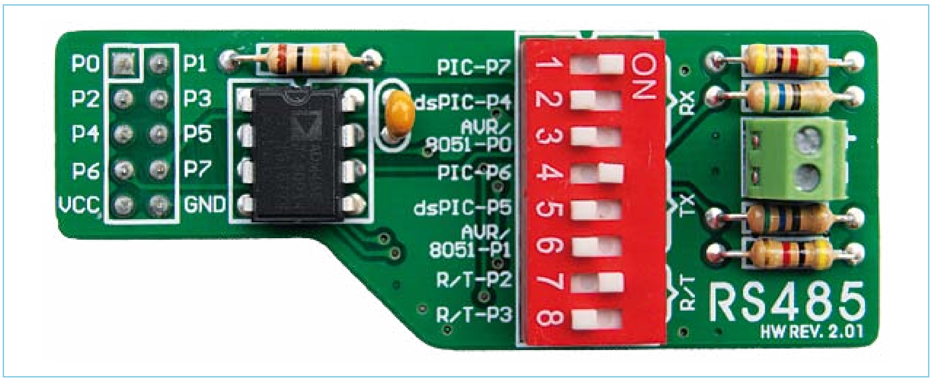


Figure 1. Adapting the signal to the line.

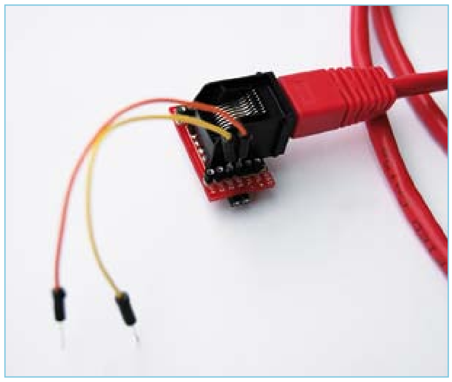


Figure 2. Breakout board: escaping pairs.

boards as ATM03 and ATM04, so they would be able to drive relays 5 and 6 or 7 and 8 respectively. MuIn will take care of giving a visual indication of every event that takes place.

So all these protagonists are going to have to get along with each other on the same EIA RS-485 bus.

Understanding the bus

The ATM0x boards don't communicate directly between themselves, as they don't have RS-485-compatible ports. A communication module [3] makes it possible to send data over the RS-485, by adapting the asymmetric serial signal (TTL) into a symmetrical differential signal to the RS-485 standard. This conversion is mainly taken care of here by the Analog Devices ADM485 line driver. **Figure 1** shows us the positions for the DIP switches so we'll have, on the serial port side, the three data lines Rx, Tx and R/T available on HE10 connector pins 8, 7 and 3 respectively. Outputs A and B available on the screw terminal block deliver the differential signal suitable for the link.

The ATM0x boards are capable of transmitting and receiving at the same time, but on the bus transmissions cannot take place at the same time — this is the very principle of the semi-duplex link.

Physically, the bus consists of a pair of conductors twisted together, keeping unwanted effects like radiation and cross-talk into other cables to a minimum. We're using the pair 1-2 of a Category 5e SF/UTP network cable (data rate up to 1 Gbit/s, 200 times greater than the maximum possible using the ADM485 device). So there are three pairs left over for sending other information — we're not going to be using these in this project. SF stands for *shielded, foiled*: the pairs are covered with foil and the bundle of four pairs is screened. This precludes interference from nearby sources to a high extent.

Access to the two conductors of our pair is made easier by an adaptor board [4] that will take your PCB-mounting RJ45 connector. In **Figure 2**, the two orange and yellow wires correspond respectively to the markings A (+) and B (−), the differential transmission lines over which the signals, perfectly complementary in terms of their waveform, are conveyed.

The potential difference between point A and point B is positive or negative, giving us either a 1 or a 0. The differential voltage balanced in this way limits the harmful influence of surrounding sources of interference. You can see the waveform of these signals in **Figure 3**. This was recorded without any trickery using the Scanalogic-2-Pro logic analyser [5], a powerful tool whose capabilities are inversely proportional to the price tag!

R/T must be kept high so that the data can be sent on Tx in the TTL RS-232 format. To receive the characters on your microcontroller's UART, R/T must be set to logic 0.

The block diagram in **Figure 4** shows the pins used for easy wiring. Up to 32 units can be connected to the bus without a repeater. The terminating resistors make it possible to attenuate signal reflections as much as possible — it would be rather tiresome if the signal came back "under the feet" of the ADM485 before you had finished sending all the bits.

A MUlti-purpose INterface: MuIn LCD

More than just a simple LCD, this interface does of course let you display text on the screen, but the display can also be driven via the USB port on a PC, via a wireless remote thanks to some XBee modules, and

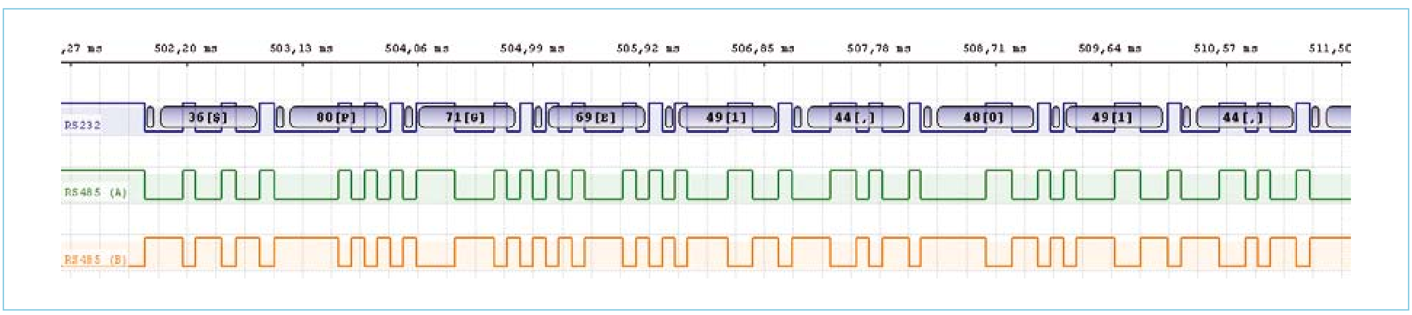


Figure 3. With the Scanalogic logic analyser, signals will never again be able to travel incognito.

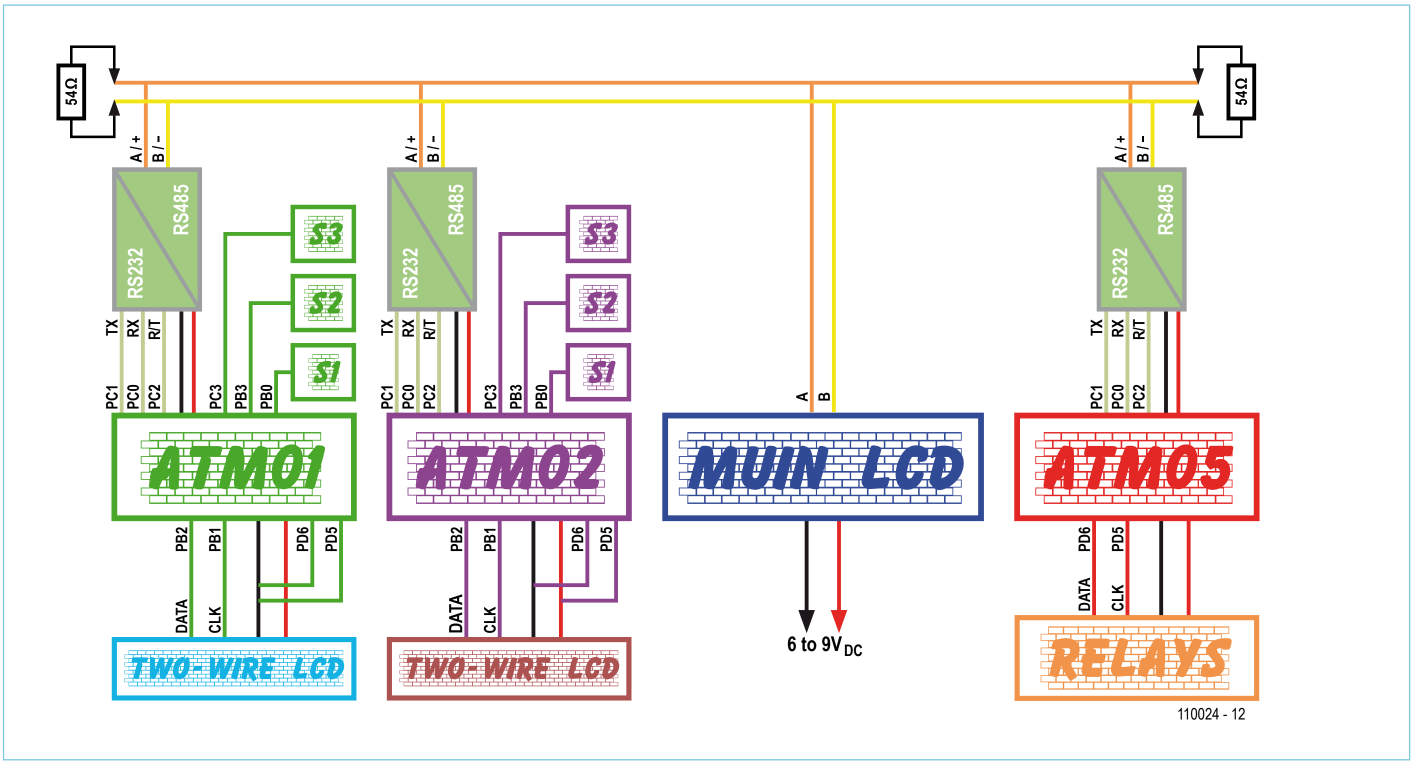


Figure 4. Block diagram for rapid wiring of all the boards.

of course via its native RS-485 link.
A set of commands interpreted by a PIC18LF2550 lets you control the cursor position, display bargraphs, adjust the brightness of the backlight, or generate tones. The board even includes six TTL- and CMOS-compatible input/outputs and five 10-bit analogue to digital conversion inputs. If you already have a compatible display, you can opt for just the driver board [6].
Before incorporating this beast into our system, I couldn't resist having a bit of a play around with this excellent bit of hardware from Droids. All the files available for this product can be downloaded from the manufacturer's website [7] — i.e. the latest firmware, complete with its little executable that lets you update the firmware in the PIC embedded on the board thanks to the built-in bootloader (and hence without needing to use a programmer), the graphical interface (GUI) that lets you test all the functions of the MuIn LCD, and of course the driver for controlling the virtual serial port. Once the driver has been installed, all you have to do to update MuIn is follow the copiously-illustrated procedure on the aforementioned website.

You can then remove all the pretty, almost fluorescent yellow jumpers, leaving just the two visible in **Figure 5**. At this point, you should be ready to connect up the USB cable so as to self-power the whole thing, then to run the fine GUI interface, offer you the result of a few tests, and insert a screen shot of the whole thing... Well, no. Instead, we're going to unplug everything and fit the jumpers so we can send commands over the RS-485 interface using an FTDI USB/RS-485 cable [8] and the Hercules terminal [9]. To do this, shift the "USB" jumper one pin to the left — this then means you'll have to power the board using an external voltage supply of 6–9 V DC. Shift the jumper that was in the "UART" position one step to the right to "RS-485". Power up, and play...

The documentation is available online from [10]. The frame is sent in hexadecimal and the start is marked by sending $FE followed by one or more bytes indicating the command and the parameters. **Figure 6** corresponds to three commands that can be sent by clicking on the corresponding SEND buttons. The first clears the screen, the second displays the message "Hello world", and the last one generates a tone.
MuIn LCD is now ready to be incorporated into the system.

Overall operation

After having configured the ATM01 and ATM02 boards by setting PD5 and PD6 as per **Table 1**, apply power to all the boards.

Table 1. Naming the ATM18 boards.

ATM0x	PD6	PD5
ATM01	0	0
ATM02	0	1
ATM03	1	0
ATM04	1	1

Table 2. Action – Reaction.

ATM01			ATM02	
Press S1	RE1 = /RE1		Press S1	RE3 = /RE3
Press S2	RE2 = /RE2		Press S2	RE4 = /RE4
Press S3	x		Press S3	x

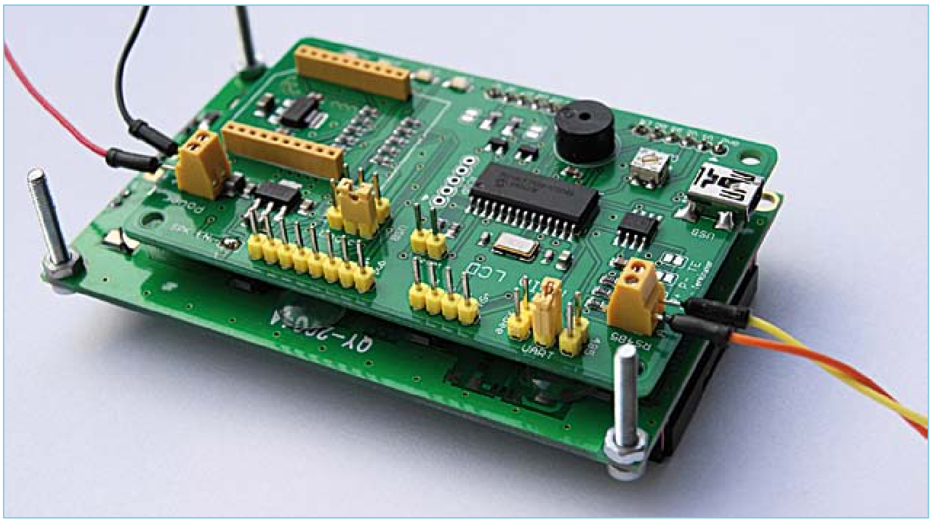


Figure 5. MuIn board mounted at the back side of the display unit.

The names ATM01 and ATM02 will be displayed automatically at start-up on the first line of their respective two-wire LCDs. Powering up ATM05 causes a long beep from the MuIn, a friendly "Hello!", and the state of the eight relays in binary (from RE8 to RE1) is written on the second line (**Figure 7**). As shown here, none of the relays are energized.

As the boards on the bus have been assigned as ATM01 and ATM02, relays 1 to 4 are the ones we can operate. Thus pressing one of the buttons S1, S2, or S3 will produce an event (**Table 2**).

Figure 8 tells us about three events that have just taken place: first, a press on ATM02 S1 has operated RE1, and the third line tells us that button S1 has just been pressed again. But what do those dots on the middle line mean?
If ATM01 and ATM02 both address the bus at the same moment, a collision is inevitable. As a result, the two dots along with a flashing cursor (not visible in the photo) on the second line mean that ATM02 is on hold, indicating that ATM01 has just sent a command to ATM05. During this time,

ATM02 must remain silent. In other words, ATM01 takes precedence in case of conflicts on the bus. However, if you fall asleep over your boards and press all the buttons, the 'guard dog' will wake you up! In this case, ATM01 and ATM02 perform a hot restart, and ATM01 has priority. Pressing S3 doesn't operate a relay, but lets you interrogate their logic states, which are displayed on the two-wire LCD display. The state of the relay is updated live on the MuIn display. If ATM01 or ATM02 restart, this is also indicated by a message on the MuIn LCD.

For the whole thing to work, two proprietary frames have been set up. The send frame (ATM0x to ATM05):

```
$PGE1,01,05,01,0001*67
```

where:

- `$PGE1`: frame '1' proprietary to Grégory Ester
- `01`: source board
- `05`: destination board
- `01`: relay to be activated
- Parameter '`0001`': here the parameter value is always '1', since the command is always the same: "toggle the relay"
- `*67`: checksum, a simple XOR on the preceding characters excluding the '$'. If the checksum is incorrect, the frame is ignored. Similarly, if you try to send ATM05 the following frame '`PGE1,01,05,03,0001*65`' using the Hercules software, it will be ignored, because, even though the checksum is correct, ATM01 does not have the right to drive relay 3.

The acknowledgement frame (ATM05 to ATM0x) could look like this:

```
$PGE2,05,02,03,0006*62
```

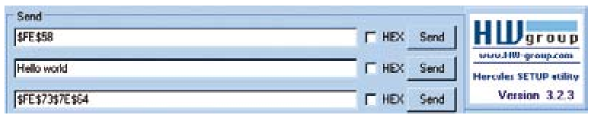


Figure 6. Sending your own commands over the RS-485 bus.

Figure 7. Hello, all the relays are de-energized.

Figure 8. Is ATM02 around?

- `$PGE2` : frame '2' proprietary to the author (can be modified in the source code)
- `05`: source board
- `02`: destination board
- `03`: relay that has just been activated
- Parameter '`0006`': a byte that is the image of the logic state of all the relays. Here $(6)_{10} = (0000\ 0110)_2$ indicates that RE2 and RE3 are energised. A logical AND on the bits we're interested in lets you recover the state of the relays.
- `*62` : checksum as before. If the checksum is wrong, the message 'xx' is displayed in place of the two bits corresponding to the state of the relays.

The system has been successfully tested with a bus 6 m long.

Conclusion

The application suggested here is of course not on the same scale as the project currently being prepared by the e-LABs. Here, it was more a question of letting you explore one possible application, some peripherals that are compatible or can be made so, and a way of communicating. Just like you, I'm waiting very impatiently for the definitive solution that's going to be devised in the Elektor labs and developed in the blue pages in the centre of the magazine...

The elements of firmware (with source code) used for this project are of course available for you on the article's web page [11].

(110024)

Internet Links & References

[1] www.elektor.com/080357

[2] www.robosavvy.com, in Products -> Display

[3] www.mikroe.com

[4] www.sparkfun.com/products/8790

[5] www.ikalogic.com/scanalogic2/

[6] www.lextronic.fr/P19764-platine-muln-pour-afficheur-lcd.html, alternatively, [2]

[7] www.droids.it, in the section Documents -> Downloads

[8] e.g. Farnell part no. 1740357

[9] www.hw-group.com/products/hercules/index_en.html

[10] www.droids.it, in the section Documents -> User guides

[11] www.elektor.com/110024

Hexadoku

Puzzle with an electronics touch

After last month's heavily Elektorized Hexadoku we revert to the standard grid of 16 by 16 boxes you've grown accustomed to these past few years. Sharpen your pencil, sit down in a WiFi-free spot and enter the right numbers in the puzzle. Next, send the ones in the grey boxes to us and you automatically enter the prize draw for one of four Elektor Shop vouchers. Have fun!

The instructions for this puzzle are straightforward. Fully geared to electronics fans and programmers, the Hexadoku puzzle employs the hexadecimal range 0 through F. In the diagram composed of 16 × 16 boxes, enter numbers such that **all** hexadecimal numbers 0 through F (that's 0-9 and A-F) occur once only in each row, once in each column and in each of the 4×4 boxes (marked by the thicker black lines). A number of clues are given in the puzzle and these determine the start situation. Correct entries received enter a draw for a main prize and three lesser prizes. All you need to do is send us the numbers in the grey boxes.

Solve Hexadoku and win!

Correct solutions received from the entire Elektor readership automatically enter a prize draw for one Elektor Shop voucher worth £ 80.00 and three Elektor Shop Vouchers worth £ 40.00 each, which should encourage all Elektor readers to participate.

Participate!

Before May 1, 2011, send your solution (the numbers in the grey boxes) by email, fax or post to

Elektor Hexadoku – 1000, Great West Road – Brentford TW8 9HH United Kingdom.

Fax (+44) 208 2614447 Email: hexadoku@elektor.com

Prize winners

The solution of the February 2011 Hexadoku is: **9084B**.
The £80.00 voucher has been awarded to: H.A. Stuut (The Netherlands).
The £40.00 vouchers have been awarded to: Moses McKnight (USA); Joachim Hey (Germany); Knut L. Bakke (Norway).
Congratulations everyone!

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

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

137 Years of Solid-state Electronics

By Andrew Emmerson (UK)

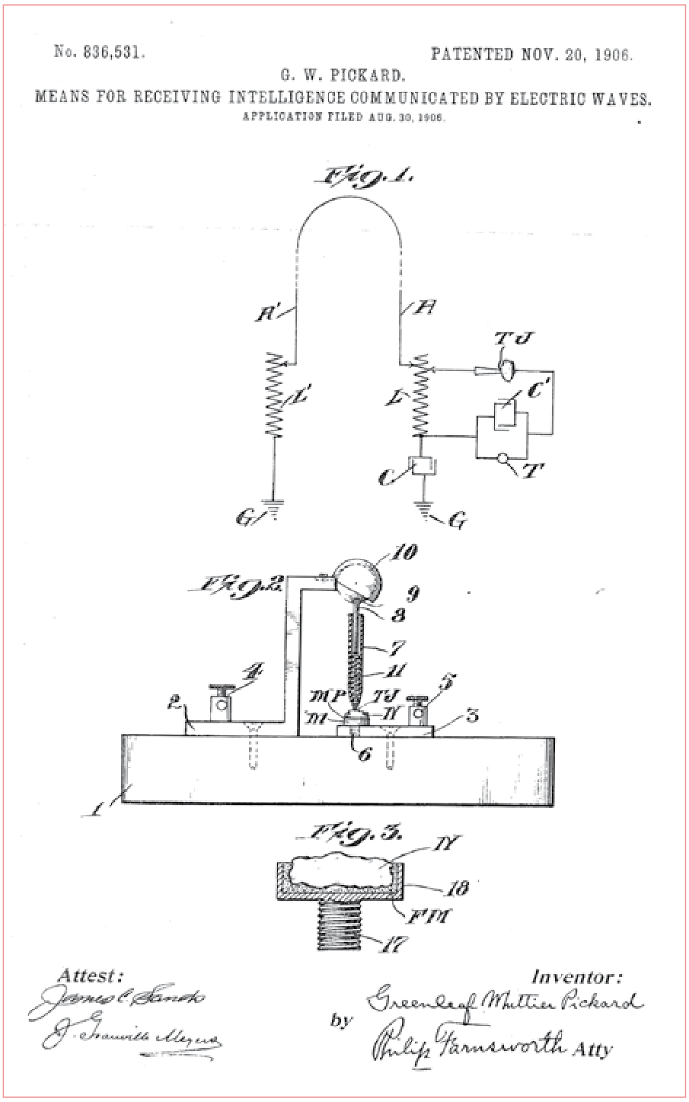


Figure 1. Patent awarded to Greenleaf Pickard in 1906 after he perfected the crystal diode.

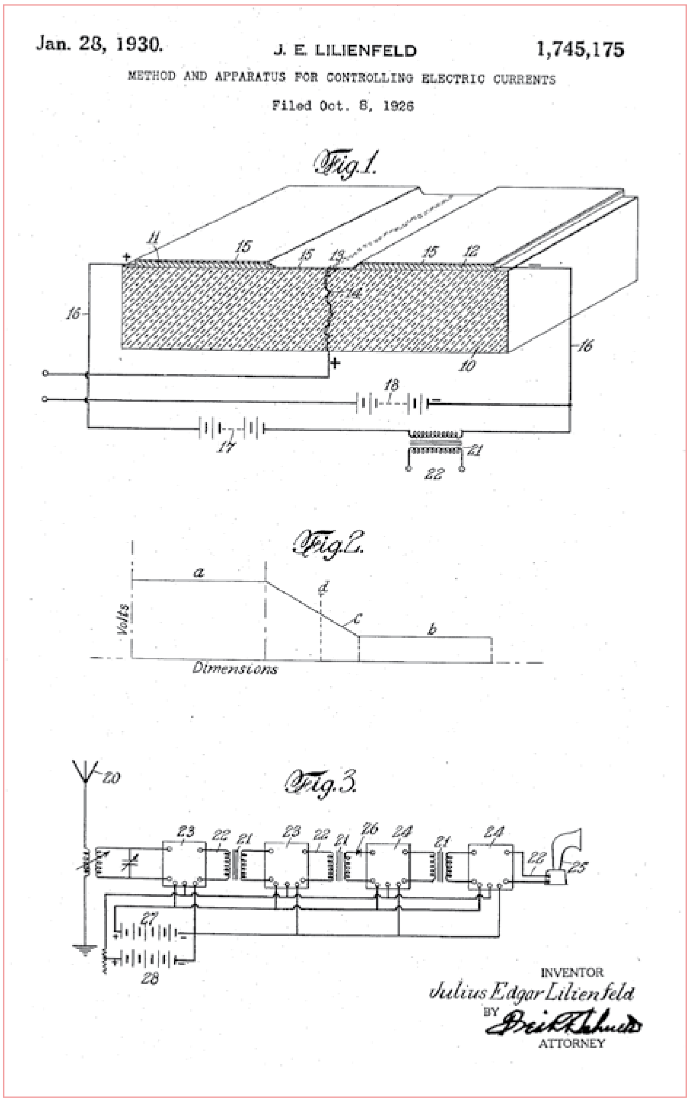


Figure 2. Lilienfeld's patent of 1926 for a 'Method and Apparatus for controlling Electric Currents'.

You might be surprised to learn that solid-state electronics date back as far as 1874, when in fact Ferdinand Braun invented a solid-state rectifier using a point contact based on lead sulphide. But the chief credit for starting the silicon revolution goes to Greenleaf Pickard of Amesbury, Massachusetts, who discovered that the point contact between a fine metallic wire (the so-called 'cat's whisker') and the surface of certain crystalline materials (notably silicon) could rectify and demodulate high-frequency alternating currents, such as those produced by radio waves in a receiving antenna.

In 1906 Pickard perfected the crystal detector (which he called a 'wave-interceptor') and took out a patent for the use of silicon in detectors (**Figure 1**). This crystal detector (point-contact rectifier) was the basis of countless crystal set radio receivers, a form of radio receiver that was extremely popular until the thermionic triode valve superseded the crystal detector. Pickard's diode was nevertheless a purely passive device and to earn the real prize somebody would have to achieve amplification using crystal devices.

This did not take long, for already in 1910 Dr W.H. Eccles read a

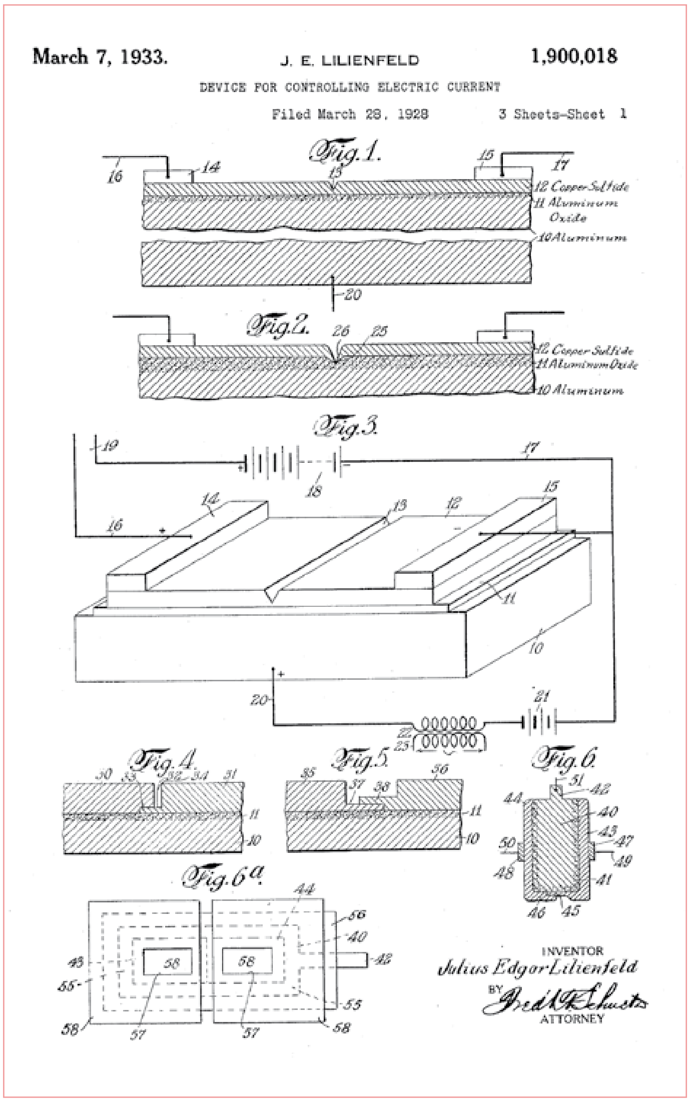


Figure 3. This 1933 patent by Lilienfeld describes the principle of the Field Effect Transistor and its advantages over “cumbersome vacuum tubes”.

paper to the Physical Society of London on his use of a galena crystal to produce sustained oscillations, although most of the credit for creating practical solid-state amplifying devices goes to Oleg Losev of Russia, who used zincite and a steel cat’s whisker with bias to make an oscillator and even a low-power transmitter in the early 1920s (it’s not clear whether Losev was aware of Eccles’ pioneer work a decade earlier). Lossev’s work was reported in considerable detail in the September 1924 issue of *Radio News* and in the October 1 and 8, 1924 issues of *Wireless World.* Hugo Gernsback, the editor of *Radio News*, even predicted, correctly, that crystals would someday replace valves in electronics. The majority of these early experiments — and additional refinements — have been replicated by modern-day researchers [1] and [2] and a *Popular Wireless* booklet of 1925 that has been posted online [3] gives full details for duplicating crystal oscillator circuits.

False history

Most of us believe the transistor was invented at Bell Telephone Laboratories in 1947, which proves how easy it is to propagate false history. In fact BTL’s team merely created a variant of a device invented and already patented a quarter of a century earlier. Whether they overlooked or chose to ignore this prior achievement is lost in history but what is not in doubt is that Dr Julius Lilienfeld of Germany secured a US. patent (**Figure 2**) for his invention in 1926. Lilienfeld believed that applying a voltage to a poorly conducting material would change its conductivity and thereby achieve amplification.

He demonstrated his remarkable tubeless radio receiver on many occasions but earned few thanks for threatening the economic domination of the vacuum tube. Lilienfeld followed up his original patent for a ‘Method and Apparatus for controlling Electric Currents’ with another granted in 1933 (**Figure 3)**. Radio historian David Topham GM3WKB comments: “US patent 1,900,018 clearly describes the field effect transistor, constructing it using thin film deposition techniques and using dimensions that became normal when the metal oxide FET was indeed manufactured in quantity well over 30 years later. The patent (and subsequent ones) describes the advantages of the device over ‘cumbersome vacuum tubes’.”

(110020)

Internet Links

[1] http://home.earthlink.net/~lenyr/iposc.htm
Nyle Steiner replicates Lossev’s oscillating crystals

[2] http://pw1.netcom.com/~wa4qal/crystal2.htm
David Glass achieves audio oscillations with iron pyrites

[3] https://docs.google.com/viewer?url=http://earlywireless.com/pdf/pw_xtal_experimenters_hdbk.pdf
Popular Wireless Crystal Experimenters Handbook, October 1925

[4] http://patft.uspto.gov/netahtml/PTO/search-bool.html
Search engine for the full text of all US patents from 1790 to the present day.

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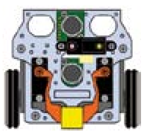

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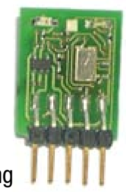

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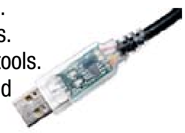

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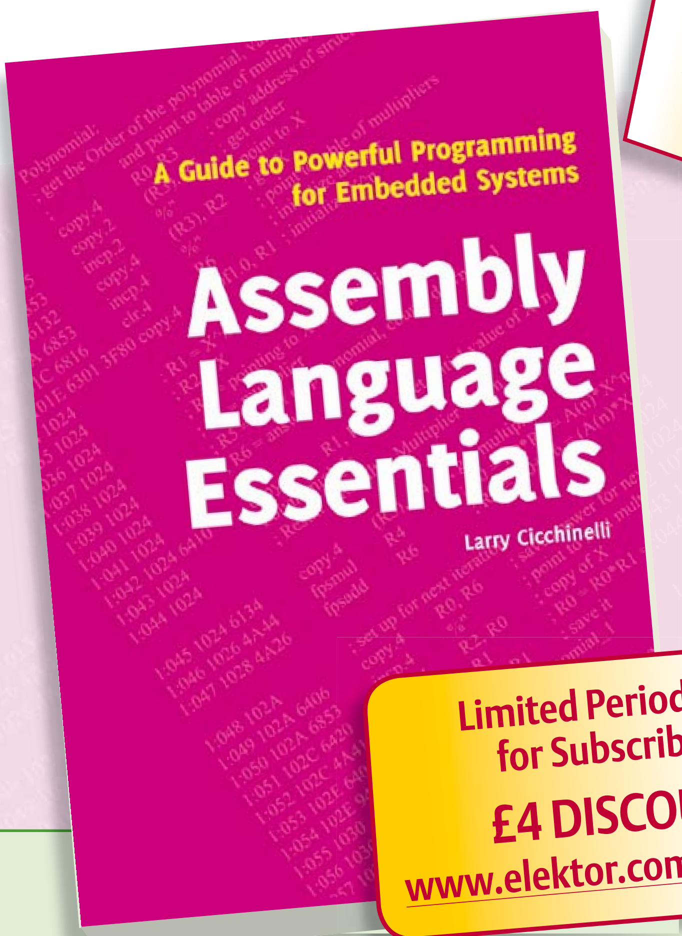

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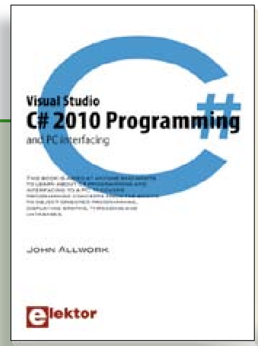

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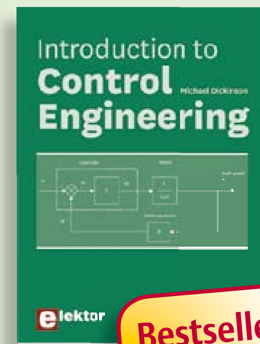

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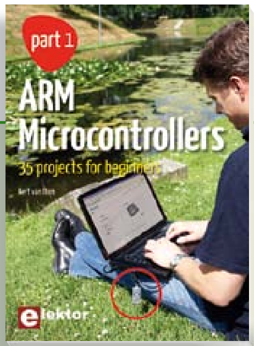

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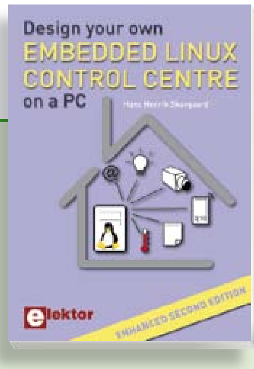

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(March 2011)

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(December 2010)

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(March 2010)

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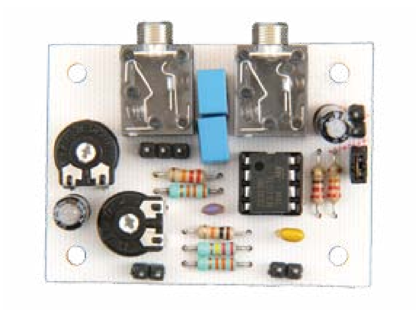
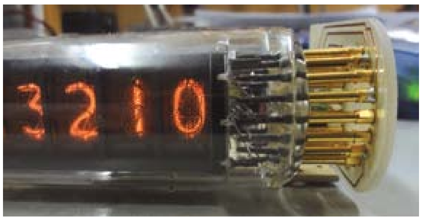


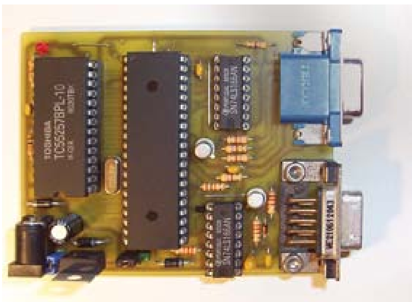
Microphone Conferencing System

Companies and families increasingly make use of on-line (video) conferencing and sound is often the problem. When a large group of people is gathered around a (laptop) microphone, it often happens that colleagues at the far end of the line have great difficulty in following the conversation. Sure, a good microphone will do the job to some extent, but in larger rooms that are not the best in terms of acoustics a single microphone just isn't sufficient. In the May 2011 edition we propose a simple conferencing system with multiple microphones.



Nixie Tubes

Nixie tubes create a certain atmosphere. The glow of these small tubes literally exudes a certain warmth. Nixie tubes also arouse nostalgic feelings for older readers. Not surprisingly Elektor has published several circuits using Nixie tubes. In the May 2011 edition we explore the world of Nixie tubes, their history, operation and applications, not forgetting to take a tour of the finest and most unique Nixie project ideas submitted by Elektor readers following a call in our e-weekly newsletter.



VGA adapter for microcontrollers

While a small LCD is a common adjunct to many microcontrollers, it may not be a grand solution when it comes to displaying information. An old monitor with a VGA input is an excellent alternative. The serial-to-VGA converter described in the May 2011 edition allows an easy way of putting information on a screen. Although our VGA Adapter is monochrome, that's usually not a problem. The circuit is compact and built around a dsPIC30F3011.

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