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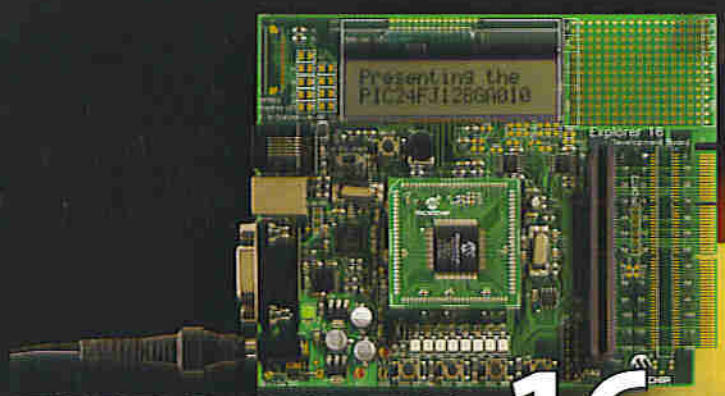

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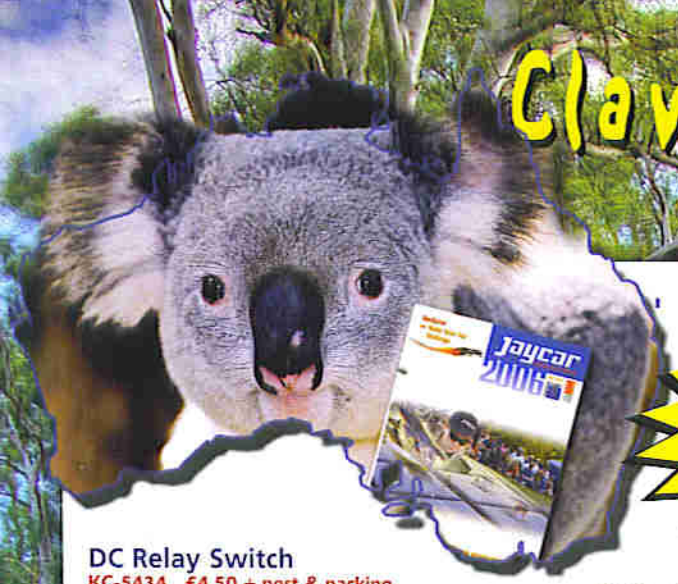

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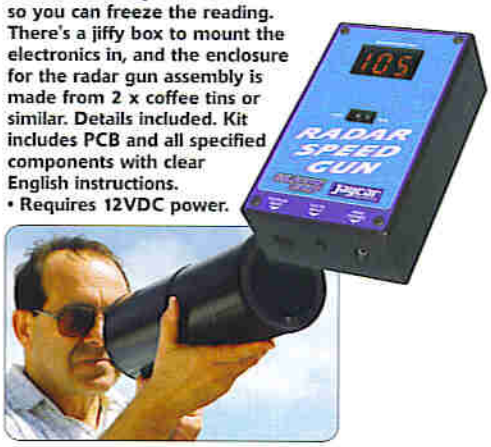
This Doppler radar gun reads speed in km/h or mph up to 250 km/h or 155 mph. It has a resolution of 1 km/h or 1 mph with an accuracy of 1%, and also has a hold switch so you can freeze the reading. There's a jiffy box to mount the electronics in, and the enclosure for the radar gun assembly is made from 2 x coffee tins or similar. Details included. Kit includes PCB and all specified components with clear English instructions.

- Requires 12VDC power.



Magnetic Cartridge Pre-amp

KC-5433 £11.75 + post & packing

This kit is used to amplify the 3-4mV signals from a phono cartridge to line level, so you can use your turntable with the CD or tuner inputs on your Hi-Fi amplifier. The design is suitable for 12" LPs, and also allows for RIAA equalisation of all the really old 78s. Please note that the input sensitivity of this design means it's only suitable for moving-magnet, not moving-coil cartridges. Kit includes PCB with overlay and all electronic components.

- Requires 12VAC power

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Be the envy of everyone at the next Interplanetary Conference for Evil Beings with this galactic voice simulator kit. Effect and depth controls allow you to vary the effect to simulate everything from the metallically-challenged C-3PO, to the hysterical ranting of Daleks hell-bent on exterminating anything not nailed down. The kit includes PCB with overlay, enclosure, speaker and all components. For those who really need to get out of the house a lot more. Take me to your leader.

- Requires 9V battery

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IR Romote Control Extender MKII

KC-5432 £7.25 + post & packing

Operate your DVD player or digital decoder using its remote control from another room. It picks up the signal from the remote control and sends it via a 2-wire cable to an infrared LED located close to the device. This improved model features fast data transfer, capable of transmitting Foxtel digital remote control signals using the Pace 400 series decoder. Kit supplied with case, screen printed front panel, PCB with overlay and all electronic components.

Requires 9VDC wall adaptor (Maplin #G574R £10.99)

Speedo Corrector MkII

KC-5435 £14.50 + post & packing

When you modify your gearbox, diff ratio or change to a large circumference tyre, it may result in an inaccurate speedometer. This kit alters the speedometer signal up or down from 0% to 99% of the original signal. With this improved model, the input set-up selection can be automatically selected and it also features an LED indicator to show when the input signal is being received. Kit supplied with PCB with overlay and all electronic components with clear English instructions.

Powertool Battery Charger Controller

KC-5436 £11.75 + post & packing

Enhance the performance of the charger supplied with your power tool with this controller. It incorporates charge timeout, min and max temperature monitoring, Delta charge detection, power and charge LED indicator, adjustable Delta V, temperature settings, and optional adjustable trickle charge. Suits both Ni-Cd and Ni-MH cells. Kit includes PCB with overlay, case, all electronic components and clear English instructions.

High Range Adjustable Temperature Switch for Cars

KC-5376 £22.75 + post & packing

This temperature switch can be set anywhere up to 1200°C, so it is extremely versatile. The relay can be used to trigger an extra thermo fan on an intercooler, a sensor near your turbo manifold to trigger water spray cooling, or a simple buzzer to indicate high temperature. The LCD displays the temperature constantly and can easily be dash mounted. Kit included PCB with overlay and all electronic components with clear English instructions.

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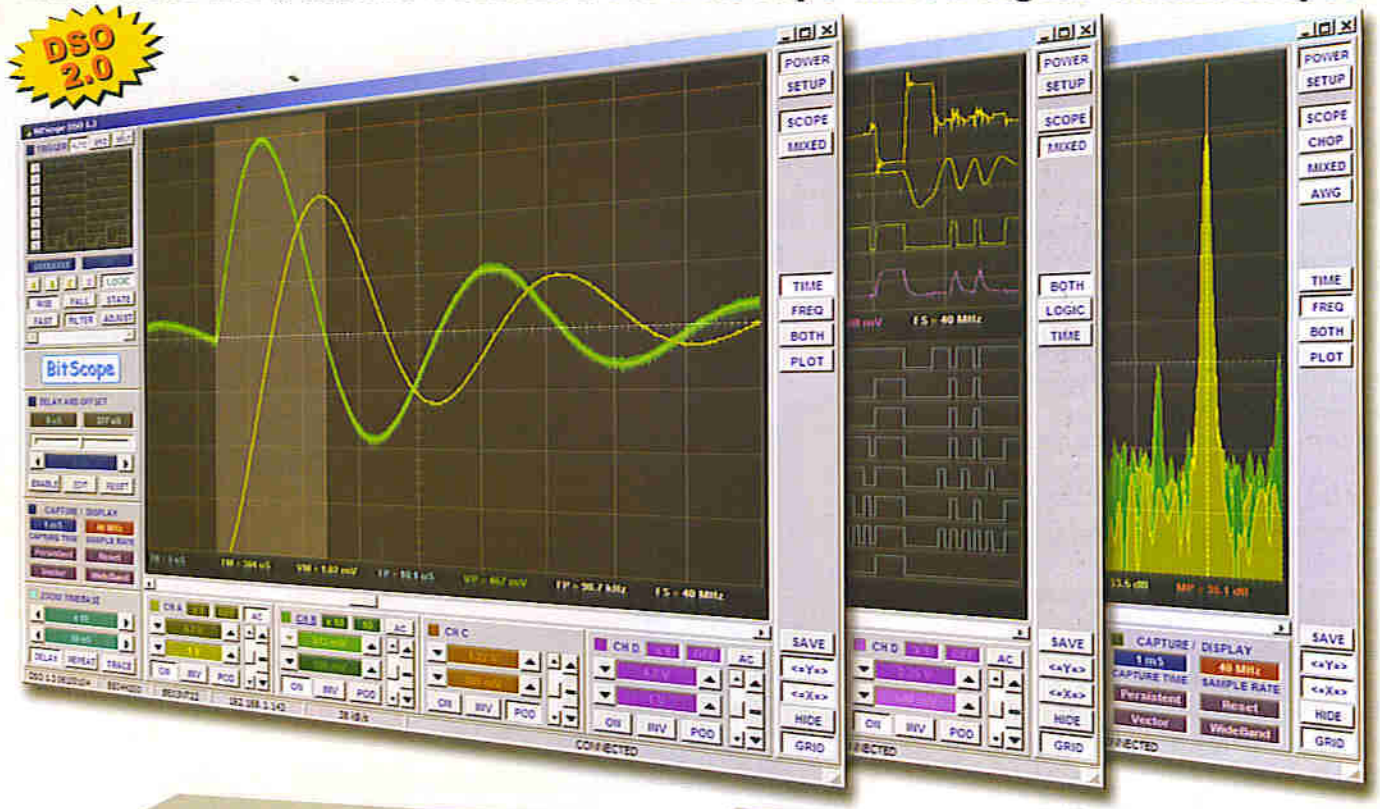

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Poke 16384,#FF

After a period of noticeable decline, reportedly owing to a boogieman called surface-mount assembly (again reportedly, a descendant of transistor) there are now clear signs that electronics as a pastime is on the up again albeit in a different appearance. Where a soldering iron, tweezers and a drawer full of colourful parts were traditionally used to create electronics on a workbench as well as demolish it again or repair it down to the component level, nowadays engineers think in terms of FPGAs, circuit boards, FedEx, helpdesks and firmware they can flash (pun intended). "No hardware if it can't talk software" is hip, but nothing new. About 20 years ago some friends of mine bought a van load full of boards and other parts off a computer manufacturer that went belly up after missing a government order for PCs to be used nationwide in schools. After assembling and powering up one of the Z80-based computers, light smoke started to curl from one of the plug-in boards. While several of the gang frantically traced the power cord buried in a tangled heap of wires, one team member sat down at the keyboard and asked in utter seriousness if anyone knew the address, in decimal or hexadecimal, of the Z80 port line used to monitor the supply voltage? Could the line be XORed? No? Why not? He still managed to launch BASIC (from ROM) but before being able to finish what must have been the fourth program line, the screen went dead and the computer called it quits. As it turned out, a wrong voltage regulator had been fitted on one of the plug-in boards and the repair, by another team member versed in hardware, took less than 15 minutes.

Today, circuit repair is often said to be a waste of time owing to the complexity of modern equipment and the use of black-box technology. I could not disagree more — defective or "surplus to requirements" as it may be, any piece of new-fangled electronics has some component you can reuse, or at least try to understand how it works.

Jan Buiting
Editor

...3, 2, 1 – Tak

Model constructors really like to see all sorts of flight data (telemetry). But how do they get hold of this data, when the rocket is soaring off at an altitude of 500 m or more? A cable is not an option. This circuit nevertheless shows you how to do this. Telemetry is taking off, literally!

Happy Hour 1 February 2007 - 9.00 am – 9.00 pm GMT
free article downloads from the Elektor website

18 Flying Robots

Sophisticated robots now assist or even replace us in difficult or hazardous environments. This is particularly true of military hardware where we have seen on our TV screens the use of unmanned aircraft and vehicles in some recent conflicts. The basic idea however is not so new; we take a look into the world of 'drones'...

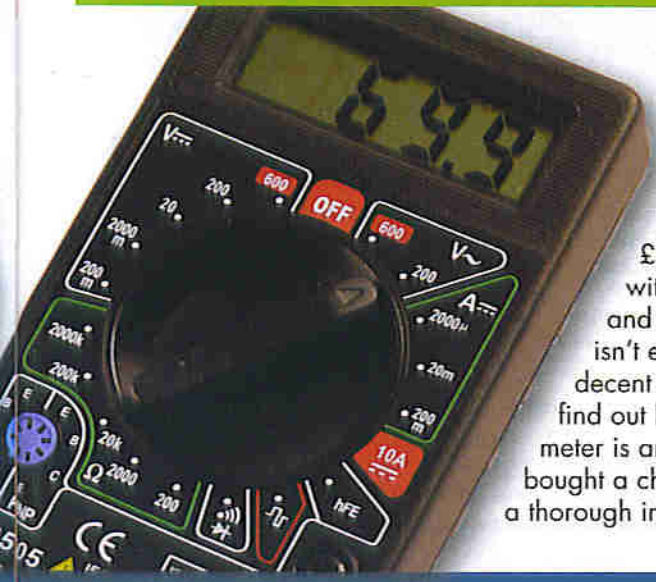
CONTENTS

Volume 33
February 2007
no. 362

32 Explorer-16 (2)

We continue with a look at the hardware to go with this article series brought to you exclusively by Labcenter, Microchip UK and Elektor. Software is covered, too, by a Proteus VSM simulation of audio signal processing. And finally there's a super discount offer waiting for you.

54 Accurate Measurements for a Fiver?



£5 for a digital multimeter with several extra functions and a set of leads! Surely that isn't enough to manufacture a decent piece of equipment? To find out how useful such a multimeter is and how accurate it is, we bought a cheap multimeter and gave it a thorough investigation.

know-how

18 Flying Robots

hands-on

32 Explorer-16 (2)
40 MP3 Preamp
46 A Telling Way of Telling the Time
58 FPGA Course (9, final)
62 I-Q: a Highly Intelligent Approach to Quality Radio
66 Toilet Guardian
69 Design Tips
LDO regulator
Bi-colour LEDs operated by LDR
72 E-blocks LED Chaser

technology

18 Flying Robots
24 ... 3, 2, 1, Takeoff!
54 Accurate Measurements for a Fiver?

info & market

6 Colophon
8 Mailbox
12 High Power (LEDs)
14 News & New Products
84 Sneak Preview

infotainment

76 Philips SFM411/100 Wobbulator (1952)
77 Hexadoku

elektor electronics

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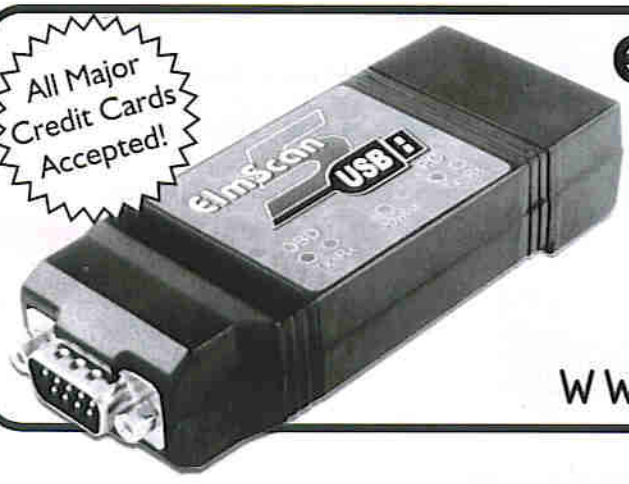

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EasyPIC4 Development Board

with on-board USB 2.0 programmer and mikroICD

3 in 1 DEVELOPMENT SYSTEM — HARDWARE ICD ON-BOARD · USB 2.0 ON BOARD PROGRAMMER · HIGH PERFORMANCE DEVELOPMENT BOARD

EasyPIC4 development board: Following in the tradition of the EasyPIC3 as one of the best PIC development systems on the market, the EasyPIC4 has more new features for the same price. The system supports 8, 14, 18, 20, 28 and 40 pin PIC microcontrollers (it comes with a PIC16F877A). The ultra fast mikroICD (In-circuit Debugger) enables very efficient debugging and faster prototype development. Many ready made examples guarantee successful use of the system. EasyPIC4 is fully optimized for fast prototype development. It allows the PIC microcontroller to be interfaced with external circuits to a broad range of peripheral devices, allowing the user to concentrate on just the software. On a silkscreen there are labels beside every component. These marks describe connections to the microcontroller, operation modes, and some other useful notes. As a result, the need for additional schematics is minimized, because all the information required is already on the board.

3 in 1 Development System : Development Board + USB 2.0 on-board programmer + In Circuit Debugger

mikroICD is a highly effective tool for Real-Time debugging on a hardware level. The ICD debugger enables you to execute a mikroC/mikroPascal/mikroBasic program on a host PIC microcontroller and view variable values, Special Function Registers (SFR), memory and EEPROM as the program is running.

On-board USB 2.0 PICFlash programmer – an ultra fast USB 2.0 programmer for fast MCU programming. Continuing its tradition as the fastest PIC programmer on the market, the new PICFlash with mikroICD now supports more PIC MCUs giving the developer a wider choice of PIC MCU for further prototype development.

Examples in C, BASIC and Pascal language: Printing text on LCD, LED blinking on PORTB, MMC/SD/CF card read and write example, USB communication, 4x4 Keypad example, PS2 keyboard example, software SPI/I2C/RS232 communications, AD conversion example Seven segment digit example, Timer 0 and Timer 1 time measuring, Measuring temperature with DS1820 and displaying on LCD, Graphic LCD example, examples for SPI communication, examples for CAN communication, examples for Sound generation, sending and receiving data over Ethernet, Interrupt upon PORTB state change, Detection of button pressed on port and many more...

Package contains: EasyPIC4 development system, USB cable, Serial cable, User's manual, MikroICD manual, CD with software, drivers and examples in C, BASIC and Pascal language.
Note: LCD, DS1820 temp sensor and GLCD are optional.

EasyPIC4 Development System ..... **$119.00 USD**
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BIGPIC4 Development System ..... **$132.00 USD**

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with on-board USB 2.0 programmer

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EasydsPIC3 Development System ..... **$119.00 USD**

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with on-board USB 2.0 programmer

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dsPICPRO2 Development System ..... **$239.00 USD**

EasyAVR4 Development Board

with on-board USB 2.0 programmer

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EasyAVR4 Development System ..... **$114.00 USD**

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with on-board USB 2.0 programmer

EasyARM board comes with Philips LPC2214 microcontroller. Each jumper, element and pin is clearly marked on the board. It is possible to test most of the industrial needs on the system: temperature controllers, counters, timers etc. EasyARM has many feature to make your development easy. One of them is on-board USB 2.0 programmer with automatic switch between 'run' and 'programming' mode. Examples in **C** language are provided with the board.

EasyARM Development System ..... **$149.00 USD**

Easy8051A Development Board

with on-board USB 2.0 programmer

System is compatible with **14, 16, 20** and **40 pin** microcontrollers (it comes with AT89S8252). USB 2.0 programmer is built in and programming can be done without removing the microcontroller. Many industrial applications can be tested on the system : temperature controllers, counters.. **Easy8051A** development system is a full-featured development board for 8051 microcontrollers. It was designed to allow students or engineers to easily exercise and explore the capabilities of the 8051 microcontrollers.

Easy8051A Development System ..... **$114.00 USD**

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RFID Reader classroom project

Dear Sir — I teach electronics at Seneca College in Toronto, Canada. This fall my APE553 Electronics class built the TIRIS RFID Reader as described in your October 2005 issue. This was an excellent construction project. Students created their schematic diagrams and printed circuit board layouts using the freeware edition of Eagle. Their printed circuit boards were built using an LPKF milling machine that our department has. Most students built the simple version of the circuit and a few others built the more complicated version. Construction was straightforward. I used a KANDA AVR-TRAIN system to program the AT90S1200 micro-controllers. My thanks to Martin Ossmann for designing this circuit. We have a troubleshooting manual and typical board layouts for anyone interested.

Jeremy Clark

Thanks for that Jeremy, and congratulations to all students on completing the project. For the 2007 curriculum you may want to consider the two RFID reader designs and the free RFID card supplied with the September 2006 issue. Let us know how you get on.

Jeremy replies:

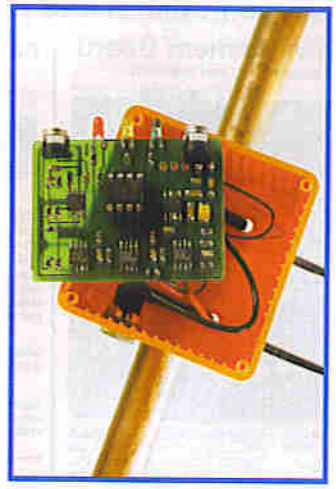
Jan — I was the first to order your RFID kit which I have and am also building the other design as well! I have built many of your projects and never had a problem. Last year our class built the SC Analyzer 2005 with great success. So far:

- DRM Receiver March 2004
- SC Analyzer April 2005
- GPS Receiver on USB June 2005
- Electrosmog Detector June 2005

ps: I devour every issue of your magazine!

Go with the Flow

Dear Sir — I am writing regarding the 'Go with the Flow' article in your December 2006 issue. I found it somewhat scary that you actually suggest people should endanger their own health just to try to save a few pennies. Bacteria, mainly legionella (http://www.legionella.org/engineers.htm#a7) easily start to reproduce in piping where the temperature falls below safe levels. Same thing applies to Kolera and others. Most countries actually have legislation that simply makes this kind of tampering besides being utterly stupid, also directly illegal.



Since I am not a resident in the UK I don't know what the law is over there but on a European Union scale I would say your article is very questionable.

There are good reasons why the temperature in the circulation pipes should be kept above 125-140 F depending on your local regulations.

I would recommend you check with your legal dept and you might want to come with a advisory not to implement this project at any circumstances in your next issue.

Otto Keronen (Finland)

Jürgen Maiß, the author/designer of the project, replies:
Initially we also considered the concerns over bacteria growth [in hot water pipes]. However, according to specialists, the growth is conditioned mainly by a too low intake temperature or boiler temperature. Also, commercial equipment freely available from heating and plumbing suppliers, is also affected by this problem.
In principle, any user should decide for him/herself if continuous [hot water] circulation at 70 degrees C is a requirement.

UV Light Box

Hi Elektor — just to tell you that I made a portable UV LED Light Box sized 100x160 mm based on your article in the May 2006 issue, and it works fine. I used a metal box case to make it. I posted the story on the construction process on my blog at this url:

http://radikaldesig.blogspot.com/2006/10/insoladora-uv-leds.html

Thanks for a good idea!

Droky (on Elektor Forum)

This particular project has drawn a lot of attention, reportedly also in the forum of our esteemed competitor EPE magazine. It works a treat and can be 'made to measure' to suit personal requirements.

Spot welding with capacitors

Dear Editor — regarding the article 'Spot welding with capacitors' in the November 2006 issue (Modding & Tweaking pages, Ed.) I can not dispute the novelty of the approach which is typical of Elektor. However I guess your author is using a pretty robust microcontroller as it's fed with 15 V (!) at its B1 port — all at a supply voltage of 5 V. After all, the top of the 33k/33k voltage divider is held at up to 30 V.

Peter Zechner (Germany)

Solution to Hexadoku December 2006

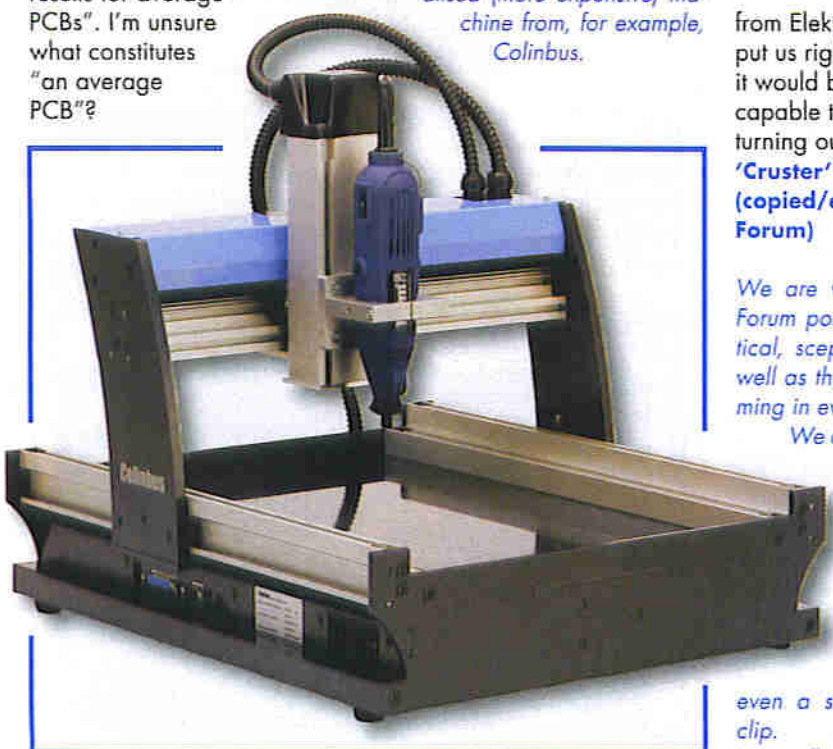
2	3	4	7	1	B	E	0	C	A	8	6	D	9	5	F
D	F	B	E	C	3	5	A	7	9	2	4	6	0	8	1
C	5	6	9	F	8	7	2	0	D	E	1	B	3	A	4
8	1	0	A	6	4	9	D	5	F	3	B	E	C	7	2
F	C	1	2	D	5	3	4	6	B	A	7	9	8	0	E
7	B	5	8	E	1	2	6	9	0	F	3	C	4	D	A
3	A	E	0	9	F	B	C	D	1	4	8	5	6	2	7
6	4	9	D	7	A	0	8	2	E	C	5	F	B	1	3
E	7	D	1	5	9	C	B	3	6	0	A	4	2	F	8
9	8	A	F	0	E	D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

Jeroen Domburg replies:
That's right Peter, but the port lines including PB1 are fitted with internal ESD protection diodes. These will faithfully conduct voltages higher than about 10 V (typical) to Vcc. The highest current that would occur is 10 V / 33 k = 0.3 mA i.e., not a problem for the diodes.

Profiler (1)

I'd like to know how the Profiler (January 2007, Ed.) copes with milling PCBs. The Profiler article says "However, based on our experience it yields excellent results for average PCBs". I'm unsure what constitutes "an average PCB"?

We would like to emphasise that Profiler is a multi-purpose milling machine, i.e. not specifically designed to mill PCBs. If you want to mill PCBs only, covering anything from 1970s through-hole right up to 0402 SMD or sub-BGA tracks, we would advise buying a specialised (more expensive) machine from, for example, Colinbus.



I think it'd be extremely helpful if Elektor could post their results so those of us interested in using Profiler for PCBs can see what the machine can do and arrive at an informed buying decision. I don't think I'm being unreasonable asking? The alternative being having to spend £1,099 to find out, which I'm naturally wary of doing until I hear more.

'Cruster' (copied/edited from Elektor Forum)

We confirm that Profiler is suited to milling PCBs for through-hole (wired) components. Boards for SMDs with extremely thin tracks may pose a problem and we cannot guarantee useable results. However we are convinced some users will able to construct and adjust their Profiler in such a way that SMD boards can be milled, all assuming that a spindle motor with less slack is used.

Profiler (2)

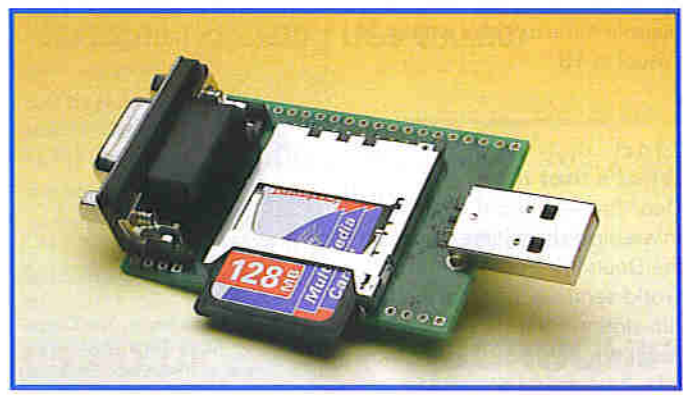
Mechanical resolution to 10 times the wavelength of red light? Who makes the lead screws? That's a 0.005% error over 6".
However, what is the repeatability and the hysteresis of the system? Those are equally important figures.
(...)
Mechanical resolution of 0.0075 mm is what it says in the article... unless it's a misprint? Perhaps some one from Elektor or Colinbus could put us right? At the same time it would be good to hear how capable this machine is at turning out PCBs...

'Cruster' and 'Binraker' (copied/edited from Elektor Forum)

We are very pleased with all Forum postings so far, be it critical, sceptical or in praise, as well as the orders for Profile coming in every day.
We are preparing a follow-up to the Profiler articles already published (December 2006 and January 2007). This may take the form of an extensive posting in the Forum topic or even a small(ish) online video clip.
We will certainly revert to the matter of milling PCBs, which is perfectly possible using Profiler.
The stated mechanical resolution of 0.0075 mm is no joke or misprint but the smallest increment of the stepper motors expressed in linear travel.
The repeatability of the milling operations is governed by the accuracy of the constructor when adjusting the specific parts mentioned in the article for a trade-off between minimum slack as opposed to highest acceptable friction. As such the repeatability will be of the order of a few tenths of a millimetre.

RS232/USB Stick with PLC data

Dear Jan — I would like to copy data supplied by a SAIA PCD2 PLC system onto your 'USB Stick with ARM and RS232' (November 2007, Ed.), then plug the stick into my PC at the end of the month and write captured data into an Excel file. I would think that's possible using your project. The PLC data has a different length all the time: date 5 bytes; regis-



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1. OBD-2 Analyser (7/2005)
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3. High-end Power Amp (3/2005)
4. High-End-Preamp, Part 1 (4/2004)
5. Build Your Own DRM Receiver (3/2004)
6. High-End-Preamp, Part 2 (5/2004)
7. Remote Control by Mobile Phone (11/2005)
8. ClariTy 2x300W (6/2004)
9. PPP HiFi Valve Power Amplifier (5/2001)
10. ESR / C Tester (9/2005)

ter 4 bytes or 6 bytes.
If the individual data values are seaparted ('delimited') when stored (e.g., with a comma, would that enable them to be copied into an Excel spreadsheet? Or will the stick only store byte-long data? Do you know of commands that enable multiple bytes to be concatenated back again?
I would like to use VBA for my purpose. Can you supply background material for similar applications?
Alois Schmidhalter (Germany)

Jürgen Engelmann replies: The USB Stick stores data byte by byte on the MMC/SD card, without inserting delimiters like commas. However you may store the data onto the stick in data logger mode and take them off again later using a VB program, insert your commas and write the lot into a second file.

We do not have the requested background material, sorry. However it should be possible to migrate the examples written in Pascal to VB.

What's that tune?

Dear Jan — I heard an interesting short 'tune' on the Deutsche Welle (German world service) shortwave radio station about 2 years ago and I am intrigued as to what it is. It is played at regular intervals of about 10 seconds in the two minutes leading up to the hourly news on the station. Is it used as some kind of time signal?
The attached .wav file is a sample of the tune (apologies for the poor sound quality).
Thanks for your help.
Jonathan Grainger

My colleague Ernst Krempelsauer of Elektor's German editorial department delved into this query and set up email correspondence with Deutsche Welle. They kindly replied that the tune you heard is a rendering from the opera 'Fidelio' by Beethoven, 2nd Act. See also: www.intervalsignals.org

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Corrections & Updates

Sputnik Time Machine

January 2007, p. 42-45, ref. 050018-I

The third sentence under the heading 'Schematic diagram' should be modified to read:
Although these ICs may appear to be standard TTL devices, they are specially designed to handle the high voltage level of Nixie tubes. Like the Nixie tubes, they are not readily available through 'regular' commercial channels.

Shortwave Capture

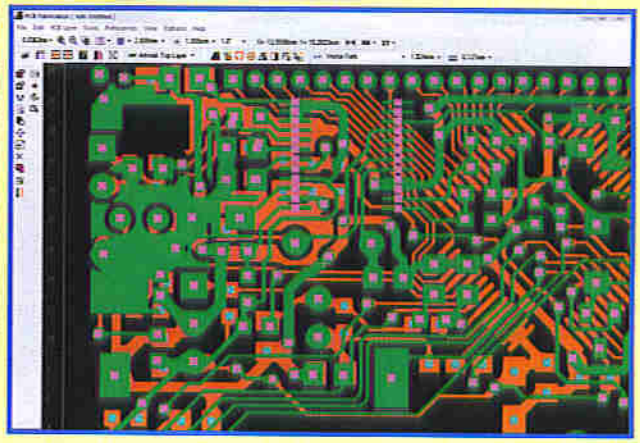
December 2006, p. 24-33, ref. 030417-I

Although the AT90S8515 used in the project is no longer recommended for new designs, it is still generally available (December 2006). A suggested replacement is the ATmega8515, which offers AT90S8515 compatibility thanks to its SC8515 compatibility mode fuse.

Profiler

January 2007, p. 14-18, ref. 060232-I

Figure 7 shows an incorrect screendump. The actual program included in the Profiler kit has more options for the design of PCB layouts. An example is shown in the screendump printed here.



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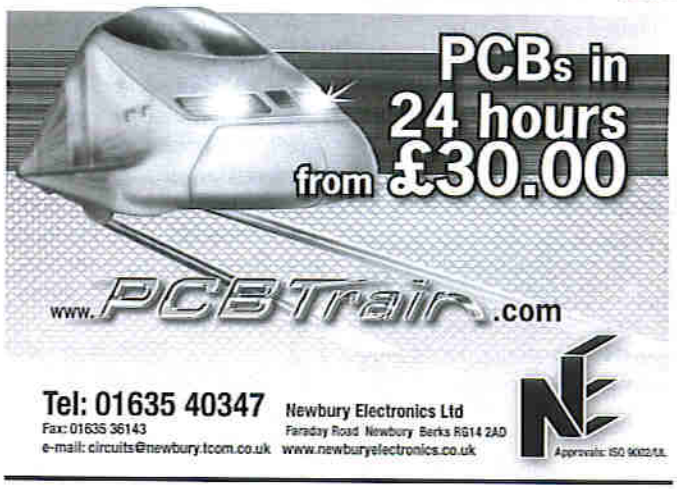

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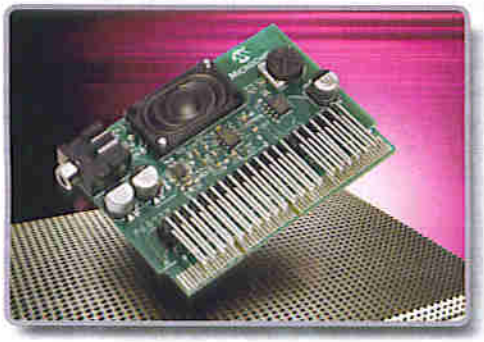

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High-Power
High-output LEDs come to town

Helmuth Lemme

The light output that can be obtained using LEDs has increased by four or five orders of magnitude over the last couple of decades. What is more, LEDs outlast all conventional light sources. As prices fall, LEDs become attractive in more and more applications.

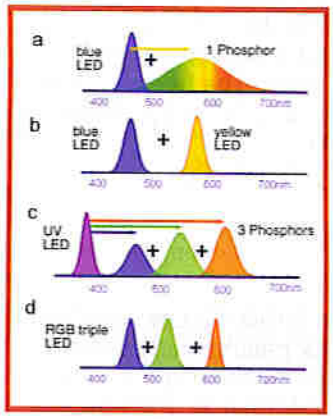


Figure 1. White LED light can be created in various ways: (a) a blue LED chip with a broadband phosphor layer (here yellow); (b) a blue chip and a yellow chip; (c) a UV chip with three phosphors (red, green and blue); or (d) a red, green and a blue LED in a single package (a so-called 'RGB' LED).

For a long time LEDs, with a typical operating current of 20 mA, were used only as indicators or displays. Thanks to research carried out by certain manufacturers, our level of understanding of the physical processes that occur in semiconductor materials has risen enormously, and it has been possible to build complex structures that achieve considerably increased levels of efficiency. A modern LED chip contains more than just a simple pn-junction: there will be a whole series of layers of different materials arranged and doped in various ways. The results are, literally, a sight for sore eyes: many modern LEDs are so powerful that they dangerous to look at directly.

Modern LEDs are based on compound semiconductors in two distinct families: the phosphides and the nitrides. Indium-gallium-aluminium phosphide (InGaAlP) covers the wavelengths from 570 nm (green) to nearly 1000 nm (infrared), with a forward voltage drop of 1.5 V to 2.3 V depending on the colour. Indium-gallium nitride (InGaN) devices run from 460 nm (blue) to 528 nm (green) with a forward voltage drop of 3.2 V to 3.8 V.

Aluminium nitride based devices can go down to about 200 nm, which is in the ultraviolet part of the spectrum, with a forward voltage drop of around 7 V. This means that practically all colours of the spectrum, visible and beyond, are available. Using the second family of materials it is also possible to make white LEDs by adding a phosphor to the chip to convert short-wavelength blue light into a range of other colours with longer wavelengths (**Figure 1**). The light that appears as white to the eye is in fact therefore not always exactly the same colour: a range of colour temperatures (from 'cold white' to 'warm white') can be produced by changing the relative amounts of the various spectral components present, just as can be done with fluorescent lamps. Intensive research is still being carried out into phosphors, and warmer white LEDs, with a higher proportion of red in their output, are expected to be available soon.

These are more suitable for lighting applications, particularly in terms of gaining acceptance for domestic use. So-called 'RGB' LEDs are also available, consisting of one red, one green and one blue chip in a single package. The overall colour of the LED can be changed by adjusting the three operating currents independently: this is a difficult trick to copy using an ordinary light source.

Strides in efficiency

The main factor in the enormous increases in brightness achieved by LEDs over recent years is improvement in the electro-optical conversion efficiency. This quantity is measured in lumen per watt (lm/W). Modern single-colour LEDs can manage around 65 to 80 lm/W (or more in some cases), while white LEDs manage 32 to 40 lm/W. Fluorescent tubes are not far ahead, at between 50 and 80 lm/W. Mains-powered incandescent bulbs produce 7 to 10 lm/W, 12 V halogen bulbs from 15 to 20 lm/W. For comparison, the earliest LEDs, on the market in 1970 or thereabouts, could manage only about 0.1 lm/W.

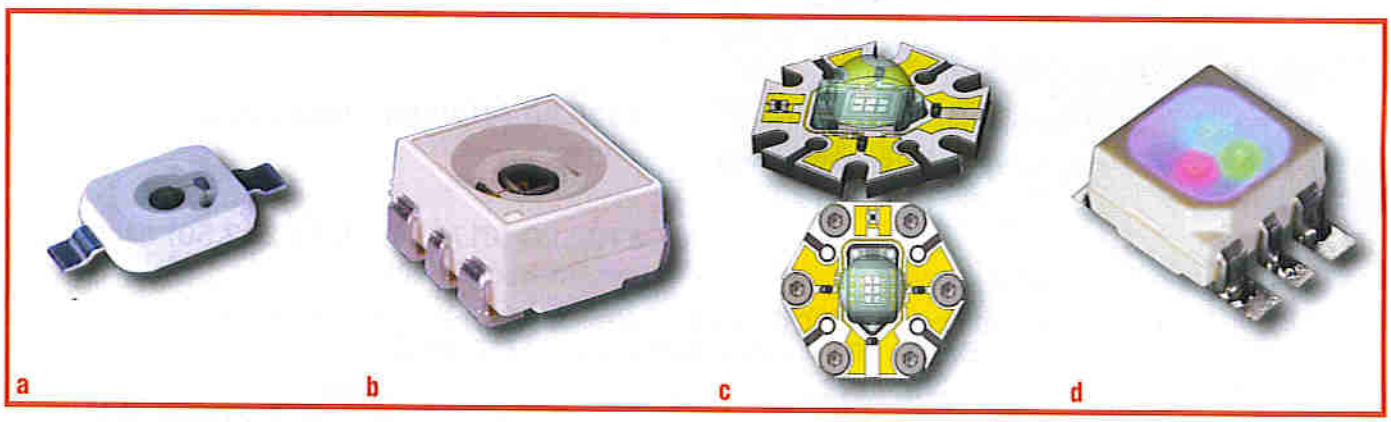


Figure 2. Designs of high-output LEDs: (a) 'Dragon'; (b) 'Power TOPLED'; (c) 'OSTAR'; (d) 'Multiled' with three differently-coloured chips in one package. (Source: Osram Opto Semiconductor)

When comparing LEDs with fluorescent tubes of apparently similar efficiency, it is important to keep in mind that the latter emit light essentially equally in all directions. This is suitable for room lighting, but in many applications a more focussed beam is wanted. LEDs produce such a beam naturally, without additional optics.

Output has also been increased by raising the operating current. The main manufacturers, Osram Opto Semiconductors in Regensburg, Germany and Lumileds (Philips) in San Jose, California, offer a wide range of devices suitable for use at currents of several hundred milliamps; the most powerful are rated at 1.5 A. The main limiting factor is removing heat from the device. The chip naturally becomes very hot and designers have developed various ingenious packages to attempt to provide as low a thermal resistance as possible between chip and circuit board (**Figure 2**). The circuit board is in turn usually fitted with a heatsink to dissipate the heat further.

Long-life LEDs

A further advantage of the LED is its long life. This is defined as the time taken for the brightness to fall to a given percentage of its original value. LEDs do not normally give up the ghost suddenly, but rather degrade gradually over time. On this point it is worth noting that some manufacturers use a percentage of 50 % whereas others use 70 %. Using the first definition, modern LEDs have quoted lifetimes of up to 100000 hours; in comparison, fluorescent lights have an average life of 10000 hours. Incandescent lamps have even shorter lives: mains bulbs typically last 1000 hours, and low-voltage halogen bulbs around 3000 hours.
Modern high-output LEDs can therefore replace incandescent bulbs in many applications. They have particular economic benefits in situations where changing the bulb is difficult or expensive, such as in traffic lights. In many cars the brake lights use LEDs, and the first LED headlamps are expected to appear soon. LEDs are now widely used in torches and LED bicycle lights are much safer and brighter than their incandescent cousins, which regularly burn out.

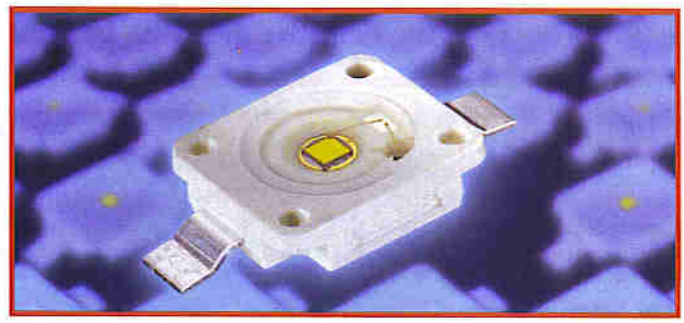
There are many new creative possibilities open to designers: LEDs can be installed in spaces where incandescent lamps would not be practical because of the heat they generate (**Figure 3**). RGB LEDs can have their colour controlled by computer, for example to change depending on the time of day.

The latest fad is to use a different colour to identify the different floors of hotels, offices, car parks and public buildings. To help the visitor get his bearings, the colour of the lighting inside the lift changes to match that of the floor just before each stop.

(060372-I)

The 'P4' from Seoul Semiconductor is, according to the manufacturer, the brightest LED in the world and can produce more than 240 lm of output at 1 A. At 350 mA the efficiency reaches 100 lm/W. Values of 135 lm/W are expected to be achieved in 2007, and 145 lm/W by the first quarter of 2008.

The 'Luxeon III Star Hex' from Lumileds produces up to 80 lm in the white version and up to 190 lm in orange-red. The heatsink has a characteristic six-pointed star shape.



The white 'Platinum DRAGON' from Osram Opto Semiconductors produces 75 lm at an operating current of 700 mA; in efficiency terms this is 30 lm/W. The package is similar in construction and appearance to the 'Golden DRAGON' high-output LED from the same manufacturer, but offers double the output power. With a price of less than one dollar, the 'Platinum DRAGON' delivers one of the best 'price-to-light-intensity' ratios in the market.

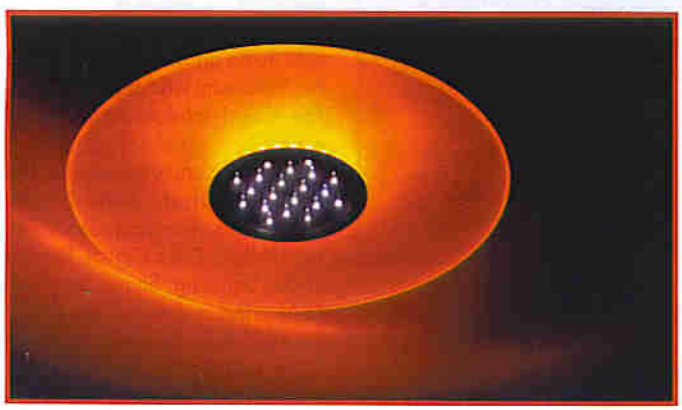


Figure 3. LEDs offer many new possibilities to designers. (Source: EBV)

Web links

Manufacturers (selection):

www.avagotech.com/led
www.eoi.com.tw
www.liteon.com.tw
www.lumileds.com
www.osram-os.com
www.plusopto.co.uk
www.zled.com
(Seoul Semiconductor)

Distributors (selection):

www.ultraleds.co.uk
www.uk.conrad.com
uk.farnell.com
www.dotlight.de
www.ebv.com
www.led1.de/shop
www.lumitronix.com

Freescale launches RAppID ToolBox

To help automotive customers streamline model-based software development, Freescale Semiconductor has introduced the RAppID ToolBox, a software solution that supports on-target, rapid prototyping for Freescale's 32-bit MPC5500 automotive microcontroller (MCU) family.

The RAppID ToolBox is designed to help control engineers reduce development time and cost when migrating from their application modeling environment to real-world implementations on automotive MCU platforms intended for production. The toolbox provides an ideal prototyping solution for a variety of automotive applications, such as engine and transmission control, anti-lock braking systems and chassis/suspension systems. Developers also can use the toolbox for non-automotive applications ranging from avionic systems to industrial printers to power generators.

Control engineers often validate their control models functionally by running auto-generated C code on commercially available rapid prototyping hardware. However, the prototyping hardware usually does not represent the MCU targeted for production. As a result, the engineers may not know the control algorithm's actual performance on the production MCU. In addition, engineers prefer to run their control algorithms on target MCUs early in the development cycle to validate their device selection. However, this can be a difficult, time-consuming task if they have to write the initialization, device drivers and scheduler code by hand, which adds to the development cycle time.

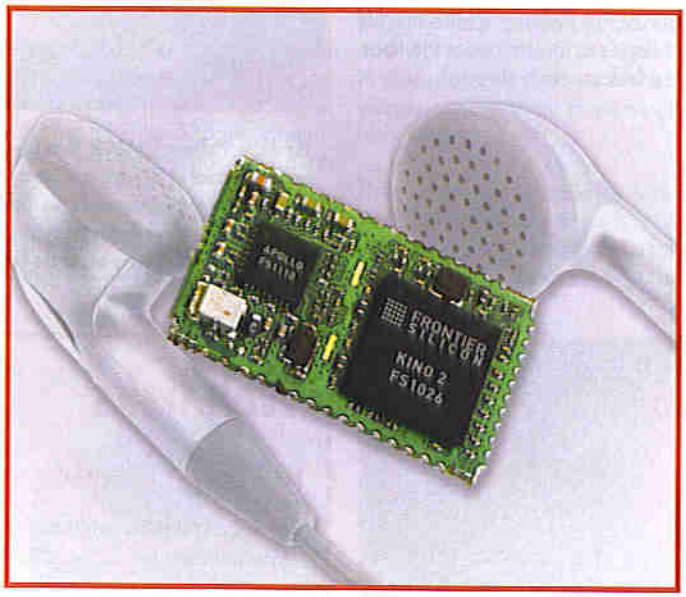
Freescale's RAppID ToolBox addresses these challenges by enabling engineers to execute their control models on MPC5500 MCU family hardware without writing code and to profile the execution of the code on their target MCU. Using the profiling feature of the RAppID ToolBox, application developers can study the performance of their control strategy on the target microcontroller early in the design cycle. The toolbox eliminates the need to invest in expensive prototyping hardware by supporting rapid prototyping on cost-effective evaluation boards for MPC5500 family devices, such as the MPC5554 MCU. Optimized DSP blocks enable developers to take advantage of the single-instruction/multiple-data (SIMD) capabilities of the MPC5554.

The Virtual Garage is a Freescale strategic business unit that provides software solutions The first RAppID ToolBox offering for the MPC5554 MCU is available now from Freescale's Virtual Garage. Software support for additional MPC5500 family devices is planned for the future.

For more information about the RAppID ToolBox, visit www.freescale.com/files/pr/vg.html.

(077001-III)

Smallest DAB radio module



Frontier Silicon has launched what they claim is the world's smallest and lowest-cost DAB digital radio module available today. The new Capri FS3010, measuring only 27 x 16 x 2.6 mm, is a miniature SMT (surface mount technology) module, which enables it to be fixed directly to the DAB radio system board and avoids the need for connectors. The small size and high level of integration in the module makes Capri ideal for low-power product applications such as tiny pocket DAB players and personal media MP3 handhelds, as well as PDAs and other portable entertainment devices.

The Capri module is based on Frontier Silicon's Apollo multi-band RF tuner and Kino 2 multistandard DAB and T-DMB digital baseband processor. Complete DAB digital radio systems can be built using Capri as a slave module controlled by a host processor, with several host interfaces available for control and data transport streams, including SPI, SCP, and I2S. The module receives both L-Band and Band 3 broadcasts, enabling worldwide DAB reception.

The Apollo/Kino 2 chipset combination is based on a highly-integrated system-on-chip architecture, with the individual chips themselves contributing to the overall low power consumption and compact size. Apollo measures just 5 x 5 x 0.9 mm, making it the world's smallest RF tuner for DAB digital radio reception, and requires very few external components.

Kino 2 measures 10 x 10 x 1.3 mm and integrates multiple peripherals and interfaces, which simplifies interfacing to the RF tuner and host processor.

Kino 2 executes multiple multimedia and communication-based tasks concurrent with the decoding and error correction of DAB audio and data streams. It decodes multiple audio and data services up to the maximum 1.8 Mbps.

The Capri module is available now.

Frontier Silicon customers include Bang & Olufsen, Bush, Denon, Goodmans, Grundig, JVC, Onkyo, Philips, PURE Digital, Roberts Radio, Samsung, Sharp, Sony and TEAC. The company has operations in UK, Ireland, China, South Korea and Japan.

www.frontier-silicon.com

(067216-V)

See the LITE on temperature monitoring

Lascar Electronics' EL-USB-LITE is claimed to redefine the concept of a small, low-cost temperature data logger. Weighing in at just 8.5 g and measuring 68 x 18 x 9.4mm the EL-USB-LITE may be small, but it delivers the essential features found on many larger, more expensive data loggers.

The EL-USB-LITE measures ambient temperatures from –10°C to +50°C at a sample rate of once every thirty minutes and can store over 4,000 readings. Setup and download of the data logger is simple: plug directly into an available USB port and open the Windows software which is supplied with the data logger. From here users can assign the logger name, set high and low alarm levels, and determine the logging start time. At any time during the logging period an integral push button will prompt a bi-colour LED to indicate the alarm status. Once the study is completed, data is downloaded as a text file; this can be graphed within the supplied software or exported to a spreadsheet for further analysis. A coin cell is supplied with the EL-USB-LITE and will provide a battery life of over one month's continuous use. The EL-USB-LITE's low cost makes it perfect for applications such as monitoring the temperature of goods during shipping or where a number of loggers may be required for a study. It is available immediately from Lascar Electronics Ltd. at a unit cost of £24.95.

www.lascarelectronics.com.

(077026-I)

Good progress in environmentally-friendly lead free soldering

TMD Technologies Ltd. has made significant advances in its programme to investigate the implications of new legislation related to environmentally-friendly lead free soldering processes in the manufacture of its microwave transmitters and associated products.

The lead-free programme is aimed at meeting the requirements of new 'green' EU legislation, which came into force in July 2006. The legislation restricts the use of a number of hazardous substances (RoHS).

Dr Shubo Gao, who was appointed last year with the responsibility for ensuring that TMD's future PCB assembly processes will be compatible with not only lead free but also any lead containing processes that may still be necessary for the near future, has reported that her team are now currently making and evaluating prototype PCB assemblies.

An investigation at TMD includes evaluation of the most popular brands of lead free solders and PCB pad finishes for hand soldering production.

The first batches of lead free PCB assembly prototypes are being tested for tin whisker growth, and are being compared with lead-tin soldered ones. After thoroughly testing many different choices of lead free assemblies, the results will be compared for reliability, ease of assembly, quality and cost.

The lead free programme was initiated early this year as a Knowledge Transfer Partnership between TMD and CRDM Research (Centre for Rapid Design & Manufacture), a Department of the Faculty of Technology, Buckinghamshire Chiltern University College. The programme is funded by the Department of Trade and Industry and TMD.

www.tmd.co.uk

(077026-VI)

Sensorless motor control platform

International Rectifier introduced a sensorless sinusoidal motor control platform that delivers quieter operation and higher efficiency for variable-speed pump applications up to 300 W. By effectively controlling pump operation over a wide range of flow requirements, variable-speed pumps can cut energy consumption by up to 50 percent. The latest iMOTION™ integrated design platform consists of a mixed-signal controller, the IRMCF371, and companion intelligent power module for the power stage, as well as algorithms, development software, and design tools.

The IRMCF371 mixed-signal control IC for pumps integrates all the control and analogue interface functions required for sensorless sinusoidal control of permanent magnet synchronous motors (PMS) using DC link current measurements. Analogue functions on the IC include differential amplifier, dual sample and hold circuits, and a 12-bit A/D converter to sample the low-voltage signal across the DC link shunt. The IRMCF371 incorporates IR's patented Motion Control Engine (MCETM), an algorithm editor that eliminates coding. An integrated 60 MIPS, 8-bit, 8051 microcontroller enables application layer software development, operating independently from the MCE, and does not compete for system resources such as interrupts or internal registers. The embedded Analogue Signal Engine (ASE™) integrates all the signal conditioning and conversion circuits required for single current shunt, sensorless control of a PMS motor.

The IRAMS06UP60B is a compact, intelligent power module optimized for electronic motor control in appliance applications that features a three-phase inverter with IC driver in a compact single in-line (SIP1) package. The device includes a shutdown function and over-current protection for safe operation. Other built-in functions include current feedback via dedicated internal shunt resistors and a temperature sensing device.
Design tools include communications software running on the 8051 microcontroller that gives the PC-based MCEDesigner™ software access to the control parameters and system variables in the shared memory. This allows modification of the controller set points and control loop gains and other constants without needing to modify or compile software.

www.irf.com/product-info/imotion/

(077026-III)

50Ω RF switch for DC – 6 GHz

Peregrine Semiconductor, announced availability of the RoHS-compliant PE42555 50-Ohm switch for high-performance broadband RF applications such as cellular infrastructure, WiMAX and high-precision RF applications. Manufactured on Peregrine's revolutionary HaRP™-enhanced UltraCMOS™ technology, the Single-Pole, Double-Throw (SPDT) device operates with exceptional linearity from DC to 6.0 GHz, pushing the upper limits for broadband performance past standard competitive devices. A proprietary design feature enables the device to eliminate the phase and insertion loss drift that occurs after a switching event, making the PE42555 the industry's fastest SPDT RF switch to reach a fully settled state.

Like all UltraCMOS HaRP-enhanced devices, the PE42555 features ultra-fast settling time, which allows systems to respond faster without a reduction in RF performance. A typical GaAs-based switch has a well-known gate lag in settling time which is not usually defined in its operational specification. This lag, which develops a phase and insertion loss drift, is non-existent on the UltraCMOS-based PE42555.
The device also delivers low insertion loss (0.65 dB @ 3.5 GHz and 0.90 dB @ 6 GHz); high IIP3 (>50 dBm DC-6 GHz); P1dB compression point of 34 dBm (DC-6 GHz); and high isolation (27 dB @ 3.5 GHz and 21 dB @ 6.0 GHz).
The PE42555 is available in the 4x4mm 20-lead QFN package. Volume production are available now through Peregrine's global sales representatives and its worldwide distribution partner, Richardson Electronics.

www.rell.com - www.psemi.com

(077026-IV)

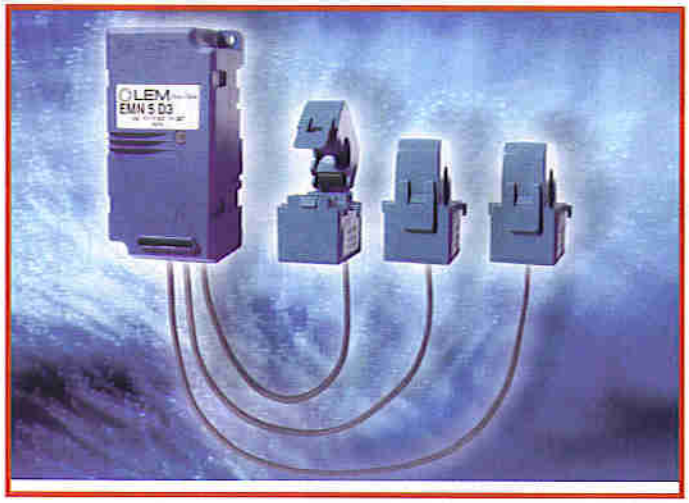
Wireless electrical sub-metering components

LEM launches the Wi-LEM (Wireless Local Energy Meter) family of components, an innovative solution that allows electricity consumption to be monitored and reduced. By using wireless communication, Wi-LEM greatly reduces the time, cost and disruption involved in deploying a sub-metering installation, increasing both the potential financial savings and removing many of the barriers to adopt this proven approach to reduce energy consumption.
The Wi-LEM family consists of:
• Energy Meter Nodes - an assembly of 1 to 3 current transducers with its signal processing module. They can be deployed to measure energy consumption at any point in the power cabinet and transmit the data.
• Mesh Nodes - a repeater linking various Nodes. They enable wireless communications throughout a large installation;
• Mesh Gate - a gateway managing the mesh network. It provides data through serial interface to a PC.

By measuring active, reactive and apparent energy plus maximum

current and minimum voltage, Energy Meter Nodes provide much more information than a simple sub-meter.

A variety of Energy Meter Nodes – all of which have their accuracy certified to IEC 62053 Active Energy Class 1 and Reactive Energy Class 3 – are available for 120 and 240 VAC voltage and configured for nominal currents from 5 to 100A. The compact sized, split-core transducers can easily be installed inside the limited free space of existing cabinets. Energy Meter Nodes take measurements at 5 to 30 minute intervals and transmit the results over the 2.4 GHz ISM band. The technologies make installation and commissioning very easy.



Mesh Nodes act as repeaters, and can be added to the network without any need for additional configuration or programming.

The Mesh Gate is a stand-alone wireless network management gateway that connects the transducer network with a PC using a serial interfaces RS-232 or RS-485 with a MODBUS RTU protocol. Each Mesh Gate allows monitoring of up to 240 Energy Meter Nodes. The 802.15.4 communication standard has a proven robustness in industrial and commercial environments.

Mesh Gate and Mesh Nodes were developed in close cooperation by Millennial Net, leader in Wireless Sensor Mesh Network technology.

www.lem.com

(077026-V)

ZigBee™ protocol platform with 2.4GHz IEEE 802.15.4 transceiver and net

Microchip announces three new offerings for wireless networking — the MRF24J40 transceiver, the MiWi™ protocol stack, and the ZENA™ wireless network analyzer.

The **MRF24J40** is Microchip's first RF transceiver. It is a 2.4GHz IEEE 802.15.4 transceiver for ZigBee™ and other proprietary wireless protocols in applications requiring low power and excellent RF performance, with very few external components. The device exceeds all standard IEEE 802.15.4 specifications, and provides full Media Access Controller (MAC) support and an Advanced Encryption Standard (AES) hardware encryption engine.

The MRF24J40 IEEE 802.15.4 transceiver is packaged in a 40-pin Pb-free/RoHS-compliant 6x6mm QFN package. It is sampling now.

Microchip currently offers the only fully-featured ZigBee protocol stack with a free of charge license and no royalty fees, which is also one of the smallest in the industry and provides a source-code format that allows designers to customize their product using a broad portfolio of PIC® microcontrollers.

However, since the full ZigBee protocol has now grown too large and complex for many applications, a large percentage of the market for IEEE 802.15.4 wireless networking is likely to use alternative, proprietary protocols. In addition, ZigBee protocol certification is a costly and cumbersome process.

Microchip's **MiWi protocol** is a free, small-footprint protocol developed for customers who do not need full ZigBee protocol interoperability but want to use standard IEEE 802.15.4 transceivers in low-cost peer-to-peer, star and mesh networks. No certification is required for MiWi protocol systems, and the protocol stack is provided under a free license, if used with Microchip's microcontrollers and the MRF24J40 transceiver.

The new **ZENA wireless network analyzer tool** (part number DM183023) uses a simple graphical interface to configure the free Microchip ZigBee and MiWi protocol stacks. This can reduce the code size by removing optional features; can cut development time by simplifying the interactions with the stacks; and can allow customization of the stack to fit a particular need. Consisting of both hardware and software, the ZENA wireless network analyzer that is capable of decoding IEEE 802.15.4 ZigBee and MiWi protocol packets — from the lowest layers to the top of the stack (including the security modules). The network-configuration display window allows users to see the traffic in real time, as it travels from one node to another. A session can also be saved to a file, to allow further analysis of all the network traffic.

Regardless of which protocol a design engineer selects, Microchip's complete solution enables them to rapidly evaluate and begin developing a vast array of wirelessly networked IEEE 802.15.4 applications, including security, lighting, access control, industrial monitoring and automation and personal computer peripherals.

In addition to the ZENA protocol analyzer, Microchip offers the **PICDEM™ Z 2.4 GHz Demonstration Kit** (part number DM163027-4), which is an easy-to-use evaluation and development platform for IEEE 802.15.4 application designers. The kit includes all of the hardware, software source code and printed circuit board (PCB) layout files needed to rapidly prototype wireless products. A detailed application note is also available on Microchip's website. This development platform is based on Microchip's PIC18 high-performance microcontroller family offering a wide selection of products with up to 128 kBytes of Flash program memory in 28- to 100-pin packages.

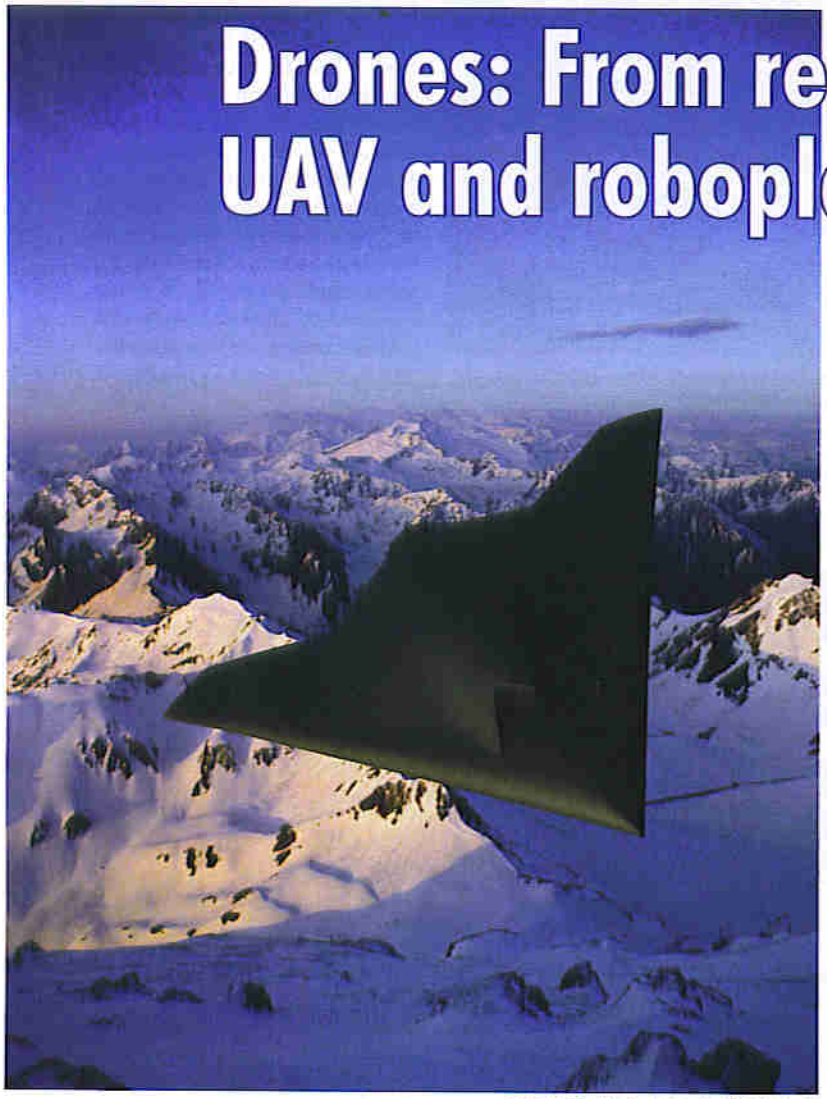
For additional information, visit Microchip's Web site at **www.microchip.com/zigbee.**

(077026-II)

Flying Robots

Drones: From remote control to UAV and roboplane

Michael Naderhirn and Benjamin Hackl



Dassault Aviation/Alain Ernoult. Photoref.: NEURON3_15cm.JPG

As processors become ever more powerful we are witnessing the rise of more 'intelligent' systems. We now look to sophisticated robots to assist or even replace us in difficult or hazardous environments. This is particularly true of military hardware where we have seen on our TV screens the use of unmanned aircraft and vehicles in some recent conflicts. The basic idea however is not so new; we take a look into the world of 'drones'...

The history of remotely controlled aircraft can be traced back at least to 1935 when the aircraft manufacturer De Havilland installed a radio control receiver in the passenger seat of a tiger moth biplane (christened the 'Queen Bee' [1]) for use in gunnery target practice. The bee analogy was maintained when unmanned aircraft were then given the name 'drones'. In the intervening 70 years the unrelenting drive for electronic devices to become smaller, faster and cheaper has led to the development of small artificial insects and also to 'flying robots' with control systems capable of piloting an aircraft autonomously. Falling costs and the availability of increasingly powerful processors means that enthusiastic amateurs and student groups have also been able to make contributions to the field of autonomous aircraft and helicopters.

UAV classification

Drones are categorised according to their size and purpose. Collectively they are known as *Unmanned Aerial Vehicles* (UAVs). Military versions of these aircraft basically fall into one of two categories; they can be passive; gathering intelligence, making radio intercepts and video reconnaissance or as *Unmanned Combat Aerial Vehicles* (UCAV) they can be fitted with weaponry enabling them to take part in offensive strikes.

The UAV is further classified by the method which it achieves flight; it can be classed as a fixed wing, a rotating wing or an ornithopter (flapping like a bird). Unmanned balloons and airships are lighter than air and are not classed as drones.

A further distinction is made with reference to the level of autonomy at which the UAV operates. At its simplest level the aircraft is controlled remotely via a radio link, the next level of complexity provides the aircraft with some degree of self-control (autopilot function). The most sophisticated aircraft receive GPS positional information and can follow

a flight plan using pre-programmed waypoints, sensors detect obstacles and there is sufficient on-board computing power to calculate an avoidance strategy while maintaining aircraft stability. An ongoing research topic involves the development of control algorithms enabling a group (swarm) of UAVs to collaborate on a task.
The most important classification however relates to the size of the craft:

Micro UAV

These drones can be operated by one person (**Figure 1**). In principle every average-sized model aircraft is a Micro-UAV. They are typically powered by either internal combustion or electric motors (**Figure 2**). The availability of relatively low-cost modelling components including sensors (gyroscopes and accelerometers) coupled to microprocessors enable rate-of-turn and acceleration values to be measured and an inertial guidance control system to be produced quite cheaply. On these grounds the Micro UAV is an attractive development platform for a small design team who could expect to produce a vehicle with a number of commercial applications at a reasonable cost.

Mini UAV

As you might expect this class of drone is bigger than the micro UAV and requires a larger team of operators on the ground. The 'Luna' system (**Figure 3**) produced by EMT is one example of this type of drone which has been used by the German army for a number of years, most recently seeing service in both Afghanistan and the Balkans. The Luna has a reconnaissance speed of 70 km/h with a maximum altitude of 3,500 m. It can stay aloft for around four hours carrying a payload of up to 4 kg.

MALE/HALE

MALE (*Medium Altitude Long Endurance*) is a category of UAV capable of long duration flights and operating at an altitude of 10 to 15 km. HALE (*High Altitude Long Endurance*) can operate for a similar time but at an altitude of around 20 km. Both of these are classed as large UAVs and can remain airborne for up to two days. Two of the most recognisable UAVs in this category are the Predator (MALE) and the Global Hawk (HALE) both operated by the US air force. The 1020 kg Predator (**Figure 4**) is powered by an Austrian Rotax-Motor developing around 100 hp through a pusher propeller which gives it a top speed of approximately 130 km/h at an altitude of 7600 m. It has an operational radius in the order of 640 km carrying a 200 kg load. A more recent version of the predator can be used as a UCAV. A long range variant is powered by a 130 hp German Thielert diesel [2] which is based upon the 1.7 litre engine used in the Mercedes A-class vehicles. The Global Hawk (**Figure 5**) uses a Rolls-Royce gas turbine giving it a top speed of around 600 km/h at an altitude of around 20,000 m. The craft has a 'global' range of 26,000 km with an all-up weight of 12 Tonnes. It can remain airborne for two days carrying a payload of 700 kg.

UCAV

The development of armed UCAVs for military use is currently a very active field of research and development. Preliminary performance figures of the X-45 currently under development by Boeing indicate that it has a maximum speed of Mach 0.85, service altitude of 12,000 m, an operational radius of 2000 km with a maximum payload of 200 kg. The UCAV shown on the title page is a prototype craft by the French company Dassault.

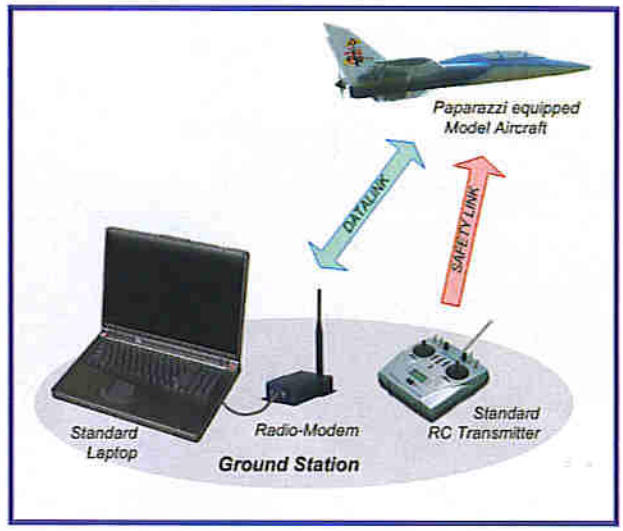


Figure 1.
The 'Open-source UAV' ground station consists of a laptop with a radio modem for communication and a standard R/C transmitter for autopilot backup.

Figure 2.
The 'Carolo' is a typical example of a micro UAV using model aircraft components.

Figure 3.
The German reconnaissance vehicle LUNA has been in service with the German military since 2003.

Figure 4.
The General Atomics 'Predator' is probably the most recognisable middle category (MALE) drone.

Figure 5.
The long endurance reconnaissance Global Hawk.

Flight control

The scope of this discussion will be limited to fixed-wing drones; they present fewer technical challenges and are by far the commonest type. **Figure 6** shows the structure of a typical flight control system. In a manned aircraft the pilot steers and controls the aircraft but with a UAV the pilot is replaced with a control loop, sensors and actuators to steer the UAV.
In order to maintain aircraft stability it is necessary for the control software to have information from sensors giving the craft's current situation. The following values are therefore important:

- Position (geographical coordinates and altitude)
- Speed in all three planes (forwards, sideways and altitude).
- Euler angle (Rotation around all three axes: pitch, yaw and roll **Figure 7**)

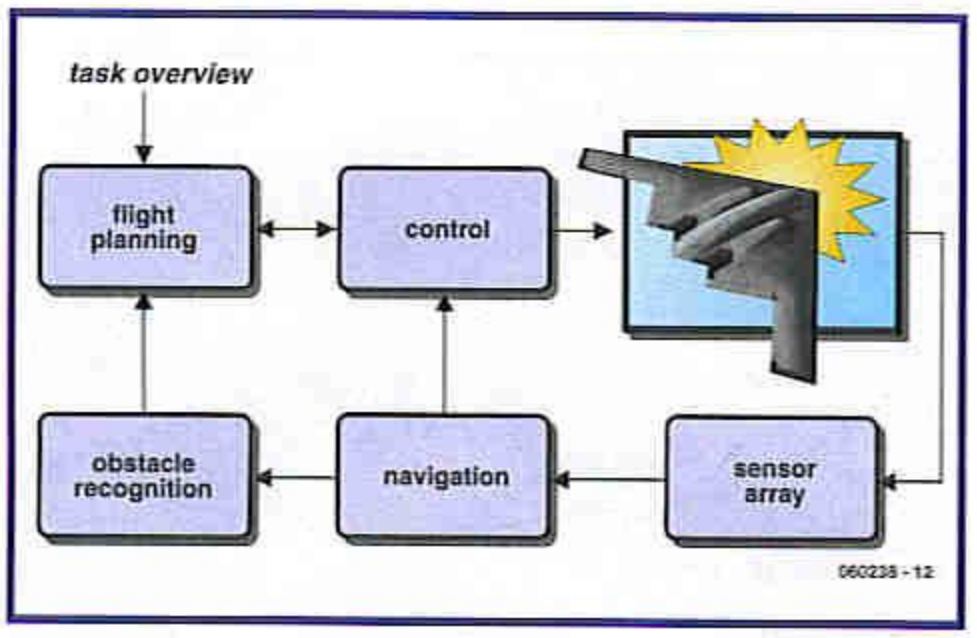


Figure 6.
The structure of a UAV-flight control system.

The aircraft's status can also be described using airspeed, angle of incidence and sideslip angle.
There are a number of different sensors available to measure these values. The Paparazzi UAV [3] uses a low-cost two-axis infrared thermometer for attitude determination while geographical coordinates are given by a GPS receiver. Altitude is provided by an absolute pressure sensor while rate-of-climb is measured by a dynamic air pressure sensor. The sensor readings are then scaled and converted into meaningful values in the navigation filter software.

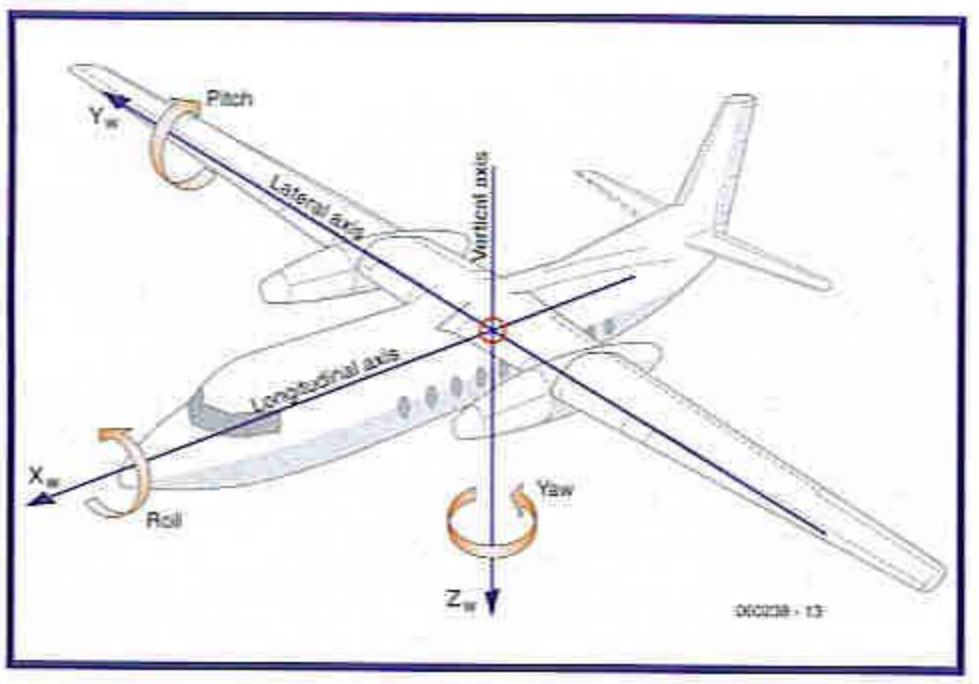


Figure 7.
Automatic aircraft control requires information from all three axes.

The greater the processing power the more sensors can be used, it also allows more complicated filter algorithms to be applied to the sensor data. Additional systems can also be integrated with the motion sensors already described for example an inertial gyroscope can also provide motion information. When this additional sensor data is correctly interpreted with the existing data it will give a more complete picture of the crafts behaviour. This process known as 'sensor fusion' mimics the process occurring in the brain when you view two pictures taken by a 3D camera from slightly different positions. Both images are just two dimensional but when the left and right pictures are viewed by the corresponding eye your brain is immediately able to extract depth information from the images. In the navigation system accelerometers are used together with gyroscopes to give angular velocity information.

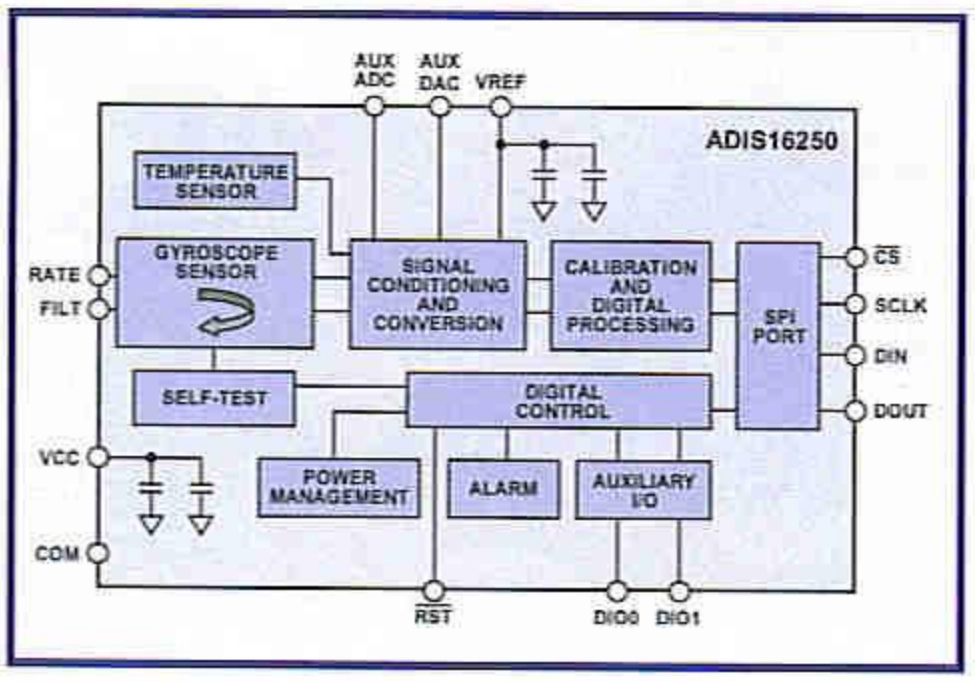


Figure 8.
This gyroscope evaluation board from Analog devices is also ideal for your own UAV project.

Figure 8 shows a gyroscope module evaluation board from Analog Devices [4]. The filter algorithm used in this device is also know as a Kalman filter. In comparison to simpler filtering techniques Kalman filtering requires the use of a powerful processor (by current day standards). The desired values are the pre-programmed waypoints defining the flight path. These waypoints can be programmed into the on-board navigation computer at the ground station before the flight begins or during flight over a radio link. Alternatively they can be generated automatically by a higher level control loop known as a trajectory planner; this represents a more sophisticated level of vehicular autonomy.

The topics of automatic trajectory planning, collision avoidance and coordination of groups (swarms) of autonomous UAVs are currently hot topics at numerous research institutes and universities.

The Record book

The first UAV to cross the north Atlantic non-stop was manufactured by the Australian company Aerosonde. The flight was made in August 1998 by the 13 kg twin-boom craft with a 2.9 m wing span carrying 7 l of fuel. It took almost 27 hours to fly the 3270 km course from Newfoundland to Scotland. The 20 cc 4-stroke Enya motor required just 5.7 litres of petrol to go the distance which works out at about 570 km per litre at an average speed of 120 km/h. This particular drone is designed to gather metrological data; its rear mounted 'pusher' prop allows the nose cone to be fitted with instruments where they are free from propeller wash.

Five years after this event in August 2003 a much smaller model aircraft named TAM 5, built by the model aircraft enthusiast Maynard Hill set an FAI record by making the 3000 km journey from Newfoundland to Ireland in 38 hr and 52 mins. Like the Aerosonde, conventional remote control was used for take-off and landing but the rest of the journey was controlled by an on-board autopilot using GPS positional data. The 5 kg balsa model has a wing span of 1.8 m and uses a modified 10 cc 4-stroke OS motor. It used all but 100 ml of its 3.3 l of fuel to make the crossing giving it a fuel economy figure of 1000 km per litre!

The altitude record set in August 2001 is held by Helios, a 75 m span electrically powered UAV which was developed by the Californian company AeroVironment in collaboration with NASA. The 580 kg craft flew to a height of 29,413 meters (about three times the height of a typical commercial flight!) driven by 14 solar-powered electric motors.

The largest unmanned aircraft at 106 tonnes was a converted Boeing 720 operated by NASA. Its final test manoeuvre carried out in December 1984 (controlled impact demonstration) was designed to test the effectiveness of a fuel additive during crash landing.

The December 2006 issue of New Scientist reported a test recently conducted on a BAC 111 airliner fitted with a UAV control interface to assess pilot workload while controlling a simulated swarm of UAVs in a battle situation. Pilots were on hand to perform the take-off and landing.

Web Links

www.aerodesign.de/peter/1999/Aerosonde/Aerosonde.html

www.aerosonde.com/drawarticle/4

www.aa.washington.edu/research/aerosonde/laima.htm

www.mfc-osnabrueck.com/TAM-5.htm

tam.plannet21.com/

www.dfrc.nasa.gov/Newsroom/X-Press/stories/050802/res_record.txt.html

www.dfrc.nasa.gov/gallery/movie/CID/index.html

www.newscientisttech.com/article/dn10675

Brain power

One or two ATmega processors usually provide sufficient processing power for a simple micro UAV but as system complexity increases for example with the use of Kalman filtering the addition of DSPs become essential. With more vehicle autonomy the necessity to process video information and data from additional sensors in real-time dictates that FPGAs and highly specialised DSPs need to be integrated into the vehicle's control system.

Payload

The on-board sensors usually take up the majority of the available payload in the UAV. The types of sensors fitted depend largely on the size of the UAV. Mikro-UAVs are most commonly fitted with cameras operating in the visible and IR part of the spectrum. Reconnaissance drones usually carry high-resolution and thermal imaging cameras for use in darkness and conditions of low visibility. Larger UAVs like the MQ-1 Predator are also fitted with conventional radar or SAR (Synthetic Aperture Radar). With the addition of anti-tank rockets this particular drone can be configured as a UCAV. The UAV payload can also consist of communications equipment to provide a radio-relay function, thereby extending the range of battlefield communications in difficult terrain. Fitted with ECM (Electronic Counter Measures) equipment the drone can also play a role in the so-called 'electronic warfare' where it can actively disrupt communication systems or identify the source of unwanted jamming signals.
The number of commercial applications for drones is also growing and they have been used for forestry surveillance and traffic monitoring. The number of internet sites devoted to this subject is evidence that the goal of producing a truly autonomous aircraft or helicopter is very appealing to many model fliers with electronics backgrounds.

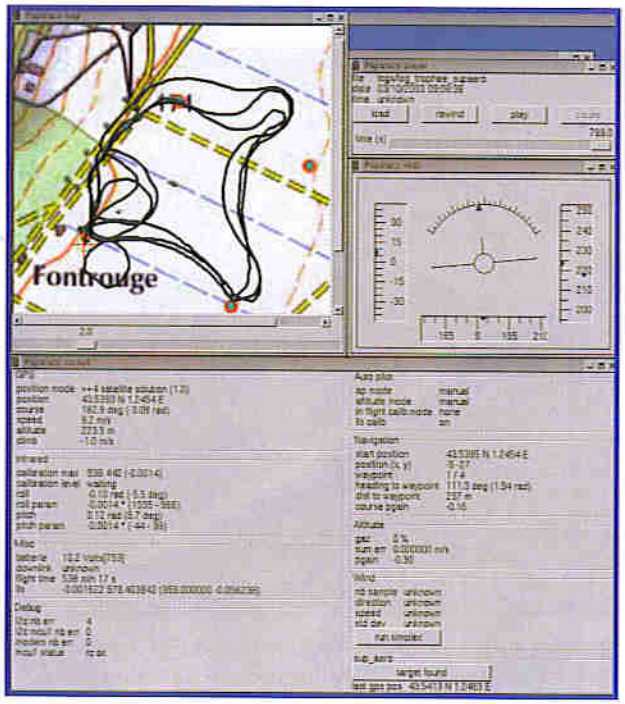


Figure 9.
Screen capture of a Paparazzi flight [3] during the 2003 Supaero contest.

Quad' in Karlsruhe [8]. The University of Delft in Holland has an ornithopter project 'Delfly' [9] while 'WITAS' [10] is a helicopter UAV from the Linköping University in Sweden (based on a commercial RMAX mini helicopter from Yamaha [11]) and of course the Paparazzi project in France.

DIY UAV?

Anyone fired up sufficiently to start work on their own UAV can make a good start by browsing the pages of the open-source projects described on the internet [3] [12]. The hardware designs are available in Eagle or target file format. Software for the paparazzi project is a compiled Linux distribution containing all the necessary files. Those of you who cannot wait to get their own project off the ground could of course splash out on one of the systems offered by the US companies MicroPilot [13] or UNAV [14] these ready-made auto pilot solutions are available in a number of different versions offering varying degrees of control sophistication but expect to pay somewhere in the five-figure (dollar) region for the most complex, fully-featured system.

(060238-1)

Projects and Competitions

A quick trawl of the Internet identifies several interesting open-source projects with a UAV theme. The most widely known is probably the 'Paparazzi' project [3], which began life at the ENAC in Toulouse and has been running for a number of years. In the process of development a small PCB fitted with ATmegas has been designed.
In Europe there are a number of competitions and conferences where researchers and design engineers meet, show off their latest designs to the public and generally exchange ideas. The European Micro Air Vehicle Conference and Competition (EMAV 2006) included a challenge with the aim to find the smallest autonomous aircraft able to most quickly fly a route using pre-programmed waypoints and finally to recognise a high-contrast symbol marked on the ground. It was impressive to see just how many of the entrants were able to complete the tasks. This year will see the third annual meeting of the 'US–European Competition and Workshop on Micro Air Vehicles' [5] held in Toulouse from the 18th to the 21st of September. There are also several small aircraft and helicopter UAV projects currently under development in some German universities for example the 'Carolo' in Braunschweig [6], the MAV series in Aachen [7] and the four rotor 'Air

Web Links

[1] www.jaapteeuwen.com/ww2aircraft/

[2] http://web.thielert.com/typo3/index.php?id=514&L=1

[3] www.nongnu.org/paparazzi/

[4] www.analog.com/UploadedFiles/Evaluation_Boards_Tools/170491614ADIS16250_PCBZ.pdf

[5] www.mav07.org

[6] www.ilr.ing.tu-bs.de/forschung/mav/

[7] http://www.dynamik.rwth-aachen.de/mav/

[8] www.presse.uni-karlsruhe.de/6400.php

[9] http://www.tudelft.nl/live/binaries/5ba8080d-6331-49cb-9d68-658e450299f9/doc/DO05-4-1microplane.pdf

[10] www.ida.liu.se/~marwz/papers/ICAPS06_System_Demo.pdf

[11] www.yamaha-motor.co.jp/global/industrial/sky/index.html

[12] www.albatross-uav.org

[13] www.micropilot.com

[14] www.u-nav.com

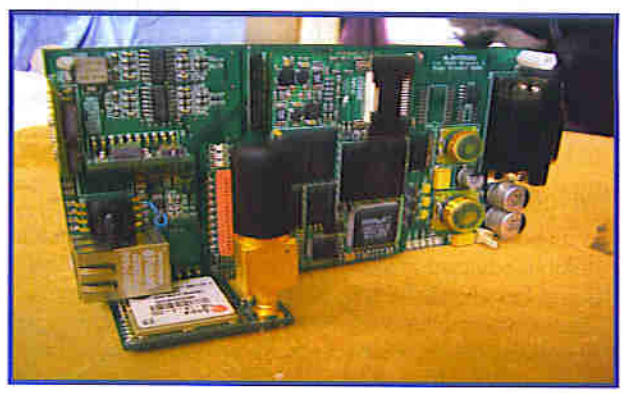


Figure 10.
Two main parts of the Albatross project [12] by John Stowers and Hugo Vincent from New Zealand. Micro-UAV (left) and main board fitted with an ARM controller (right).

Paltronix Limited

www.paltronix.com

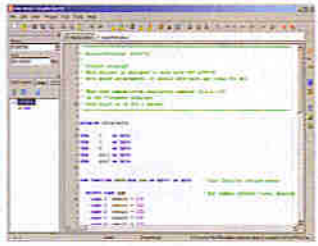
Microcontroller Development Tools

PICmicro Starter Pack now with ICD—still £99

- High-quality development board with on-board USB programmer and built-in I/O devices.
- Supports 8, 14, 18, 20, 28 and 40-pin PICs in 10F, 12F, 16F and 18F families.
- Now features mikroICD in-circuit debugger.
- Supplied with PIC16F877A.

The new EasyPIC4 development board now supports even more PICs including 8, 14, 18, 20, 28 and 40-pin devices from the 10F, 12F, 16F and 18F families. With its on-board USB programmer, mikroICD in-circuit debugger and useful I/O devices, the EasyPIC4 must be the best-value development board on the market. Our Starter Pack includes the EasyPIC4 board, USB cable, 16x2 LCD, 128x64 GLCD, DS1820 temperature sensor and a starter's guide with example programs in assembly language, BASIC, C and Pascal.

PICmicro BASIC, C and Pascal Compilers—from £59.50



- Easy to use with user-friendly IDE.
- Features simulator and mikroICD in-circuit debugger.
- Plentiful ready-written routines and example programs.
- 30% discount for customers purchasing EasyPIC4/BIGPIC4 development boards.

MikroElektronika's popular mikroBASIC, mikroC and mikroPascal compilers now include the mikroICD in-circuit debugger for use with the EasyPIC4 and BIGPIC4 development boards—programs can now be executed on a target PIC with variable values, special function registers, memory and EEPROM viewed on the PC screen. Great value at £85 each for mikroBASIC/mikroPascal and £145 for mikroC, or when bought with an EasyPIC4/BIGPIC4 only £59.50 each for mikroBASIC/mikroPascal, and £101.50 for mikroC.

We also stock development tools for 8051, ARM, AVR, dsPIC, PICmicro, PSoC and other devices—please see our website for details

Educational Products

PICmicro Microcontroller Training System—£99

- Teaches both assembly language programming and interfacing.
- Based on the popular PIC16F877A.
- Includes USB programmer.
- Features built-in I/O devices and solderless breadboard.
- Supplied with tutorial and program examples.

The PICmicro Microcontroller Training System is an ideal platform for students and hobbyists alike to learn about PIC microcontrollers. The experiment board features a range of built-in I/O devices and a solderless breadboard on which experiments may be conducted. Circuits are connected using the provided jumper wires. A USB programmer is also supplied and connects to the experiment board to program the PIC. Also included are a mains power adapter, 16x2 character LCD, connecting leads and a tutorial with example programs.

Digital Logic Training System—£99

- Ideal for learning about and experimenting with digital logic devices.
- Built-in logic and pulse switches, LEDs, 7-segment displays, piezo speaker, pulse generator, logic probe and solderless breadboard.
- Supplied with useful range of ICs, jumper wire and mains adapter.

The Digital Logic Training System makes learning about digital logic and experimenting with discrete logic ICs easy. The experiment board features a range of built-in I/O devices and a solderless breadboard on which experiments may be conducted. Circuits are connected using the provided jumper wires and the system includes features such as a power supply, pulse generator and logic probe. Also included is a mains power adapter, selection of ICs and a tutorial with example circuits.

We also stock other trainers, circuit labs and solderless breadboards—please see our website for details

Robots and Accessories

Robo-BOX 3.0 Robot Kit—£99

- Complete robot kit including controller, programming software and all mechanical parts.
- Build different robot configurations from one kit, including wheel-based and track-based.
- Program intelligence to follow light, detect collisions and trace lines.

Learn about, experiment and have fun with robotics with Robo-BOX 3.0—an incredibly easy-to-build yet adaptable and expandable robot. Various wheel-based and track-based robots can be built from the standard kit including light-following, collision-detecting and line-tracing models. Programming is carried out in graphical Logo. A range of low-cost options allow for easy expansion and the development of more sophisticated robots. We also stock similar robot kits based on PICmicro, 8051 and 68HC11 microcontrollers.

Test Equipment

PoScope USB Oscilloscope/Logic Analyser—only £99

- Low-cost PC-based instrument featuring oscilloscope, spectrum analyser, logic analyser, pattern generator, and chart recorder.
- Decodes serial buses including UART, SPI, I2C and 1-wire.
- Supplied with logic analyser test lead set, two oscilloscope probes, USB cable and software.

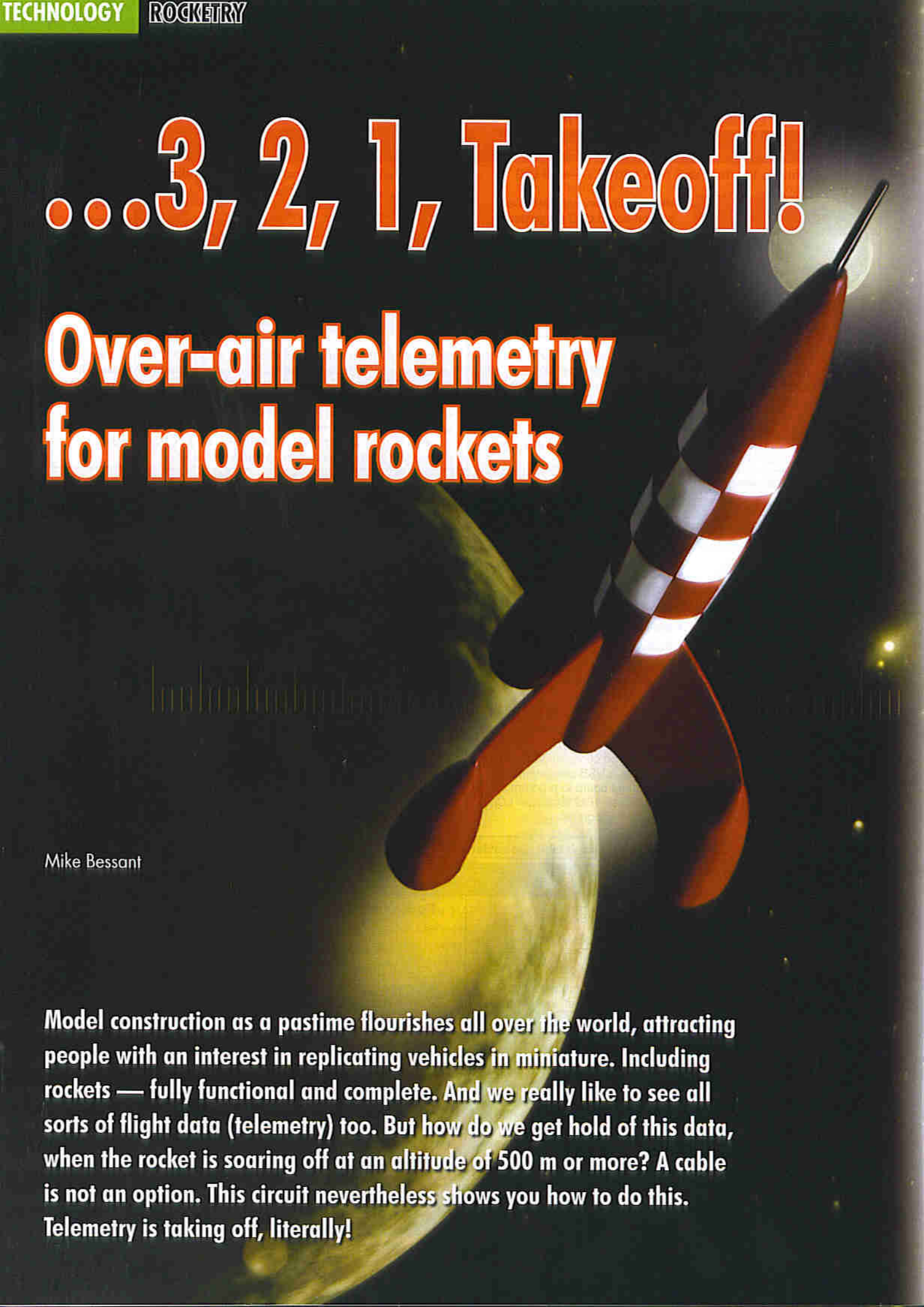
PoScope has to be one of the best-value pieces of test equipment available and features a dual channel oscilloscope (100Hz to 200kHz sample rate), 16 channel logic analyser (1kHz to 8MHz sample rate), and 8-channel pattern generator (1kHz to 1MHz). What makes the PoScope really useful to those working with microcontrollers is its ability to decode serial communications including RS-232, I2C, SPI and 1-wire. Priced at only £99, the PoScope comes with a USB cable, logic analyser test lead set, two oscilloscope probes and software.

Tel: 0845 226 9451 **Fax: 0845 226 9452** **Email: sales@paltronix.com**

All prices exclude UK delivery (£5 standard/£10 next-day) and VAT. Major credit and debit cards accepted. Secure online ordering.

...3, 2, 1, Takeoff!

Over-air telemetry for model rockets



Mike Bessant

Model construction as a pastime flourishes all over the world, attracting people with an interest in replicating vehicles in miniature. Including rockets — fully functional and complete. And we really like to see all sorts of flight data (telemetry) too. But how do we get hold of this data, when the rocket is soaring off at an altitude of 500 m or more? A cable is not an option. This circuit nevertheless shows you how to do this. Telemetry is taking off, literally!

The amateur rocket building community in Europe grows at a steady pace. According to a US agreement there is a distinction between two separate groups: those that occupy themselves with model rockets and those that work with high power engines. The vast majority of launchings fall in the category of model rockets. That is because high powers demand stringent safety requirements and relatively expensive materials.

A standard model rocket vehicle kit can be found in hobby shops from about £ 25, including the disposable engine. More advanced models that use a cluster engine to lift a usable cargo ('payload' in space terms) hundreds of meters or even a few kilometres into the sky can stimulate electronics enthusiasts with all kinds of interesting challenges. Applications range from aviation technology to environmental monitoring.

On board

An example of a payload is described here. The system can transfer information from the sensors wirelessly to a ground station. The starting point is a real-time video link. Aside from the high entertainment value of on-board video images, they also contain useful information regarding various flight data such as rotation speed, highest point, time instant of parachute deployment, etcetera. This data can also be related to data from other sensors that are on also board.

The audio channel of the video link proved to be eminently suitable to send the sensor data. The result was better than that obtained from using a separate transmitter. The audio and video signals are received on the ground and stored on a portable video recorder or a camcorder for further analysis on a PC. Data storage on board of the rocket is also a possibility of course, but if something goes wrong you would really like to be able to access this data. It is usually the case that those rockets that have something wrong with them are the ones that end in fireworks, at which point the data stored on board cannot be rescued any more. A second advantage of using a transmitter is that the rocket can be easily found after landing, using a directional antenna.

Figure 1 shows the block diagram of the telemetry system. The part that flies with the rocket is contained on one circuit board that fits in a standard 6 cm model rocket tube. One side of the Airborne Video Telemetry (AV-T) board is fitted with the telemetry components, while the other side contains the camera and transmitter module (see **Figure 2**).

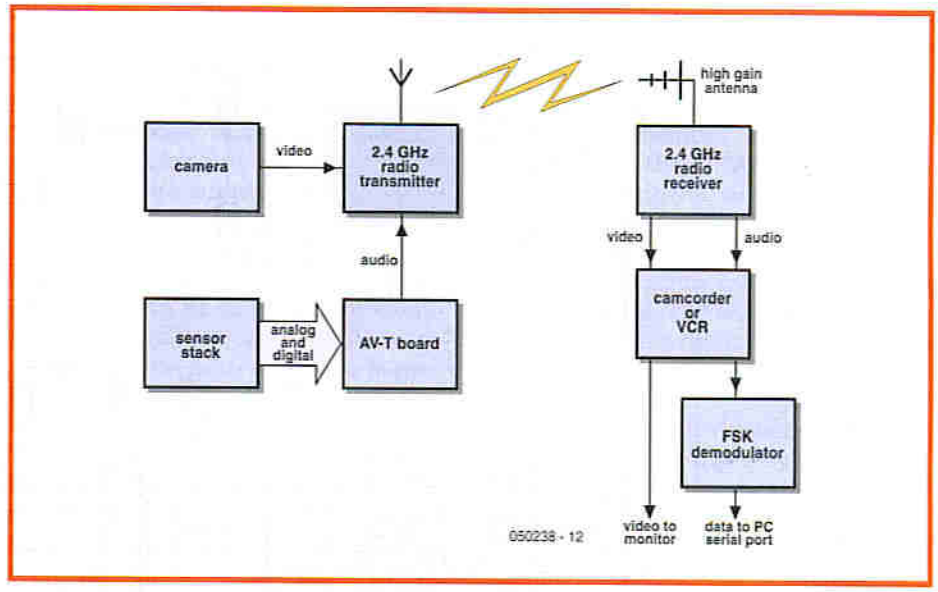


Figure 1. Block diagram of the air borne (hopefully skyborne!) telemetry system.

The AV-T board has a versatile sensor port and can be configured for a large number of analogue and digital sensors using the BASIC programming language. The sensors and their signal conditioning electronics are fitted on several stackable printed circuit boards that are interconnected with a ribbon cable. **Figure 2** shows that the sensor boards are perpendicular to the main circuit board. In this way, sensors such as accelerometers and gyroscopes are correctly aligned with the longitudinal axis of the rocket. A typical payload would consist of one or more of the following sensors: accelerometer, gyroscope, barometer, Hall-sensor and GPS receiver.

Picture

The selection of a usable camera is determined by working backwards from the video standard of the recording system on the ground. We have assumed a PAL TV system, but the principle is the same for other standards.
There is now a large choice of miniature full-colour cameras that can be bought for less than £ 75. Cameras based on CMOS technology are usually cheaper, use less energy, but are generally not as good as their CCD counterparts.
During the flight the camera is subjected to continually changing light conditions. The rocket rotates around its axis and turns around at the highest point. In order to get pictures of reasonable quality it is best to choose a camera that is fitted with automatic

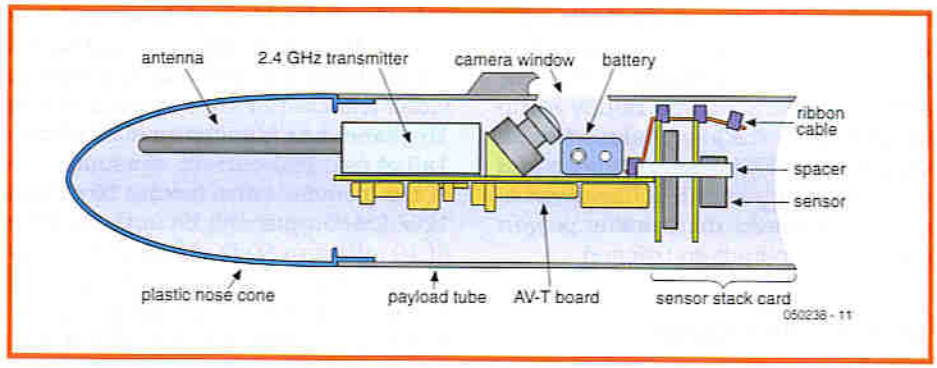


Figure 2. Cutaway view of the payload, showing an example of construction inside the rocket.

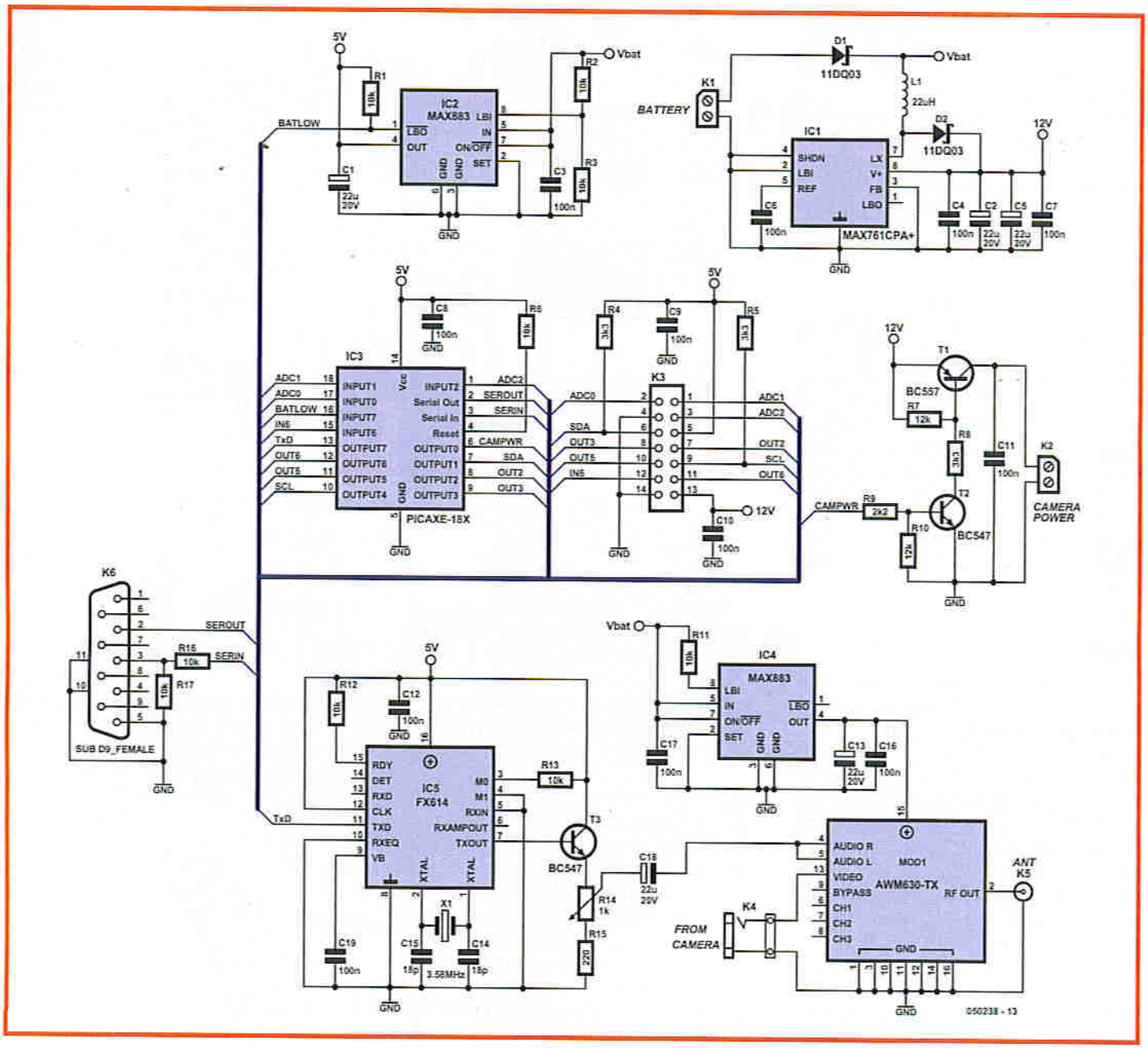


Figure 3. Circuit diagram of the AVT circuit board.

gain control (AGC), electronic shutter speed (AES), white balance (AWB) and backlight compensation (BLC).
A standard PAL TV camera including the lens will easily fit in a cube with 3 cm sides. The weight will be about 10 grams and the camera will be happy with 50 mA at 12 V. The standard resolution amounts to 380 TV lines and the output is typically 1 V_{pp} into 75 Ω. Three wires suffice to connect the camera: power supply, video-output and ground.

Transmitter and antenna

An easy way to transmit live video over a few hundred meters (vertically) is to use cheap transmitter and receiver modules intended for consumer applications such as security cameras and TV video links. Most of these modules use the Industrial, Scientific and Medical (ISM) band at 2.4 GHz. A standard video transmit module weighs about 15 g and has dimensions of about 1×3×4 cm. The current consumption of the module is also around 50 mA at 12 V. The output will be in the region of 10 mW into 50 Ω via an SMA connector. Four signal wires are generally enough: (video and audio inputs, power and ground). If the camera and transmitter module use the same video standard then the output of the first can be directly connected to the input of the second.

Rules

National organisations such as OfCom and DTI in the UK, or FCC in the US, look after the rules for the ISM bands, so that only products that comply with these rules are permitted. These rules vary from country to country and it is the responsibility of the user to use only equipment that complies with the requirements of the country it is used in.
An example of a restriction is that the antenna in the ISM band is not allowed to have any significant gain. So an om-

nidirectional antenna has to be used. This type of antenna radiates the same amount of energy in all directions. Fortunately this is just what we need for this application. Omni directional ¼λ whip antennas that fit directly to an SMA connector are readily available. It is ideal if the antenna can be fitted in the plastic nose cone of the rocket, located as far as is possible from the circuit board, the batteries and other metal objects.

AV-T board

Figure 3 shows the schematic of the Airborne-Video-Telemetry-system. The circuit uses a PICAXE microcontroller (IC3). The PICAXE family consists of PIC Flash microcontrollers from Microchip which are pre-programmed by a company called Revolution Education Ltd (REL) with bootstrap code. With this code, the PICAXE microcontroller can be repeatedly programmed in BASIC with a simple 3-wire connection to the serial port of a PC. In this way, a conventional In-Circuit-Programmer (ICP) is not necessary.

The PICAXE family comprises 8, 18, 28 and 40-pin versions that REL sells for about the same price as that of a one-off unprogrammed PIC.
The AV-T uses a PICAXE-18X (the bootstrap code indicates that it is a PIC16F88). In addition to the standard general-purpose I/O-lines, the IC contains three 10-bit ADCs, an I²C bus and a UART port. The AV-T has a serial port to support the ICP and software development with the PICAXE Programming Editor [1]. This Windows program has a version of BASIC that supports many special interface commands (readadc, count, pwmout, readi2c, etc.). This greatly simplifies the development of the software and the testing of the sensors. The internal PICAXE clock can be programmed to run at either 4 or 8 MHz. This corresponds to about 10 k or 20 k BASIC instructions per second. The non-volatile memory of the PICAXE can hold about 600 lines of BASIC code.
The FX614 (IC5) is an FSK-modem (Frequency Shift Key) that has been designed for communications using asynchronous data at a speed of 1200 bps (bits per second). In the transmit mode, which is controlled by the AV-T, two discrete frequencies are produced at the output. These depend on the level of the logic signal at the serial port of the PICAXE. A logic zero results in 2200 Hz and a logic one in 1200 Hz. This FSK signal consists of a sinewave with low distortion and has continuous phase when transitioning between the two frequencies. In this way unwanted higher harmonic frequencies are avoided at the audio input of the video transmitter. These generally have a bandwidth from 50 Hz to 10 kHz. The amplitude of the FSK signal can be adjusted with P1 to maximum modulation but without causing distortion or interference with the video signal. For the transmitter module we use an AWM630-TX from Saelig.
The dimensions of the AV-T PCB are determined by the diameter of the rocket, together with the dimensions of the video module, camera and battery. This results in a reasonably large PCB of 6 by 13 cm (see **Figure 5**). As a result the prototype could be built with standard components. The PCB artwork files can be downloaded from www.elektor-electronics.co.uk
During the launch the circuit board is subjected to an acceleration of several g (1 g = 9.8 m/s²). The leads of some components could bend as a result, for example those of an axial tantalum capacitor. It is best to fix those components that are sensitive to this in place with silicon adhesive.

Power supply

The MAX761 (IC1) step-up switch-mode power supply delivers a regulated 12 V/150 mA at a minimal input voltage of 5 V. A 9-V PP3 battery is therefore eminently suitable as the energy source for the video camera and the transmitter. After the rocket has landed, the PICAXE switches off the camera power supply (via T1 and T2), but leaves the transmitter module powered up. The rocket can then be easily found by tracking the transmitted signal. The battery is therefore loaded with the maximum load for only a few minutes.

The MAX761 uses a switching frequency of 300 kHz. In this way the efficiency remains reasonably high. A disadvantage is that at this frequency extra attention has to be paid to the PCB layout and the choice of components. L1, in addition to having a ferrite core, needs to have a saturation current of more than 1 A and a DC resistance of less than 0.1 Ω. To limit radiated energy, toroidal cores, pot cores or shielded inductors have to be used. Diode D2 needs to be a high-speed 1 A Schottky diode. The prime consideration for the output capacitors C2, C4 and C5 is a low series resistance (low ESR). That is because ESR is the main cause of ripple in the output voltage.

In addition to the AV-T circuitry, the MAX883 (IC2), a low-drop, 5-V regulator IC also provides the power for the sensors that are connected to the ribbon cable. Depending on the battery

Author's rocket at various launch stages..

DESIGN CONTEST:
Sky-rocket your own design!

Elektor Electronics and NERO (Dutch federation for Rocket Research) together have organised a design contest for an interesting payload that, based on apparent suitability, will fly on the rocket that will attempt to break the European altitude record in 2008. In this attempt it is the intention to reach an altitude of no less than 40 km.

NERO has occupied itself since 1959 with the design, construction and launching of amateur rockets. In the past, NERO has bagged a number of records: the highest amateur rocket flight in the Netherlands, the first European flight with a hybrid motor and the first Dutch two-stage rocket flight. Rocket amateurs from NERO are busy with a project to break the European altitude record for amateur rockets. A project team of 14 people is busy with the design and construction of a two-stage rocket that will have to turn this into reality in 2008. The goal is to take the UK altitude record, that stands at over ten kilometres, to the Netherlands and improve it by about thirty kilometres.

The submitted design needs to contain an interesting experiment (for example measuring the Earth's magnetic field with sensors or measure rotation based on the sun's position). The mechanical and electronic requirements that the design has to comply with can be downloaded from the Elektor Electronics website [3].

The submission must comprise an electronic as well as a mechanical design. In addition the design needs to pay attention to:

- **the method of testing, qualifying and calibrating on the ground;**
- **the method of activation in the rocket;**
- **the method of protection against vacuum and condensation;**
- **the relevance of altitude for the experiment;**
- **the method of storage and retrieval of the measurement data.**

A winner will be chosen on the basis of the submitted designs. The winner may let the design fly on a qualification flight in the Netherlands. If the design is deemed suitable for launching with the altitude record rocket (safe enough, light enough and reliable enough) then launching with the altitude record rocket becomes an option. Due to air traffic regulations the altitude record will take place outside the Netherlands — the exact location is not known yet. Scandinavia or Poland are under consideration. A complete ground station will be built on location, complete with tents, generators and assembly facilities.

Designs need to be submitted to Elektor Electronics before 1 July 2007 (send to Elektor Electronics, Regus Brentford, 1000 Great West Road, Brentford TW8 9HH, England, mentioning 'Rocket Contest').

The rocket that will be built for the record attempt is called H10. It will have two motors with a total thrust of 26,000 Ns. These motors will give the rocket an initial acceleration of 15 g and a maximum speed in excess of Mach 3. Several qualification flights – where the developed components will be tested – will be carried out in the Netherlands, before an attempt is made to break the record abroad. More than 400 mechanical parts will be especially manufactured to make this flight possible.

The rocket is also subjected to extreme environmental conditions in the stratosphere. Aerodynamic heating of the nose cone up to 300 degrees, ambient temperatures of –60°C and an air pressure of less than 1% of the air pressure at ground level. Two parachutes, a pilot parachute and a main parachute ensure a soft landing. The decoupling system of the first stage and the opening of the parachutes are driven with the aid of pyrotechnics.

A remarkable aspect of this record attempt is that this rocket will fly with complete instrumentation to this altitude. So, for example, a GPS module, a video camera and a transmitter will be taken along. The central board computer compares the information from several sensors in order to determine the reliability of the sensor data. Both the video images from the rocket as well as the data collected by the board computer will finally be transmitted to the ground station using a powerful transmitter.

The ground station receives the video and data signals. Three antennas are used for this. The purpose of the first antenna is to receive the signal during the first part of the flight. The second antenna is mounted on a platform with two degrees of freedom and uses the received GPS signal to point the dish antenna to that part of the sky where the rocket is. The third antenna serves as backup and is able to receive during the last part of the flight – just before the landing. The strongest signal from the three antennas is selected and split across three computer monitors. The first screen will show the real-time video signal from the rocket, the second screen a map of the surroundings with the position of the rocket superimposed and on the third screen vital information regarding the functioning of the board systems of the H10 and the actual altitude of course!

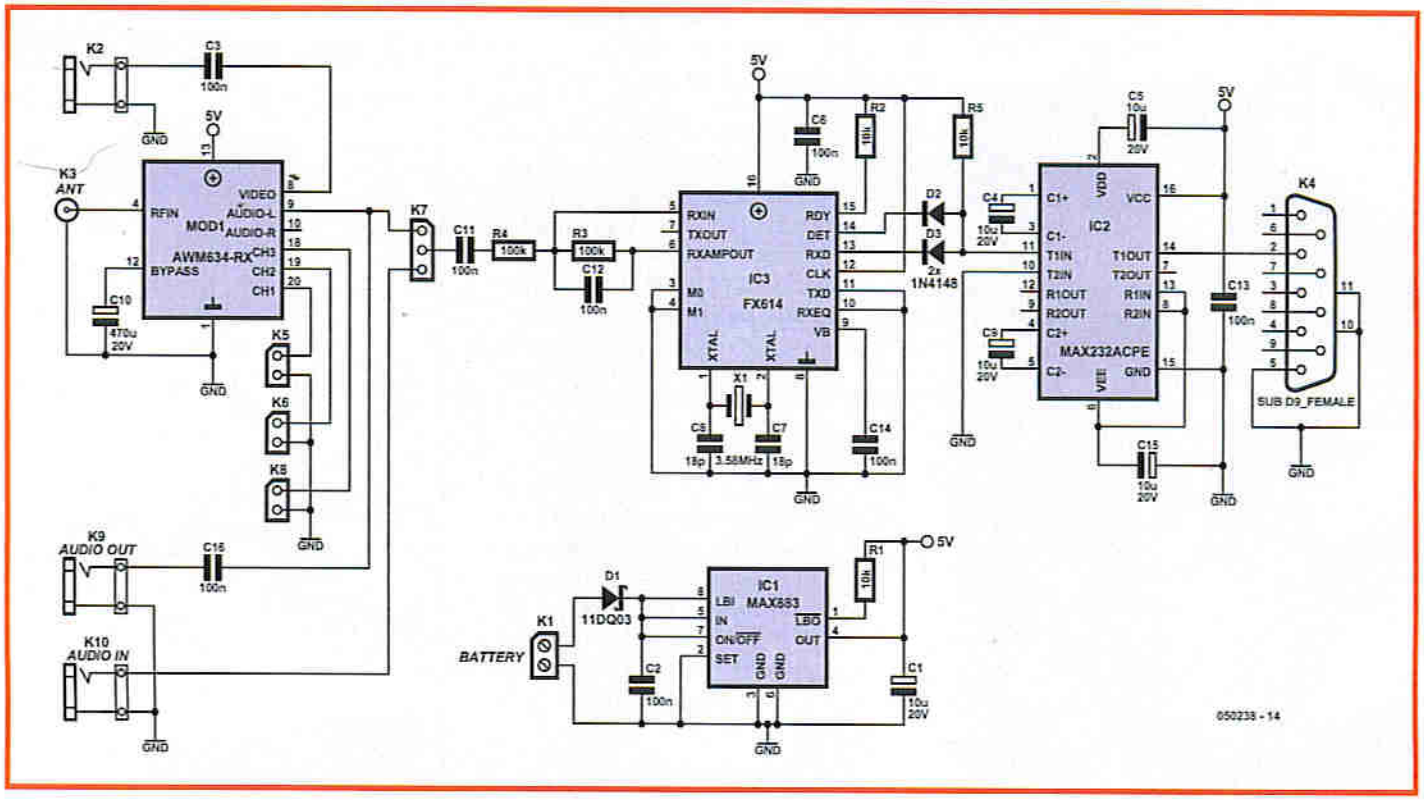


Figure 4. Circuit diagram of the 2.4 GHz receiver and the FSK demodulator.

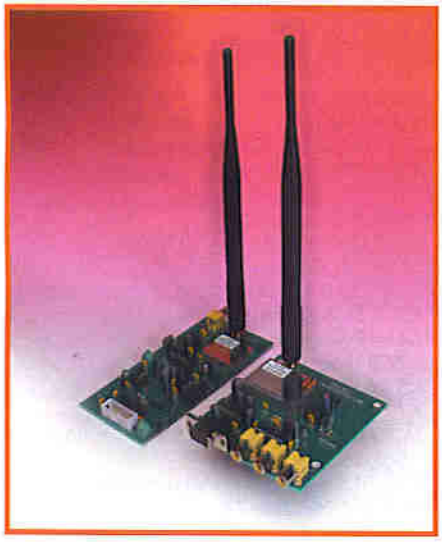
that is used, the MAX883 can deliver more that 100 mA. Output $\overline{\text{LBO}}$ goes low when the input voltage drops below 6 V. The PICAXE checks the output from the MAX883 and can generate a warning when the battery voltage is too low. The transmitter module has its own regulator (IC4).

Ground station

At the receiving side there are no limitations with regards to the antenna used. So we can use a Yagi directional antenna with high gain. The range through the air (in a straight line without any obstacles) can then amount to several kilometres. The greater the number of elements on the Yagi, the larger the range and directional sensitivity. But since the antenna has to be pointed manually towards the rocket, high directional sensitivity and large size are not convenient.

There are plenty of choices for cheap ISM video/audio receivers and most of them can be easily attached to the base of the antenna to limit the cable losses at 2.4 GHz.

The circuit that is mounted on the antenna (**Figure 4**), uses a small Airwave AWM634-RX module that is powered from a battery and a 5-V low-drop voltage regulator (IC1). Jumpers K5, K6 and K8 are used to select one of the four standard frequency bands. K10 allows an external audio signal to be connected. K7 allows the choice whether the direct signal or the external signal is connected to the FSK-demodulator. The received video signal is available



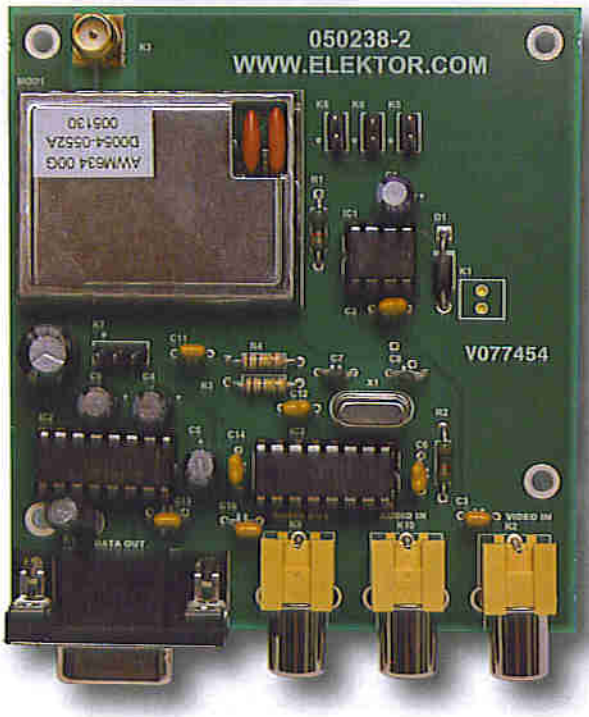
Firmware

Our telemetry system has no firmware — the idea being that you write it yourself to match the sensors you wish to use. This is unlikely to cause problems as the programming language used on the PICAXE micros is really simple.

The programming language also contains sufficient resources and support for signal measurement and the use of the I2C bus, making application software writing a breeze, really.

To simplify copying your own software into the PICAXE, the transmitter circuit is equipped with a programming interface. The circuit is connected to a PC via an RS232 cable, whereupon the software can be transferred in a simple manner.

Figure 5. Components mounted on two of our prototype boards. Above: transmitter; below: receiver.



on the outside on K2.

The demodulator circuit for the data is based on the same chip as that used on the AV-T board, the FX614. In this circuit however, pins M0 and M1 are set so that only reception is enabled. The demodulator has an input amplifier and a band-pass filter. If the signal drops below a certain reference level the DET-output prevents erroneous data from being sent to the serial port of the PC.

To record the data it is best to use a camcorder with an S-video input. The video signal can be played back on a TV and the demodulated audio signal can be connected to the serial port. In this way synchronised video and data can be examined.

SelmaWare Solution's StampPlot Pro software generates nice charts from data received via the serial port. This Windows application accepts data as a string or as binary values with up to ten channels. The program has many powerful options that can store raw or processed analogue and digital data, attach a time stamp and display it on a chart. A free evaluation version can be downloaded from the SelmaWare website [2]. You can also find a number of example applications on this website, including an application that overlays a recording from a PC-video capture card with a StampPlot Pro screen.

Although the system described in this article has been developed for rocket applications, it is also suitable for other video/telemetry systems such as remote controlled aircraft including helicopters, cars, boats or other interesting development projects.

(050238-1)

Web links

[1] www.picaxe.co.uk

[2] www.selmaware.com

[3] www.elektor-electronics.co.uk

COMPONENTS LIST

(transmitter)

Resistors
R1,R2,R3,R6,R11,R12,R13,R16,R17 = 10kΩ
R4,R5,R8 = 3kΩ3
R9 = 2kΩ2
R7,R10 = 12kΩ
R14 = 1kΩ preset
R15 = 220Ω

Capacitors
C1,C2,C5,C13,C18 = 22µF 16V radial
C3,C4,C6,C7-C12,C16,C17,C19 = 100nF
C14,C15 = 18pF

Semiconductors
D1,D2 = 11DQ03
IC1 = MAX761
IC2,IC4 = MAX883
IC3 = PICAXE-18X
IC5 = FX614
T1 = BC557
T2,T3 = BC547

Miscellaneous
K1,K2 = 2-way PCB terminal block (e.g. Phoenix Contact # 1725656)
K3 = 14-way boxheader
K4 = RCA connector
K5 = SMA connector
K6 = 9-way sub-D connector, female, PCB mount
L1 = 22 µH
MOD1 = AWM630-TX (Low Power Radio Solutions)
X1 = 3.579MHz (3.58MHz) quartz crystal
PCB, ref. 050238-1

(receiver)

Resistors
R1,R2,R5 = 10kΩ
R3,R4 = 100kΩ

Capacitors
C1 = 22µF 16V radial
C2,C3,C6,C7,C8,C11-C14,C16 = 100nF
C4,C5,C9,C15 = 10µF 16V radial
C10 = 470µF 16V radial

Semiconductors
D1 = 11DQ03
D2,D3 = 1N4148
IC1 = MAX883
IC2 = MAX232 (DIP case)
IC3 = FX614

Miscellaneous
K1 = 2-way PCB terminal block (e.g. Phoenix Contact 1725656)
K2,K9,K10 = RCA jack, PCB mount
K3 = SMA connector
K4 = 9-way sub-D connector, female, PCB mount
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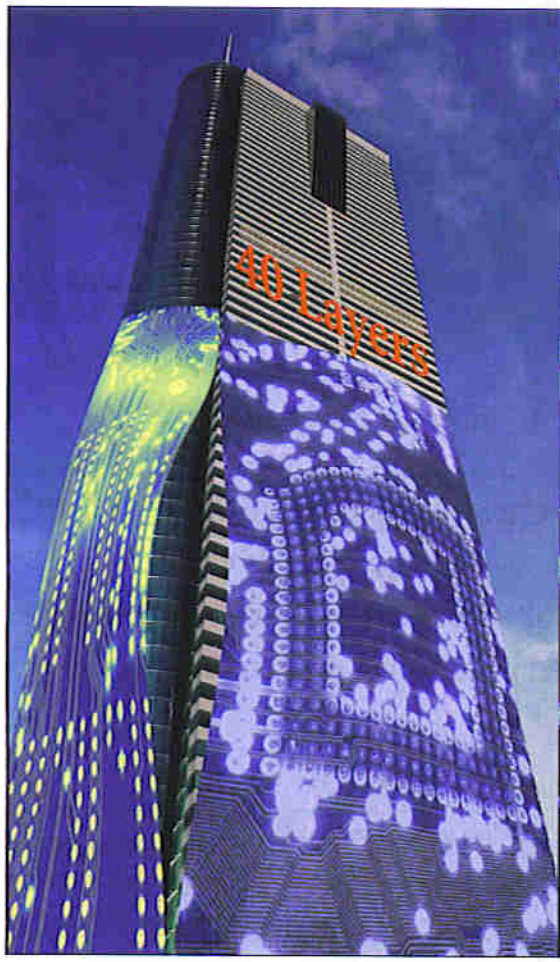
K7 = 3-way pinheader
MOD1 = AWM634-RX (Low Power Radio Solutions)
X1 = 3.579MHz (3.58MHz) quartz crystal
PCB, ref. 050238-2



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Explorer-16 (2)

Jan Buiting & Luc Lemmens, in cooperation with Microchip Technology & Labcenter Electronics

Assuming the free Explorer-16 CD-ROM you got with last month's issue was not mislaid, Ebayed off or frisbeed out of the window we can continue with a look at the hardware to go with this article series brought to you exclusively by Microchip, Labcenter and Elektor. Software is covered, too, by a Proteus VSM simulation of audio signal processing. And finally there's a super discount offer waiting for you.

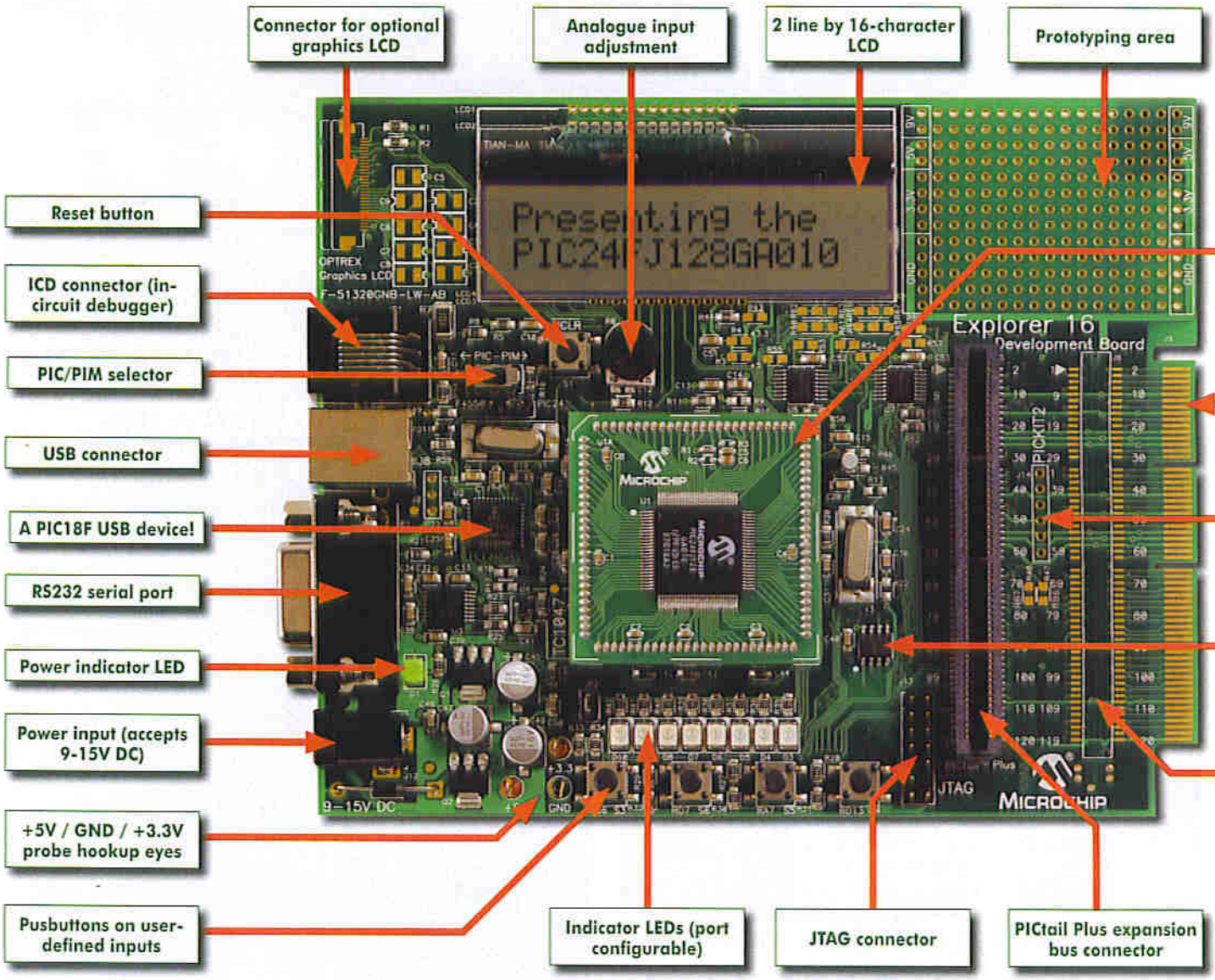

Figure 1. The Explorer-16 board pictured from above.. Here, the PIC24FJ is shown inserted.

Part 2: Explorer-16 Value Pack and audio signal processing

The free Explorer-16 and PIC24F downloads tell more than can be printed in this entire magazine

Good response was received to our initiative to supply a free CD-ROM with the complete European print run of *Elektor Electronics* January 2007. Feedback ranged from "nice to be able to run such a simulation of a complete microcontroller board, all free of charge" and "ho-ho a free C compiler for high-end PICs" to "can't wait to buy the Explorer-16 hardware". Before we start with a look at the Explorer-16 Value Pack, there are some additions and extras to mention that come in the wake of publishing the January 2007 instalment.

Will not fit on a page or two

An immense amount of free documentation, including an introduction to PIC24F programming, tutorials, datasheets, application notes, PowerPoint presentations and a lot more has been compiled and gathered for you on the Explorer-16 page of our website. You'll find it at www.elektor-electronics.co.uk/explorer-16. This page is only accessible to registered users — a login screen will be shown.

At the time of writing, some ten downloads are available that tell more about Explorer-16 and the PIC24F device than can be printed in this entire magazine. The video presentation by Don Schneider is highly recommended. The presentation comes as a Windows Media File (wmf) with a size of about 40 MB. A 'still' version in the form of a pdf is also available and takes much less space.

Besides this Aladdin's Cave of free software and documentation for PIC enthusiasts (in particular the 24F devices) we are running a dedicated **Explorer-16 topic** on our online Forum. Questions the authors are unable to answer (but give us a try) will be forwarded to, or dealt with directly, by experts at Microchip and Labcenter.

Explorer-16 Value Pack

Before moving on to the hardware we have on offer we should reiterate here that the Explorer-16 CD-ROM you got for free with last month's issue can be used on its own for as much Proteus VSM simulation, C language practising and PIC programming as you wish — all without the need to buy hardware.

In response to feedback to January's free CD-ROM we should stress that the Proteus simulation tools in particular do require a relatively fast PC so it's unwise to try running these on a 486 machine or under Windows 98 — you will only frustrate yourself.

There is a vast amount of permanently useful information behind the seemingly simple opening menu on the CD — the information that's free from Microchip and Labcenter websites would take you a long time to locate and collect even on a broadband internet connection. The special release of Proteus VSM with the PIC24F simulation module cannot be found anywhere in this form as it was specially made by Labcenter Electronics for Elektor readers.

The Explorer-16 Value Pack, then, represents great value for money as you can check for yourself using the two **insets**. It is only available from Elektor Electronics at a special discounted price. Ordering details for the pack may be found on the SHOP pages of our website. So, what's in the pack?

Explorer-16 Demo Board

This is the main component of the Explorer-16 Value Pack. An attempt at 'functional dissection by component'

PIC24FJ128 100-pin plug-in module (PIM)

PICtail Plus expansion bus PCB edge connector

PICkit 2 Programmer connector

Serial EEPROM

PICtail Plus expansion bus connector (optional)

Figure 2. PICkit 2 is a kit-in-a-kit with great potential for all PIC users as it contains a debugger and a programmer.

is shown in **Figure 1**. The demo board has an overall size of 140×115 mm and comes with two MPU modules: one PIC24FJ and one dsPIC33F. Microchip calls these 'PIMs' (one 'm' there...), for 'plug-in module'. Both are 100-pin plug-on modules with a square footprint. Although we're using the PIC24FJ PIM for this project, the dsPIC33F PIM is a good catch for those of you wishing to delve into digital signal processing. Lots of information is available on the dsPIC series from the Microchip website.

Both the PIC24FJ and dsPIC33F PIMs can be obtained as one-offs from Microchip-Direct (or national distributors) for the purpose of building stand-alone application circuits developed using the Explorer-16 motherboard and PICkit 2. The modules are not too expensive considering that the PICmicro ICs come ready fitted on a 40×40 mm size carrier board with a 100-pin connector at the underside made from four SIL receptacles arranged in a square.

Details on how to use the Explorer-16 board 'out of the box' may be found in the Development Board User's Guide that's available on the CD-ROM supplied with this beautiful kit. Besides acting as a development platform, the demo board may be used straight away for real-life applications of PIC24F and dsPIC33 micros.

In good Microchip tradition, tutorial programs are available to get you going in no time. What's more, these programs are preloaded on the two PIMs. The Explorer-16 board is powered from a mains adapter with a capacity of about 250 mA at 9-15 volts DC. User programs are stored in non-volatile memory. If desired, they are automatically executed at power-on so you can transfer the software you've developed on Explorer-16 to the application circuit simply by relocating the PIM. Your application circuit needs to have four 25-pin 0.05 inch pinheader receptacles just as on the demo board. To avoid costly mishaps, **always observe the bevelled edge indicator on the PIM.**

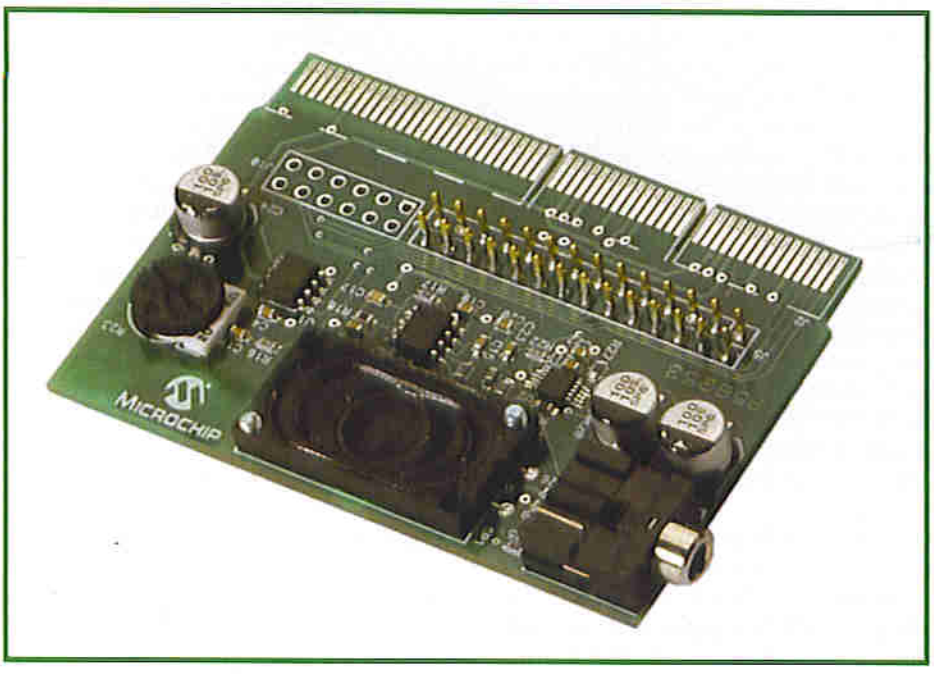

Figure 3. The Audio PICtail Plus board contained in the Explorer-16 Value Pack.

PICkit 2 Starter Kit

The second main item in the Value pack is the PICkit 2 which may be familiar from its hugely popular predecessor the PICkit 1. PICkit 2 comes with the 'Low Pin Count Demo Board' which supports 8-, 14-, and 20-pin PIC-MCUs. We probably don't have to spell out that this makes a useful tool even if you do not regularly use the hefty Explorer-16 board, but there you are — it's printed.

The PICkit 2 communication module is plugged onto the 6-way pinheader on the Explorer-16 board and *hey presto* you can do your programming and debugging. PICkit 2 comes with its own documentation, user guide and software, all on yet another CD-ROM. PICkit 2 is pictured in **Figure 2**.

Audio PICtail Plus

The Audio PICtail Plus Daughter Board included in the Value Pack and pictured in **Figure 3** can be plugged into the Explorer-16 development board. It is used to create analogue waveforms from a PWM signal. To do this it uses a low-pass filter (LPF) which is preceded by a potentiometer that can be used to change the volume. The output of the LPF is then fed to a speaker amplifier. This amplifier allows either the onboard

speaker to operate, or the external speaker connected to the jack. You can connect a cable from this jack to amplified speakers to boost the sound level for large rooms. The amplifier automatically detects if something is connected to the jack and will turn off the onboard speaker. The design also includes a serial EEPROM which can be used to store compressed speech files.
A few pins of the angled pinheader on the board will need to be isolated as they are dangerously close to the pins of the JTAG connector on the Explorer-16 board.

More hands-on simulation: Audio PICtail Plus in VSM

This month we do our second simulation using Proteus VSM supplied on the free Explorer-16 CD-ROM (January 2007).
Download the file Demo2.zip from the Explorer-16 page at www.elektor-electronics.co.uk/explorer-16. Save the unzipped Demo2 folder the directory: c:\program files\microchip\mplab c30\examples. Buckle up.
The audio PICtail virtual demo board for VSM is a cut down version of a full hardware variant in that some of the Explorer-16 demo board and some components on the Audio PICtail have been removed for clarity and also to aid simulation time. The demonstration board, though virtual, will not fail to show the capabilities of Proteus VSM and the PIC24F.
To keep the download size reduced, the Audio Analysis Graph will contain no data, therefore a simulation will need to be performed in order to listen to the sound output on the PC.
The Audio PICtail demo consists of two sheets. The one shown in **Figure 4** contains the audio elements of the PICtail and the interactive elements needed to run the VSM simulation. The second sheet contains the PIC24F required to run the source code. Some elements of the hardware are removed since this is a pure simulation we are performing rather than a simulation as part of complete design with PCB. The demo is node-locked so no components can be added or removed. However the demo will allow you to modify passive component values and hence change the characteristics of the filter. The results of these changes can then be viewed in the Frequency Response Window. The C source code can also be changed, so you will be able to analyse the speech output from the source code attached to the PIC24F.

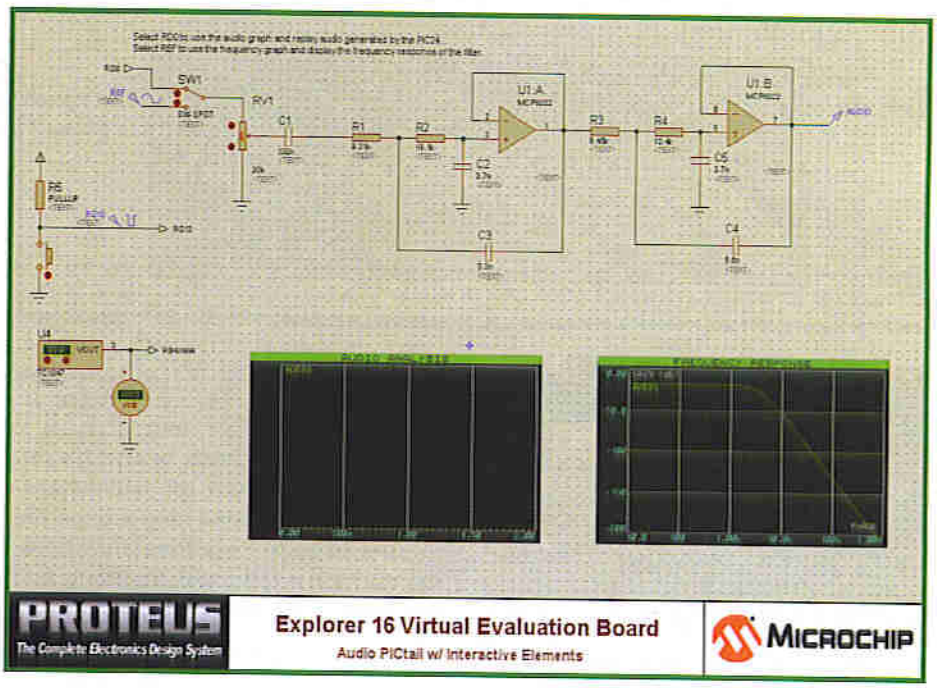

Figure 4. Audio PICtail Virtual Demo Board with all essential interactive elements.

The ability to run both an Audio Analysis and a Frequency Response on the same simulation would normally require a full version of the software to remove the connection to the MCU and add a sinewave generator. However the boffins at Labcenter have devised a new **interactive switch (Figure 5)** which will ensure that the two signal sources can remain mutually exclusive.
The switch position should be changed to suit the type of graph analysis you wish to perform. Just click on it.

- Select RD0 to use the audio graph and replay audio generated by the PIC24.
- Select REF to use the frequency graph and display the frequency response of the filter.

The Audio PICtail also has interactive elements for:

- pushbutton to start code in real-time simulation
- temperature sensor

The **pushbutton** is required to allow the source code to perform an ADC reading, subsequently compute the relevant value, and then output the speech. Also included in the pushbutton section is a stimulus injection, see **Figure 6**. This is required to allow the Audio Analysis Graph to operate, since in batch simulation mode the interactive components are disabled. There-

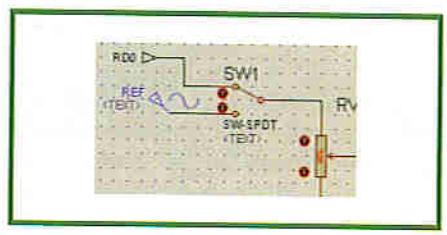

Figure 5. Interactive virtual switch.

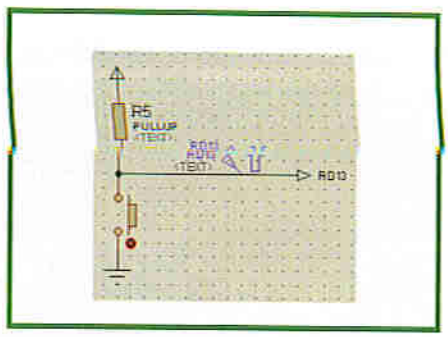

Figure 6. Interactive push button and batch mode stimulus injection.

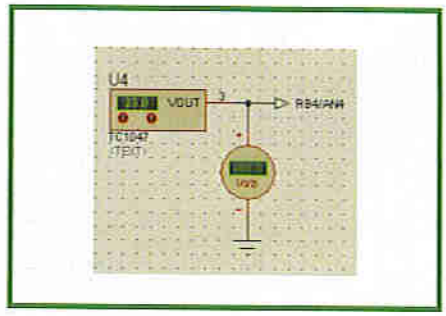

Figure 7. Interactive TC1047 temperature sensor and DVM – all virtual!

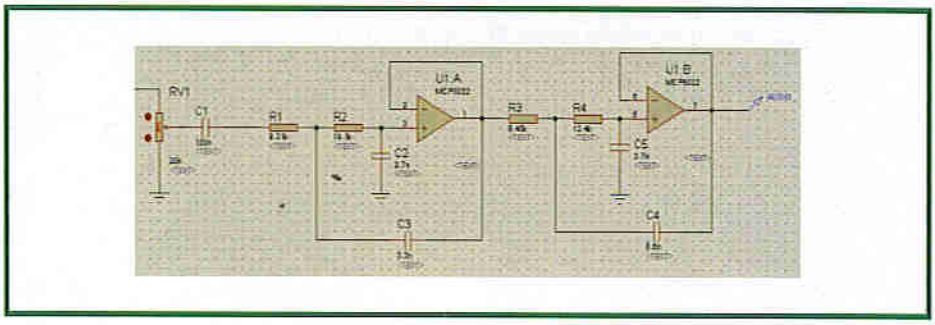

Figure 8. Virtual output filter stage using the MCP6022.

fore without this stimulus the batch simulation would be unable to run.
The **temperature sensor (Figure 7)** is a fully interactive component. This will allow the designer to modify the temperature using the ↑ and ↓ buttons.

such operations, wich would be relatively difficult with physical hardware. These of course help reduce the number of code iterations and therefore may aid a reduction in debug and test time. As a additional aid to this

The Explorer-16 Value Pack is only available from Elektor at a special discounted price.

The output of the temp sensor will vary exactly as per the datasheet specifications and can then be read by the PIC24F ADC. This capability allows the designer to perform operations such as limit checking of code, response to expected ADC value and many other

process, a virtual voltmeter has been attached to the output of the temp sensor. This should allow you to determine if the values being referenced in code for a given ADC reading are meaningful relative to the set temperature and expected sensor output value.

Figure 9. Audio Analysis window maximised.

The **output filter section (Figure 8)** is the same physical topology and values as provided on the actual Audio PICtail hardware. However the output driver stage has been removed and modifications have been made to allow simulation to be performed as outlined above. The bonus with the simulation is that it will allow you to quickly and easily change the passive component values to change the filter response. This response can then be checked by running a simulation using the Frequency Response graph. The other benefit afforded by simulation is the ability to analyse and save the speech output to a .wav file, which will allow filter modifications and code changes to have some form of offline quantifiable analysis performed quickly and easily. Great stuff for microprocessor fans keen on using digital audio.
To allow simulation to be performed, a Voltage Probe is attached to the filter output. In this case it has been labelled 'Audio'. This is then used as a reference for the traces within a graphical analysis window.

Running the Demo

The code should run out of the box within ISIS as the PIC24F will be pointed at the .cof file in the design directory. To use the design with MPLAB® a build operation may be required. MPLAB will prompt if this is the case.
The **Audio Analysis graph** will allow you to record and listen to the output of the design. The analysis is performed as a batch process and the Spice calculations are performed based on a computed output from the PIC24F. This allows the VSM simulation engine to perform a mixed-signal analysis and offer such features as the audio analysis capability.
The operation of the graphical simulation is largely the same regardless of the design being open within the Proteus ISIS schematic capture package, or the Proteus VSM window within MPLAB. The basic operation is to ensure the interactive switch is in the correct position for the signal source required, move the cursor over the Audio Analysis graph in the schematic and either press the space bar or right click and select Simulate Graph. The simulation engine should then run. If successful, the speech output for the set temperature (in degrees) should be seen as an audio waveform. To listen to the output again you can press CTRL-space or right click and select Play Audio.

Explorer-16 Value Pack

As of this article instalment Elektor sells the ***Explorer-16 Value Pack***. It consists of four components packaged together in a single box:

1. Explorer-16 Demo Board

A modular development system for Microchip's new 16-bit microcontrollers. It supports devices from the PIC24F, PIC24H, and dsPIC33 families. It is capable of interfacing with 5V peripherals and also provides basic generic functionality with the added ability to expand to vertical markets via modular expansion. The board comes with one dsPIC33F256GP710 plug-in module, one PIC24FJ128GA010 module, an RS232 data cable and a CD-ROM.

2. PIC Kit 2 Starter Kit

A PICkit 2 Microcontroller Programmer and a PICkit 2 Low Pin Count Demo Board containing a PIC16F690 PDIP for getting started with programming baseline and midrange flash microcontrollers. PICkit 2 takes advantage of Microchip's Full-Speed USB device. The Low Pin Count Demo Board supports 8-, 14-, and 20-pin PICmicros. In addition to the PIC16F690, the board comes with 4 LEDs, a pushbutton, and a potentiometer. Also included are 12 lessons to help get developers up to speed quickly on programming PICmicro MCUs.

3. Audio PICtail Plus daughterboard

This plug-in board for the PICtail bus on the Explorer-16 Demo Board effectively turns digitized audio into an audible signal that can be heard through the on-board mini speaker or through a set of amplified speakers.

4. MPLAB C30 Discount Voucher

By completing this voucher and returning it to Microchip, you change your student version of C30 into a full version for £94.12 less than the list price of the full package.

The graph can also be expanded to perform additional operations — this is achieved by clicking in the title bar of the audio analysis graph which is embedded within the schematic. This should then provide a maximised window as shown in **Figure 9**.

The mechanism for the **Frequency Response graph** is the same as for the audio analysis, however the interactive switch will need to be set to link the sinewave generator into circuit.

Using MPLAB and Proteus VSM to Debug

The real capability to perform a system level debug operation is achieved when MPLAB and the Proteus VSM plug-in are married together. This combination allows VSM to become the development tool within MPLAB and operate in a similar manner to using MPLAB-SIM or MPLAB ICD2. The big difference, however, reads: '*no hardware required*' and the capabilities of VSM allow a much more interactive code simulation to be performed. This allows serial ports, A/D converters and other asynchronous operations, which are generally difficult operations in a code simulator, to be performed with uncommon ease. The benefits of mixed-mode simulation are very much apparent when a debug operation is performed.

Your savings

Thanks to an exclusive and one-off arrangement with Microchip UK, the Explorer-16 Value Pack is both unique (you won't find it anywhere else in this configuration) as well as much cheaper than the individual components.

Item	*Microchip-Direct price (£)*
Explorer-16 Demo Board (DM240001)	£69.45
PICkit 2 Starter Kit (DV164120)	£26.71
Audio PICTail Plus (AC164125)	£38.00 (tentative)
Subtotal	£134.16
VAT	£23.48
Total	***£157.64***
P&P	(depends on destination)

Item	*Elektor SHOP price*
Explorer-16 Value Pack, includes DM240001, DV164120, AC164125, C30 discount voucher	£122.90 (€ 179.00 / US$ 232.50)
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Assuming you complete and return the C30 discount voucher (20% off the list price of £470.61), the total saving you get through ordering an Explorer-16 Value Pack may amount to £129 (€ 187).

Labcenter VSM plug-in modules

These guys have a super offer for Elektor readers available at *www.labcenter.co.uk/products/elektoroffer.htm*. Simulation of microcontrollers in real-life circuits is the way forward and Proteus VSM a market leader in this area.

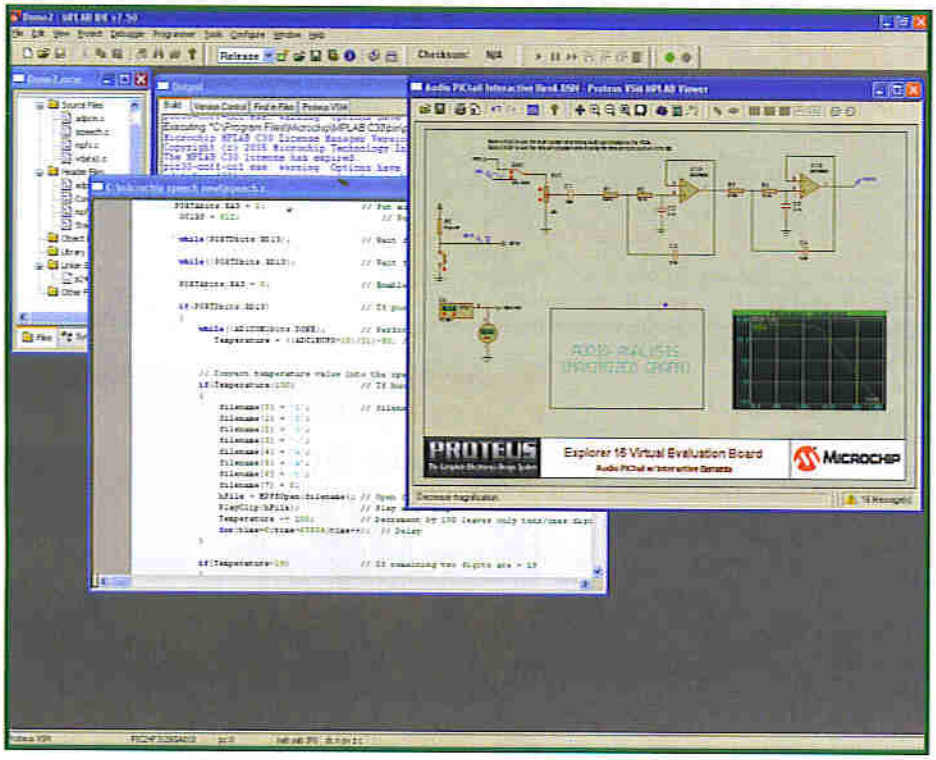

Figure 10. MPLAB and the Proteus VSM viewer window.

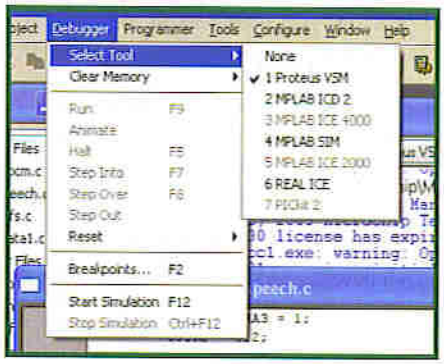

Figure 11. Selecting Proteus VSM as debugging tool.

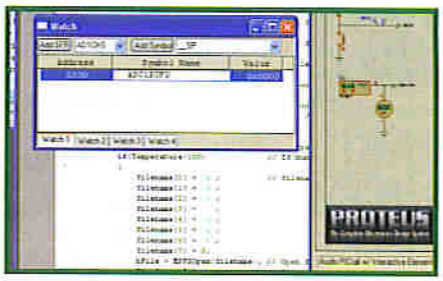

Figure 12. Correlation between a Read ADC breakpoint, Set Temperature, Sensor Output Voltage and resultant ADC reading.

However, keep in mind that Proteus is a view window within MPLAB — see **Figure 10**. Whilst the functionality is similar to that of the actual schematic environment, some operations, such as placing components, cannot be performed since these are better suited to the schematic capture package. However, it is still possible to modify component properties and add items such as virtual instruments and hook these up whilst in the viewer. Batch simulation operations can also be performed, so it's easy to make a code modification, build the source code tree and then move to the viewer and run an audio analysis using the same actions as would be used in the schematic capture tool.

The viewer can operate in effectively two modes. To run a batch operation, the viewer needs to be opened. Do this: Debugger → Select Tools → Proteus VSM.

As shown in **Figure 11**, this will open the viewer window and will show the status of the connection to the VSM Simulation engine in the toolbar. In this case the **green button** indicates that the connection is yet to be made. However it is in this mode that the batch simulations for Audio Analysis and Frequency Response can be performed. If the green button is pressed, a link to VSM is formed to allow the real time simulation of code and system to be performed. This will then make the standard simulation buttons in MPLAB active, keeping the process of simulation and debug seamless across all of the debug tools, both hardware and software.

You can now:

- add a breakpoint on an ADC event;
- add a Watch window to view the value held in the ADC result register;
- view the set temperature on the temp sensor;
- view the output voltage of the temp sensor.

In other words, correlate all the elements and functions as illustrated in **Figure 12**. How does this speed up things? Well, as can be seen we can now very quickly determine that 20 degrees C is an output voltage of 0.7 V which results in a ADC reading of 0x00D9. We can also quickly determine if the values for the sensor and ADC are correct and take the necessary action. This operation is significantly simpler than trying to accurately time external instruments with debug tools to achieve the same net result.

The video presentation by Don Schneider is highly recommended.

Conclusion, outlook

The above descriptions are aimed at providing an insight into the Audio PICtail and the MPLAB and VSM Viewer tools. Whilst being relatively brief and covering a lot of ground they should serve to introduce a few basic concepts and operations prior to simply trying things out.

In Part 3 of the series we'll look at interfacing mass storage cards and revert to our speaking thermometer, this time in hardware.

Join our online Forum topic on the Explorer-16 series and tell us how you get along.

(060280-I)

Updates, extensions and downloads for this article series are posted at www.elektor-electronics.co.uk/explorer-16

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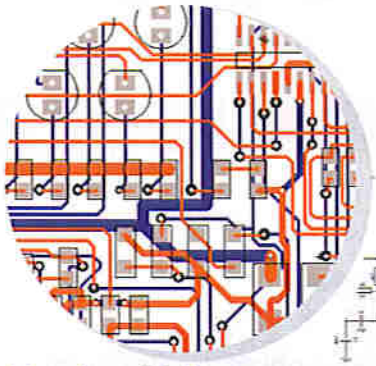

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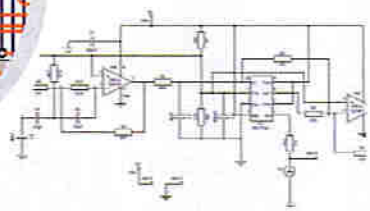

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MP3 Pre

Stereo microphone

Marcel Cremmel

There are still a lot of hobbyists who enjoy making high-quality live audio recordings of concerts, interviews, radio broadcasts, natural sounds, and so on. Professional equipment such as Nagra and the like is simply too expensive. We can thus be thankful that many MP3 players are equipped with an analogue input and a high-performance MP3 or WMA encoder.

You need portable equipment if you want to make recordings in the field. Professional equipment for this purpose is very expensive, and many affordable alternatives (such as MP3 players) cannot handle microphone signals. Microphones require some sort of assistance to supply the high signal levels that must be provided on the line inputs. Although some players have built-in microphones, the quality is often barely adequate for use as a dictating machine. This means you need a microphone preamplifier to adapt the microphone output to the line input.

The characteristics listed in the 'MP3 preamplifier features' inset can be obtained without using any special components. Transistors and opamps that you have tucked away in a drawer somewhere should do just fine. Aside from the potentiometers and connectors, all the components are SMD types. But there's no need to be afraid – even beginners can assemble the circuit board if they are blessed with a grain of patience, an ounce of dexterity and a pinch of precision.

Microphones

Even the best preamplifier won't perform well with a mediocre microphone or a poor cable. A wide variety of systems are available, with prices ranging from a few euros to several hundred. The preamplifier described here is optimised for dynamic microphones. The characteristics of the microphone (see the 'Principal characteristics of a microphone' inset) are a major factor in selecting a microphone.

The Sennheiser MD21 is a genuine reporter's microphone that has been on the market for several decades already. It has a sensitivity of 1.8 mV/Pa and generates an output signal of 0.36 µV in a quiet room, or 3.6 mV if you aim it toward a pneumatic hammer.
It has a very large dynamic range: 3.6 mV ÷ 0.36 µV is a healthy 80 dB. Based on this information, we can specify the following properties of an ideal preamplifier:

- An input noise level that is significantly less than 0.36 µV, in order to obtain a satisfactory signal-to noise-ratio (SNR).
- No overdrive or signal distortion at 3.6 mV.

A good SNR can be achieved by using a well-considered design and choice of components for the preamplifier. The second property requires using a potentiometer so the output level can be adjusted to suit the maximum acoustic pressure.
The distance between the microphone and the preamplifier is often more than 10 metres. The cable used for this link is thus exposed to interference from magnetic fields, in particular AC mains fields at a frequency of 50 Hz. The signal carried by the cable has a low amplitude and must be protected against this interference, since otherwise the interference will be audible as the well-known 'mains hum'. This protection is

amp preamplifier

provided by the screen of a screened cable. For proper operation, the screen must be connected to ground, and it cannot be used to carry the signal.
Despite this protection, some interference signals still manage to reach the active conductors. If these conductors have the same impedance relative to ground, the induced signals will also be the same. Their effect can then be neutralized by the differential input stage of the preamplifier. In addition, the low impedance of a dynamic microphone reduces the effect of external interference.
In short, use a screened cable with two conductors and solder the cable together as shown in **Figure 1**.

Features

- Stereo
- Compatible with dynamic and electret microphones
- Maximum input sensitivity: 50, 60 or 70 dB, selectable
- Level control using two potentiometers
- Bandwidth: 50 Hz to 50 kHz at maximum gain (70 dB)
- Distortion: 0.04% at –10 dBV (316 mV_{eff})
  0.12% at 0 dBV (1 V_{eff})
- Input noise: –124 dBV (0.63 μV_{eff})
- Power source: 9-V battery
- Current consumption: 3 mA per channel
- Designed to fit in a commercially available enclosure with a battery compartment.

Schematic diagram

The schematic diagram consist of two identical amplifier channels. Here we describe one of the two channels.
The circuit is powered by a 9-V battery. An LED wired in series indicates that preamplifier is switched on. The voltage drop of the LED (1.6 V to 2 V for a red LED) does not affect the performance of the preamp. The supply voltage is switched via the contacts of the audio socket. In the quiescent state, two contacts prevent T9 and T10 from conducting. The TMOS transistor is thus cut off, so no voltage is applied to the other components. When a microphone cable is plugged in, the contact in the socket is opened. The supply voltage is now applied to the gate of T9 or T10 via R3 or R33. The TMOS transistor is thus switched on and provides power

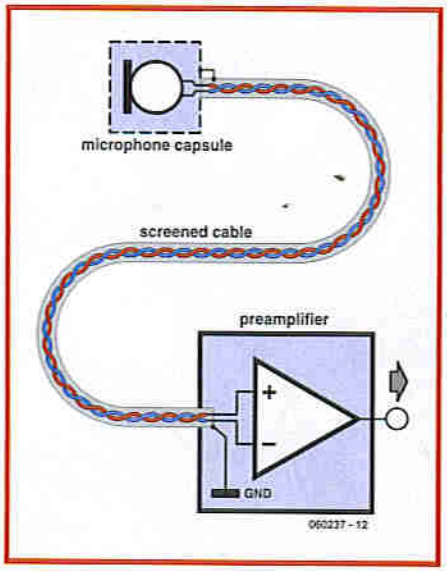


Figure 1. Construction of the screened cable link between the microphone and the preamplifier.

to the amplifier channel. The high resistance of R3 and R33 limits the current consumption to 1.6 µA per channel in the 'off' state.

Amplifier design

Why is it necessary to amplify the signal? The line input of an MP3 player requires a peak signal level of approximately 1 V, which means 2 V peak-to-peak. This range is converted to 16-bit digital values in the device, which thus provides a resolution of 30 µV. However, the signal produced by the MD21 at a normal conversation level is only 3.6 µV, which is much to low for the analogue-to-digital converter (ADC) of the MP3 player. If you connect the microphone directly to the player, you will make a recording without any sound. For a satisfactory SNR, the level of the signal applied to the input of the player must be at least 100 times as large as the value of the least significant bit, which means at least 3 mV. The signal from the microphone must be amplified by a factor of 833 to achieve this level. This is the job of the preamplifier.

The preamplifier described here provides a choice of three gains: 315 (50 dB), 1000 (60 dB), or 3150 (70 dB). Such high gains cannot be obtained in a single stage in combination with an acceptable bandwidth, so this task is split over two stages. The first stage is built using discrete transistors, while the second stage is implemented using an operational amplifier.

In the first stage (shaded grey in **Figure 2**), you can see the classic structure of a differential transistor amplifier (T1 and T2). The microphone signals arrive via IN1 and IN2, with the capaci-

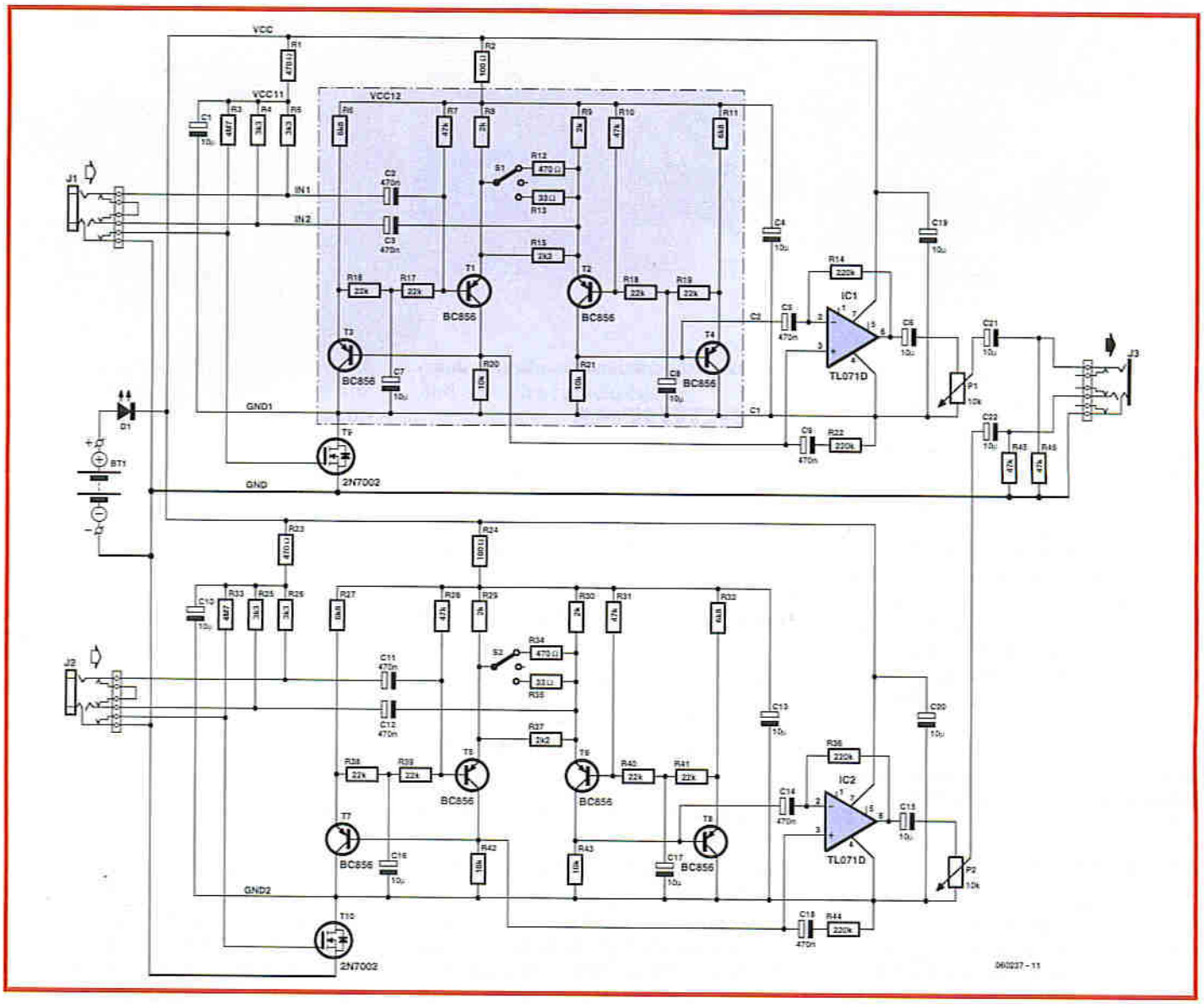


Figure 2. Full schematic diagram of the microphone preamplifier for MP3 players.

tors providing DC blocking to avoid upsetting the DC bias setting. The output of the first stage is taken across the collectors of T1 and T2.
The gain is determined by the equivalent resistance between the two emitters:
– 2.2 kΩ: 13.6× (23 dB)
– 2.2 kΩ || 470 Ω: 43× (33 dB)
– 2.2 kΩ || 33 Ω: 135× (43 dB)
Transistors T3 and T4 stabilise the operating point of the stage, which makes it unnecessary to use a matched pair for T1 and T2.

Why use transistors?

Could be first stage be built using an opamp and a few passive components instead of transistors? The answer is yes with regard to the gain, but no with regard to noise. This can be shown using a simple comparison. We compared the behaviour of two amplifier designs with the same input sensitivity: the transistor stage described above (with S1 set to R12 for a gain of 33 dB) and an amplifier built using a TL071, which is known for its low noise level. The frequency characteristics are shown in **Figure 3**. Both circuits meet the requirements, but the transistor stage does it better.
We can use a PSPICE simulation to determine the effective input noise voltage. This calculation takes all noise sources into account. It yields the following results:
- *Design using a TL071*: noise level 500×10^{-18} V²/Hz over the frequency range of 100 Hz to 20 kHz (white noise). This yields

$V_{eff} = \sqrt{[(500 \times 10^{-18}) \times (20{,}000)]} = 3.2\ \mu V$.

- *Design using transistors*: noise level 11.5×10^{-18} V²/Hz over the frequency range of 100 Hz to 20 kHz. This yields

$V_{eff} = \sqrt{[(11.5 \times 10^{-18}) \times (20{,}000)]} = 0.48\ \mu V$.

The noise level is thus a factor of 6.6 lower, so the transistor stage wins hands down. This noise level is of the same order as the signal produced by the microphone in a quiet room. This means you can hear a fly buzzing around in the room.
Strictly speaking, you also have to take into account the thermal noise generated by the internal resistance of the microphone. The MD21 has an internal resistance of 200 Ω, which yields an effective noise voltage of $8.6 \times 10^{-9} \times \sqrt{R}$ = 0.12 µV (at 25 °C and a bandwidth of 20 kHz).
Due to the gain of the first stage, an opamp can be used for the second stage with satisfactory results. A TL081 can also be used in place of the TL071 without any appreciable degradation of performance.
The differential structure is maintained to avoid losing 6 dB in input sensitivity. The gain is fixed at 22 (27 dB) as determined by resistors R14, R20, R21 and R22 for the one channel or R42, R43, R36 and R44 for the other channel. Potentiometers P1 and P2 can be used to independently adjust the output levels as desired. Capacitors C6 and C15 block the DC component to prevent crackling from the potentiometers.

Construction

All components except the battery are fitted to a printed circuit board. This

Examples of acoustic pressures

Condition	P [Pa]	P [dBSPL]
Auditory threshold	20 µ	0
Quiet room	200 µ	20
Conversation	2 m	40
Lively conversation	20 m	60
Busy street	0.2	80
Pneumatic hammer	2	100
Pain threshold	20	120

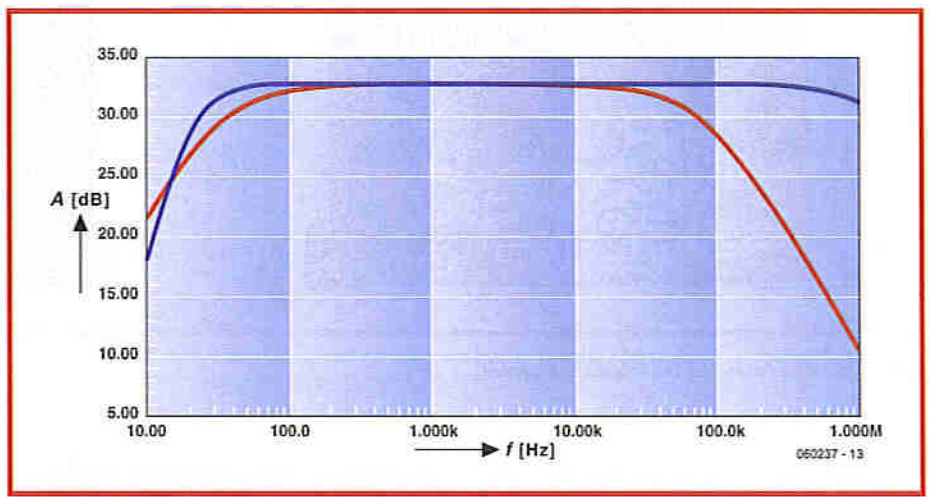


Figure 3. Bandwidth of the first stage. Blue: transistor version. Red: TL071 version.

Principal characteristics of a microphone

- Sensitivity in mV/Pa
- Output impedance
- Bandwidth
- Directional sensitivity
- Maximum acoustic pressure

An electronics specialist is interested in the first three characteristics, while a recording specialist is interested in the last three.

The signal voltage provided by a microphone is proportional to the acoustic pressure and the sensitivity of the microphone:

- $V_{MIC} = S \times P$
- S: sensitivity in V/Pa
- P: acoustic pressure deviation in Pa

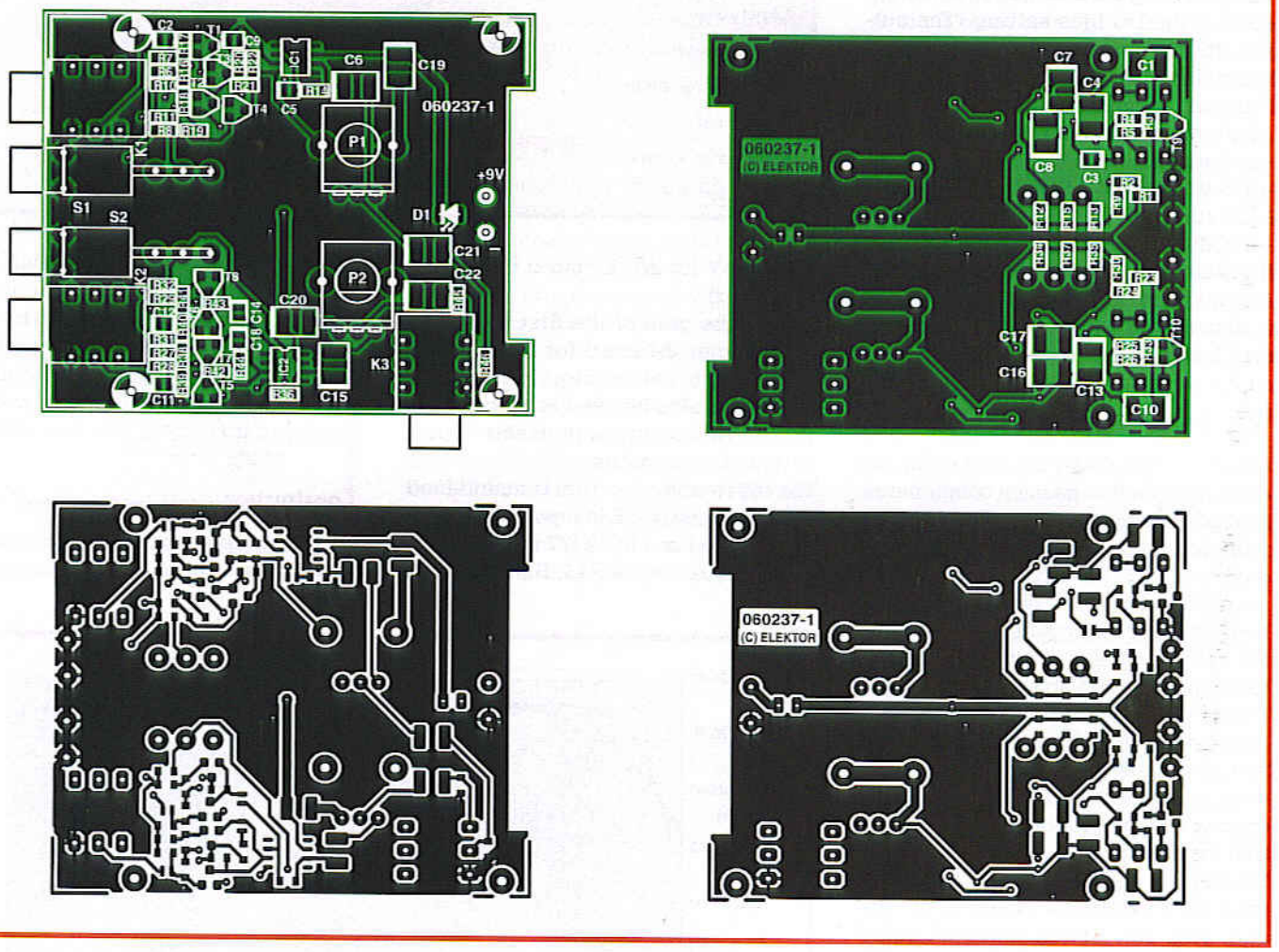


Figure 4. Layout of the double-sided PCB designed for this project.

is a double-sided, through-hole plated PCB. If you make the board yourself, you will have to make the through-hole connections by hand. The shape of the board is specifically designed to fit an enclosure distributed by Farnell with a compartment for a 9-V battery. We selected PCB-mount chassis connectors for the audio sockets to ensure optimum contact. **Note:** these are not standard versions.

We advise using a soldering iron with a very fine tip. Start by soldering the SMD parts, since they will difficult to reach later on due to the other components. Pay good attention to the polarity of the electrolytic capacitors, which are present in generous numbers on the bottom of the board.

The SMDs are distributed over both sides. Handle the MOS transistors carefully to avoid exposing them to electrostatic charges. Be careful when solder-

COMPONENTS LIST

Resistors

R1,R12,R23,R34 = 470 Ω
R2,R24 = 100Ω
R3,R33 = 4MΩ7
R4,R5,R25,R26 = 3kΩ3
R6,R11,R27,R32 = 6kΩ8
R7,R10,R28,R31,R45,R46 = 47kΩ
R8,R9,R29,R30 = 2kΩ
R13,R35 = 33Ω
R14,R22,R36,R44 = 220kΩ
R15,R37 = 2kΩ2
R16-R19,R38-R41 = 22Ω
R20,R21,R42,R43 = 10kΩ
P1,P2 = potentiometer 10kΩ, B, Alps type RK09K11310KB (Farnell # 119-1725)

Capacitors

(all SMD)
C1,C4,C6,C7,C8,C10,C13,C15,C16,C17,C19-C22 = 10µF 16 V tantalum, Vishay Sprague 595D106X9016B2T (Farnell # 392-8895)
C2,C3,C5,C9,C11,C12,C14,C18 = 470nF/25 V tantalum, Vishay Sprague 595D474X9025T2T (Farnell # 116-6814)

Semiconductors

D1 = LED, 3mm, red
T1-T8 = BC856ALT1G, SMD, SOT-23, ON Semiconductor (Farnell # 114-7782)
T9,T10 = 2N7002, MOSFET, SMD, SOIC, Texas Instruments (Farnell # 102-1754)
IC1,IC2 = TL071CD, SMD, SOIC, Texas Instruments (Farnell # 958-9449)

Miscellaneous

K1,K2,K3 = 3.5mm jack socket with 3 contacts, Schurter R36310000 (Farnell # 149-933)
S1,S2 = SPST switch, angled pins, PCB mount, height = 12.7mm, C&K 7103MD9 AV2BE (Farnell # 957-5510)
BT1 = 9V battery with clip-on lead
K4 = 2-way PCB pinheader
Case with battery compartment, e.g. BC2, Farnell # 223-554
PCB, ref. 060237-I from ThePCBShop

ing the resistors for switches S1 and S2 (R12, R13, R15, R34, R35, and R37): solder only the ends of these resistors that are not connected to the corresponding switches. The other ends will be soldered when you fit the switches to the board. If you solder them before you fit the switches, the holes may be filled with solder.

Be sure to do a neat job of soldering, since many of the solder pads are close together. If you etch your own PCB, be sure to make the through connections between the top and bottom sides carefully and avoid making any shorts, which would be difficult to find later on.

Enclosure

Once the circuit board is finished and you have checked that it works properly, you can fit it in the enclosure with the battery compartment. Make holes in the bottom part of the enclosure for the input and output connectors and the two switches. The top part must have holes for the two potentiometers and the LED, which adds a bit of flair to the top of the enclosure (a square or rectangular LED is a good choice here, with the leads trimmed to the right length).

Putting it to use

After you're satisfied that the preamplifier is working properly, you can start using it. All you have to do is to connect two microphones to the input connectors (K1 and K2) and connect the output to the line input of your MP3 player, and you're ready to go. Use a length of screened stereo cable for the connection to the MP3 player.
Here's to good recordings!

(060237-I)

Some MP3 players with audio inputs

Creative:
Zen Nano Plus

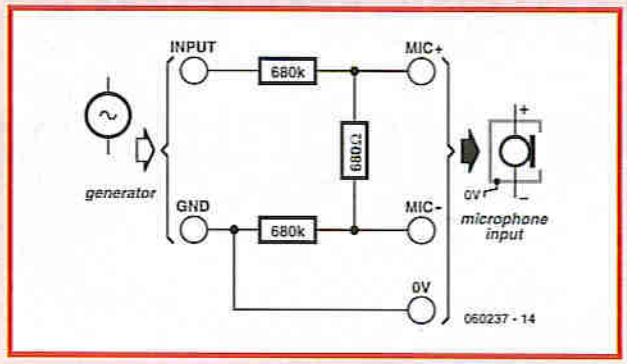
Packard Bell:
Audio Dream Colour

IRiver:
T20 and T30 series

Samsung:
YP-ST5, YP-T6 and YH-925 series

Measured results

Due to the very low input levels and the fact that it was not possible to produce the necessary levels directly using the available signal generators, we made an attenuator cable as shown in ***Figure 5.***



Characteristics:
Attenuation: 2000 (66 dB)

Output impedance: 680 Ω
(nearly the same as a dynamic microphone)
Preamplifier operating in differential mode

Figure 5.
Electrical diagram of the attenuator cable.

Results

The three curves correspond to the three settings of switch S1.

Measured results:

Setting 1: Maximum gain = 1 dB + 66 dB = 67 dB. This is nearly the design value of 70 dB.
Lower –3-dB point: 50 Hz

Setting 2: Maximum gain = –8 dB + 66 dB = 58 dB. This is nearly the design value of 60 dB.
Lower –3-dB point: 50 Hz

Setting 3: Maximum gain = –18 dB + 66 dB = 48 dB. This is nearly the design value of 50 dB.
Lower –3 dB point: 50 Hz

The upper –3 dB point is above 100 kHz (–2 dB at 100 kHz).

Noise and distortion

The noise and distortion figures were measured by the author. The results we obtained with our own analyser (Audio Precision) are nearly the same.

Results

Switch S1	S_{gen} [dBV] at 1 kHz	S_{out} [dBV]	Measured gain	S/N	THD	Output noise level	Input noise level	
Gain max	–1	0	67 dB	57 dB	0.12%	–57 dB	–124 dBV	0.63 μV_{eff}
Gain moyen	+8	0	58 dB	65 dB	0.12%	–65 dB	–123 dBV	0.71 μV_{eff}
Gain mini	+18	0	48 dB	72 dB	0.12%	–72 dB	–120 dBV	1 μV_{eff}

Distorsion 0.12% at V_{out} = 0 dBV
0.04% at V_{out} = 10 dBV

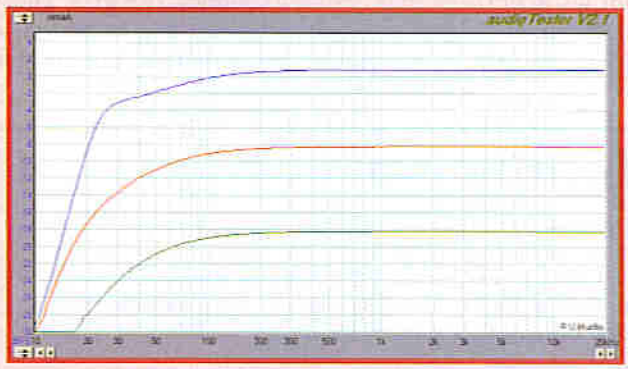


Figure 6.
The results measured by the author are very close to our measured results.

A Telling Way of Te

Radio timecode clock using graphical programming and a CPLD

Horst-Walter Granitzki

A fair number of radio-controlled clocks have appeared in *Elektor Electronics* but none before like this. What makes it unique is the use of highly flexible CPLD technology to decode the signals. Despite its complexity, our straightforward instructions will make sure that even beginners make a first-class job of this design.

A dread of complexity is entirely human, as is fear of the unknown. If you haven't encountered CPLDs before, you may not be happy to hear that CPLD stands for Complex Programmable Logic Device. This time you've nothing to worry about, however. The article describes a familiar application — clocks controlled by radio time signals — and you'll be able to exploit the power of CPLD chips without needing a higher college education or learning Hardware Description Language.

The first DIY projects for radio time clocks used vast numbers of chips. They were veritable 'TTL pits' — and 'money pits' as well. Far less of an undertaking is this new approach using a single CPLD chip to handle the many logic functions. In line with projects published previously in *Elektor Electronics* we have once again chosen a MAX7000S from Altera for our CPLD [1]. The MAX+plusII development software [2] that you can download free gives users by and large a free hand in allocating the input/output pins, enabling us to set out the circuit described here on a single-sided printed circuit board (PCB) without the need for wire links.

Our radio clock consists of just a receiver module for the DCF transmitter (see footnote), some ICs for pulse preparation and supporting the CPLD chip, which itself decodes the timecode pulses and controls the display. Also included is a brightness control for the display using a photoresistor. A serial interface for connecting to a PC is offered as an option.

Signals

The transmitter DCF77 located at Mainflingen near Frankfurt am Main in Germany radiates coded time and date signals on the frequency 77.5 kHz. These signals are available, free of charge, at just about everywhere in Europe that *Elektor Electronics* is read.

Coding of the DCF timecode signal is achieved by reducing the transmitter power by 25 per cent for either 100 or 200 ms, with the 100 ms pulse representing logical Low and the 200 ms pulse standing for logical High. This modulation takes place at the start of each second with the exception of the 59th second, which is how the start of each new minute is indicated. This sequence of digitally coded data contains the time of day — and the current date (including the year) — for the minute that follows. In this project we are interested only in evaluating the code contained in the 21st to 34th seconds (see **Table 1**).

At ranges up to around 500 km from the transmitter a low-cost receiver module about the size of a matchbox gives adequate reception; it consists of a small ferrite rod antenna and a tiny printed circuit board. These modules are available from some electron-

CPLDs in a nutshell

CPLDs are programmable logic devices that share architectural features with field-programmable gate arrays (FPGAs) and programmable array logic (PAL). CPLDs use non-volatile memory and do not rely on an external configuration ROM, enabling them to function immediately on system start-up. They contain an immense number of gates, enabling them to handle moderately complicated data processing operations.

Table 1. Coding of the DCF Signal

Number of seconds	BCD code
21 ... 24	Minutes-units
25 ... 27	Minutes-tens
28	Parity bit
29 ... 32	Hours-units
33 and 34	Hours-tens

elling the Time

chip

Figure 1. Raw data from the DCF receiver module needs to be processed before the CPLD can get to work on it. The CPLD also takes care of the display.

Figure 2. This pulse diagram illustrates how the preamplifier forms the pulses (see text). MF represents the 150-ms pulse. MPD is the product of the Missing Pulse Detector.

ics mail order firms, including Conrad Electronics (www.conrad-direct.co.uk), part number 641138 – 62. It's advisable to put this module in a small plastic box, ideally fixed firmly in place with sticky foam pads, glue or potting resin, to protect it from harm. TV receivers, poorly screened computers, electric motors and suchlike can all interfere with reception of radio timecode signals, so it makes good sense to connect the receiver module to the clock using a cable of adequate length (for example microphone cable with two conductors and a screen) to place it outside the interference zone. Moving it six feet or so will often turn marginal reception into rock-solid operation. At greater distances from the transmitter or in poor reception areas (screened mountain valleys for example) a special outdoor antenna can be bought — at a price.

The ferrite antenna should be arranged broadside on, so that its long axis is at right angles to the direction of the transmitter.

Pulse preparation

In order to process the raw data in the CPLD the information needs to be 'prepared' first. Of the various DCF receiver modules available, some invert the signal whilst others do not. The necessary decoupling and inversion (if required) are handled by IC2 (74LS14), as shown in the diagram at **Figure 1**.

Discriminating between LOW (100 ms) and HIGH (200 ms) pulses is the task of monostable IC1 (74LS122), which should be adjusted for a pulse duration of 150 ±10 ms. A value of 10 µF for C1 and 1 kΩ for R4 together with 33 kΩ for R5 will achieve this as a rule, but if not, you should make changes to R4 and R5. In the CPLD the rising flank of the DCF signal shifts the existing logical level of the inverted monostable signal into a shift register and in this way converts the time data from pulse-length format into binary-coded decimal (BCD) code.

The dual timer IC4 (NE 556) has the following functions. One half, operating as a missing pulse detector [3], recognises the absence of pulses on the 59th second. The other half is triggered by the inverted output signal from the first section and produces a short RESET pulse, whose rising edge signals the beginning of a new minute. The values given for C6/R8 and C4/R7 should produce guaranteed operation. The pulse diagram clarifies the relationships (see **Figure 2**).

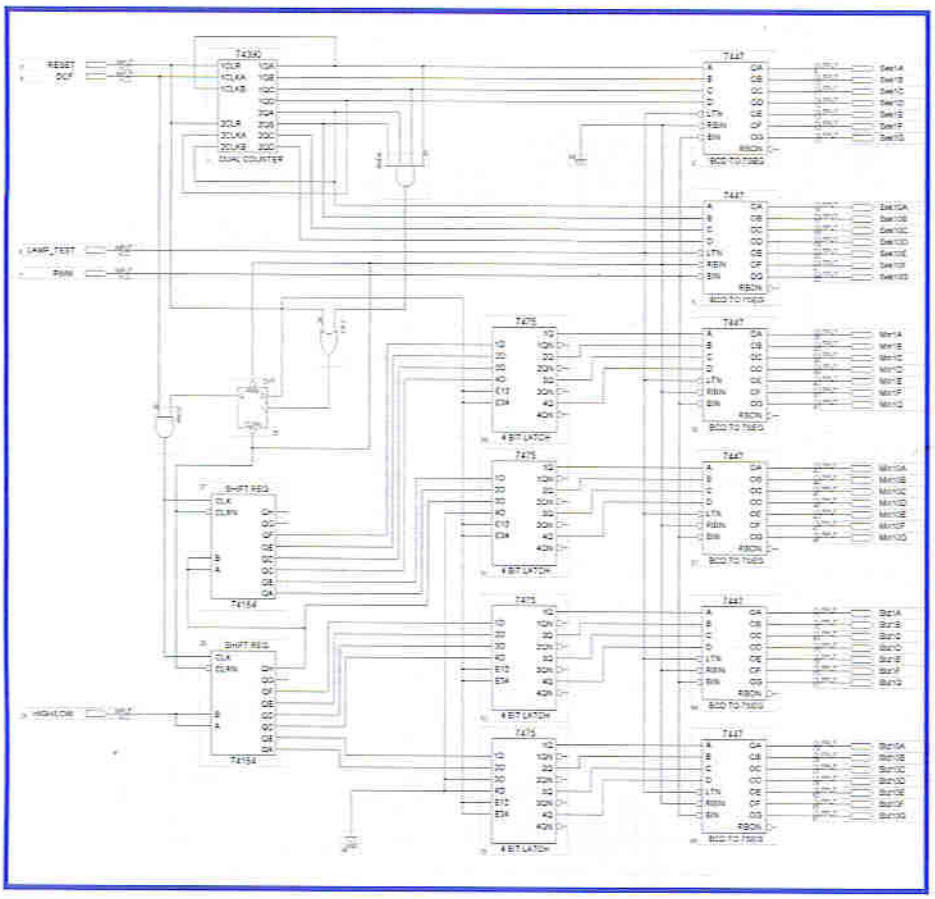


Figure 3. This circuit is implemented inside the CPLD chip and looks after further signal processing and controlling the display.

Brightness control

The brightness control uses an NE555 timer IC (IC5 on the circuit diagram). The photoresistor PH1 (type LDR 9060) has a resistance of a few kilohms in brightness but up to 10 MΩ in darkness. The timer IC converts this change in resistance into a pulse-width modulated (PWM) signal that switches the elements of the seven-segment display on and off in rapid sequence. In this way the 'on' time is about 20 per cent in darkness and approaches 100 per cent under bright conditions (with trimmer R26 set at 0 Ω).

The value of 470 kΩ for resistor R17 determines the minimum 'on' time duration and if increased to 1 MΩ, the 'on' duration drops and with this the bright-

ness of the display to around 10 per cent. R17 cannot be left out altogether as then the frequency of the PWM signals would fall too low in darkness and the display would flicker.

CPLD circuitry

The circuit shown in **Figure 3** handles further signal processing and controlling the display. It needs to be implemented in the CPLD using the MAX+plusII development software (alternatively you can obtain a ready programmed CPLD from the *Elektor Electronics* Shop as product no. 050311-31 [4]). Here we shall follow the diagrammatic method, which should be familiar to most electronics enthusiasts and produces usable results straightaway. Run the software and at upper left on the screen open a new file in Graphic Design File format (*.gdf). To add components you need to double-click at an empty position on the circuit diagram. An 'Enter Symbol' dialogue now begins. From the Symbol Libraries select the 'mf' library by double-clicking ('mf' stands for Megafunctions). A list of selections opens, offering TTL building blocks from the 74xx series. Choose the 74390 dual counter and confirm with a click on 'OK'. The symbol for the dual counter now appears on the diagram. Repeat the same operation for a 7447 seven-segment decoder and place this to the right of the 74390. Shift one of the two symbols, so that pins 1QA and A are aligned at the same height. To do this click on the symbol and move it with the mouse button pressed down. To add the input signals DCF and RESET double-click to the left of the 74390 and select 'Input' from the 'prim' (primitive functions) symbol library and confirm with 'OK'. Add a second INPUT in the same fashion. Move the two INPUT symbols to place them at the same height as 1CLR and 1CLKA of the 74390. Now right-click the upper INPUT symbol with the mouse. Select the 'Edit Pin Name' dialogue. PIN_NAME is now highlighted in black and can be renamed using the keyboard. Give this input the name RESET and confirm by hitting 'Enter'. Repeat this now for the second INPUT and name it DCF.

Laying out the links

To lay out the virtual tracks proceed as follows. Click the capital A in the Symbol column on the left-hand edge of the screen. The mouse pointer changes into a crosshair. Place the crosshair on the unallocated connection symbol of the RESET input and shift the crosshair, with mouse button depressed, to the unallocated connection symbol 1CLR of the 74390. Immediately the mouse button is released a connecting line is laid. Repeat this and link DCF to 1CLKA and outputs 1QA to 1QD with the corresponding inputs of the 7447. Your Graphic Design File should now look like the one in **Figure 4**.

Hardly difficult, is it? You should now save your project as a test. In the Menu column go to File ⑤ Project ⑤ Set Project to Current File. A 'Save As' menu opens. Name your work file 'Radioclock.gdf' and select as storage location the directory 'max2work' or some other designation of your choice.

Then finish off the circuit by adding a second seven-segment decoder, the INPUTs LAMP_TEST and PWM as well as 14 OUTPUTs for the Seconds units and the Seconds tens. Give the OUTPUTs meaningful and unambiguous names. Fields cannot be left empty.

Set out the connecting links until your diagram corresponds to the one in **Figure 5**.

This circuit is now in a position to count down the Seconds pulses of the DCF signal and shown them on two seven-segment display blocks. The RESET pulse resets the display to zero at the beginning of each new minute. The 59th second is ignored on account of the missing pulse, reminiscent of the analogue slave clocks on some railway stations. The PWM INPUT is for brightness regulation and along with the LAMP_TEST INOUT allows the correct functioning of the display to be checked.

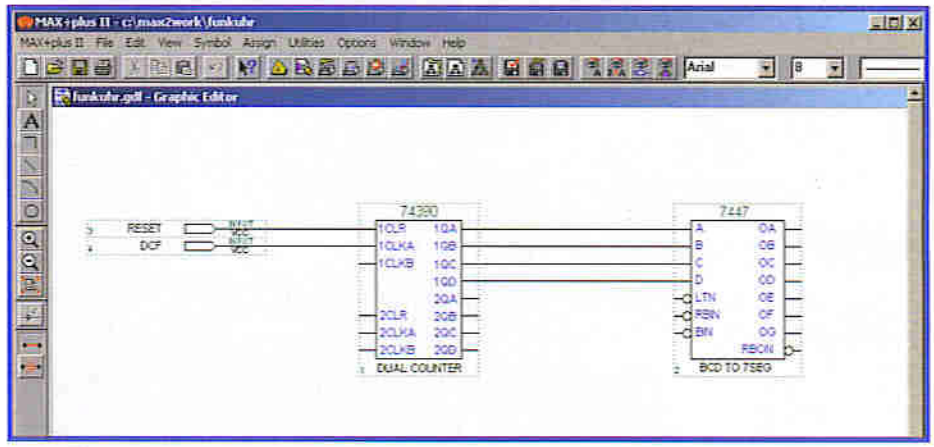


Figure 4. After the first steps your Graphic Design File should look like this.

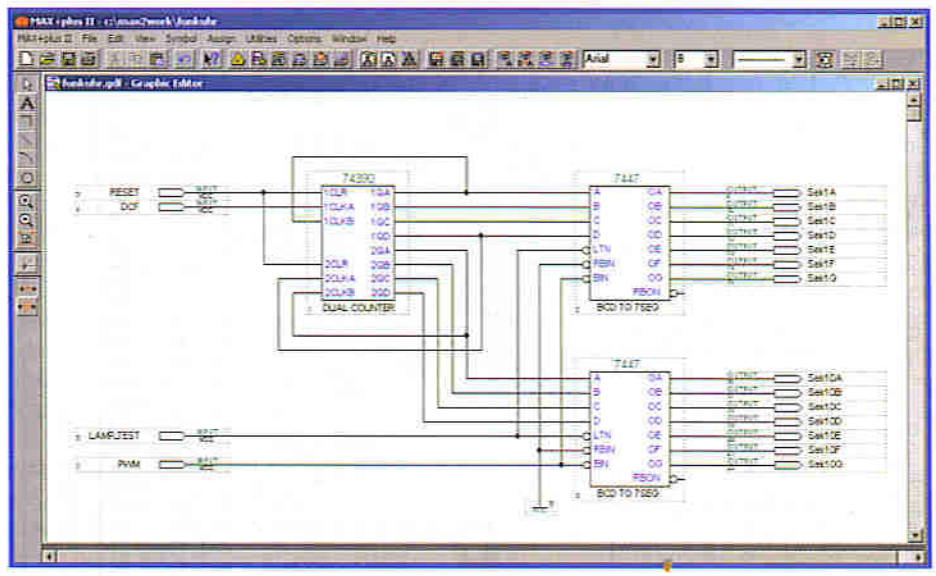


Figure 5. Setting out the 'connecting links' required. This is described step-by-step in the text.

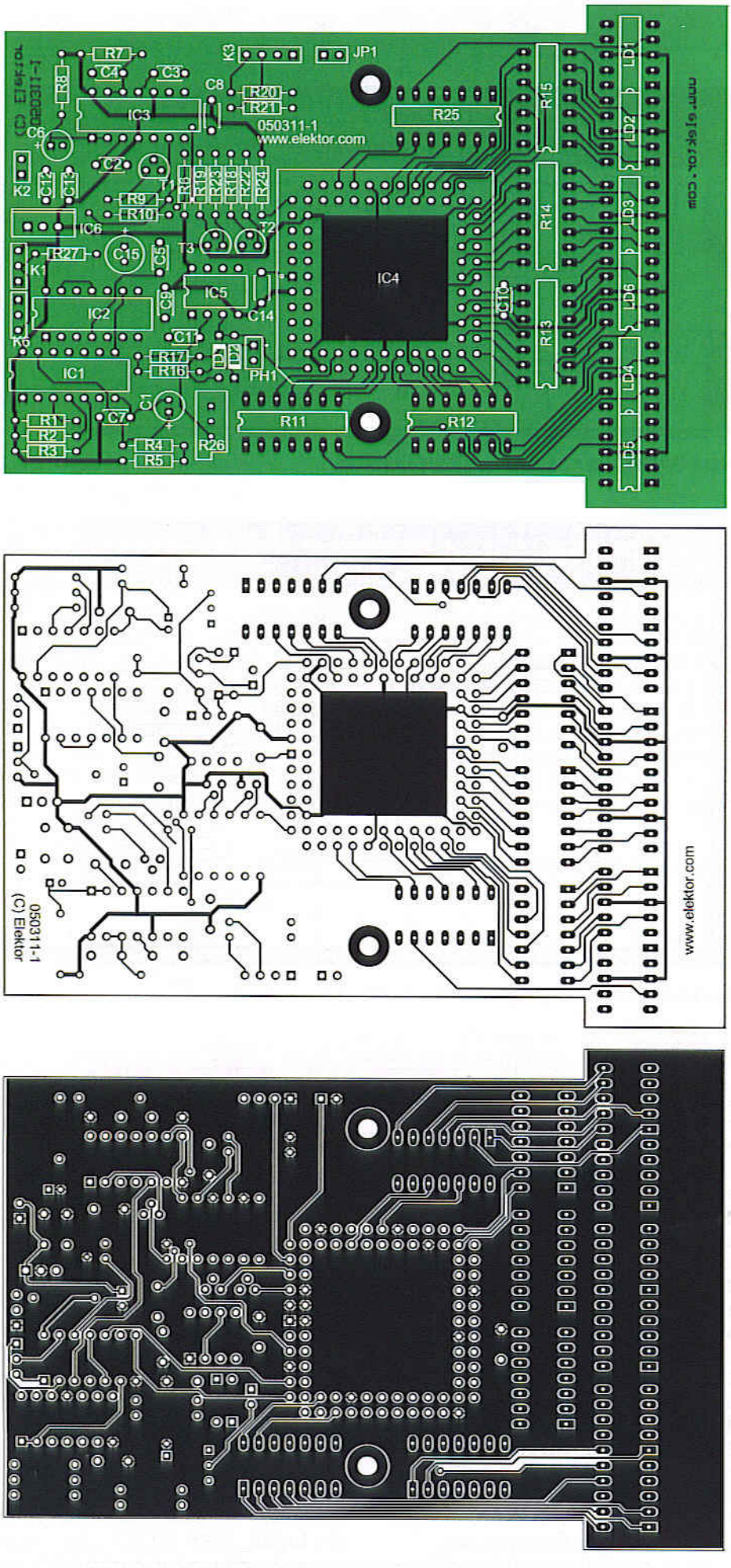


Figure 6. The PCB is designed to simplify soldering. The CPLD is the only surface-mount device used.

Decoding

Decoding of the DCF signal is handled in two type 74164 'serial in, parallel out' shift registers. The leading edge of the DCF signal shifts the current logical level of the signal into to the register. Since only data up to the 34th second is used for representing the clock time, a D-type flip-flop (DFF) is included in the circuit. The RESET pulse sets it to HIGH and the '35th Second' pulse sets it back to LOW. In conjunction with the AND2 gate it passes clock pulses through to the shift register 34 times. The '35th Second' pulse is produced by gate AND4, whose inputs are linked with 2QA and 2QB = 30, also 1QA and 1QC = 5 of the 74390 dual counter.

A different arrangement of AND4 would allow data pulses following the 34th second to be evaluated as well, in order to decode the year, month and day of the week. A corresponding number of additional shift registers would be required then.

The remainder of the circuit is routine. The type 7475 Latches are required because the display of hours and minutes can begin only after the *next* RESET pulse (remember, the DCF data pulses indicate the number of the *following* minute). On the other hand the seconds can be counted down quite simply and require no Latch. The eight ENABLE inputs to the Latches here should be linked to the RESET signal. The unused 4D data inputs of the Minutes tens together with the 3D and 4D of the Hours tens should be linked to Ground.

Outputs 1Q to 4Q of the Latches are each linked to the corresponding inputs A to D of four additional type 7447 seven-segment decoders. Their outputs OA to OG are each designated as an OUTPUT (here too you should give each OUPUT a recognisable and unambiguous name).

Almost there...

With this the circuitry is complete and can be implemented ('fitted') in a CPLD. For the seven-segment displays we have already used up 42 pins, meaning that only an 84-pin IC comes into the question. Go to Assign ⑤ Device... on the Menu strip and on the dialogue box that appears un-tick 'Show Only Fastest Speed Grades'. In 'Device Family' select the type MAX7000S und as Device the EPM7128SLC84-15. In 'Device Options...' tick 'Enable JTAG Support' and remove all others. Confirm with 'OK' and again 'OK'.

From the Symbol strip now select the

Compiler and click on the 'Start' button. If everything has gone right up to now the progress display will run through without stopping and the message < 0 Errors 1 Warnings > will appear. The circuit will function despite this warning. Using Assign ⑧ Global Project Logic Synthesis... you can make this warning message disappear if you un-tick 'Automatic Global Clock'. Compilation will now be carried out without any error and warning messages. Check out the reports data produced by the Compiler by double-clicking the 'rpt' symbol. Among other thing,s the pin allocation will be shown and at this stage this will not match up with the PCB layout. Users have virtually a free hand in allocating pins to the INPUTs and OUTPUTs, providing the subtlety necessary to produce complex circuits on single-sided PCBs.
For this project the pins are allocated according to **Table 2**. To this end mark the corresponding symbol on the diagram with a right-click and in the context menu select Assign > Pin/Location/Chip... . The designation of INPUTs and OUTPUTs is indicated at < Node Name >. In field < Chip Resource > type in the desired pin number at < Pin: >.
Pins can also be reserved for future enhancements, such as a serial interface. For this add three totally unattached INPUTS (without link tracks) on the diagram and name these, for example, 'Reserve1' to 'Reserve3'. These three pins are made tri-state, i.e. high-impedance, and therefore can remain unswitched on the PCB. OUTPUTs cannot be reserved in this fashion but they can be produced subsequently from a reserved INPUT.
Now compile your project. There should be < 0 Errors 0 Warnings > indicated as well as a notification that three pins have been reserved for future expansion and are 'tri-stated'. On the *Elektor Electronics* website [4] you can find additional information as a gratis downloadable PDF file; this includes a sample Report File with which your Report File should correspond.
The September 2002 issue of *Elektor Electronics* [5] includes a simple Parallel/JTAG interface that is well suited to programming CPLDs of the MAX-7000SLC type if the JTAG plug connector K2 is augmented or replaced by the appropriate PLCC socket.

Display details

To indicate the time we are using green seven-segment displays with a character height of 13 mm and a common anode (see heading photo). With six displays we have 6×7 = 42 connections to make to the CPLD. The data sheet [6] shows the following recommended current load values: 4 mA at TTL High level and 12 mA for TTL Low level per pin, with an overriding restriction that the total current drawn from the CPLD should not exceed around 130 mA. To avoid misoperation this must be taken into account when setting the values of the series resistors.
The maximum current draw occurs when all 42 segments are illuminated, which happens when LAMP_TEST is invoked. In normal operation a maximum of 39 segments are lit. With an operating voltage of 5 V and a voltage drop of 2 V in the LED segment the necessary series resistor per segment is calculated as follows:

$R = [(5\text{ V} - 2\text{ V}) / 0.13\text{]}) \times 42 = 969.23\ \Omega$

To be on the safe side we would use the next largest value of 1 kΩ, for which arrays of seven resistors in DIL form are available, making construction extremely straightforward. Naturally conventional resistors could also be used.
Through each segment we now have flowing a maximum of

$(5\text{ V} - 2\text{ V}) / 1000 = 3\text{ mA}$

At first this might seem rather low, as the seven-segment displays are designed for 10 mA. In practice, howev-

Table 2: Pin allocations

Inputs	Pin	Seconds	Pin	Minutes	Pin	Hours	Pin
DCF	9	Sec1A	69	Min1A	49	Hr1A	29
RESET	5	Sec1B	70	Min1B	51	Hr1B	34
HIGH/LOW	11	Sec1C	68	Min1C	50	Hr1C	30
LAMP_TEST	75	Sec1D	65	Min1D	48	Hr1D	28
PWM	12	Sec1E	63	Min1E	45	Hr1E	24
Reserve1	77	Sec1F	64	Min1F	46	Hr1F	27
Reserve2	79	Sec1G	60	Min1G	44	Hr1G	25
Reserve3	81	Sec10A	52	Min10A	39	Hr10A	20
		Sec10B	61	Min10B	41	Hr10B	22
		Sec10C	58	Min10C	40	Hr10C	21
		Sec10D	56	Min10D	37	Hr10D	18
		Sec10E	54	Min10E	35	Hr10E	16
		Sec10F	57	Min10F	36	Hr10F	17
		Sec10G	55	Min10G	33	Hr10G	15

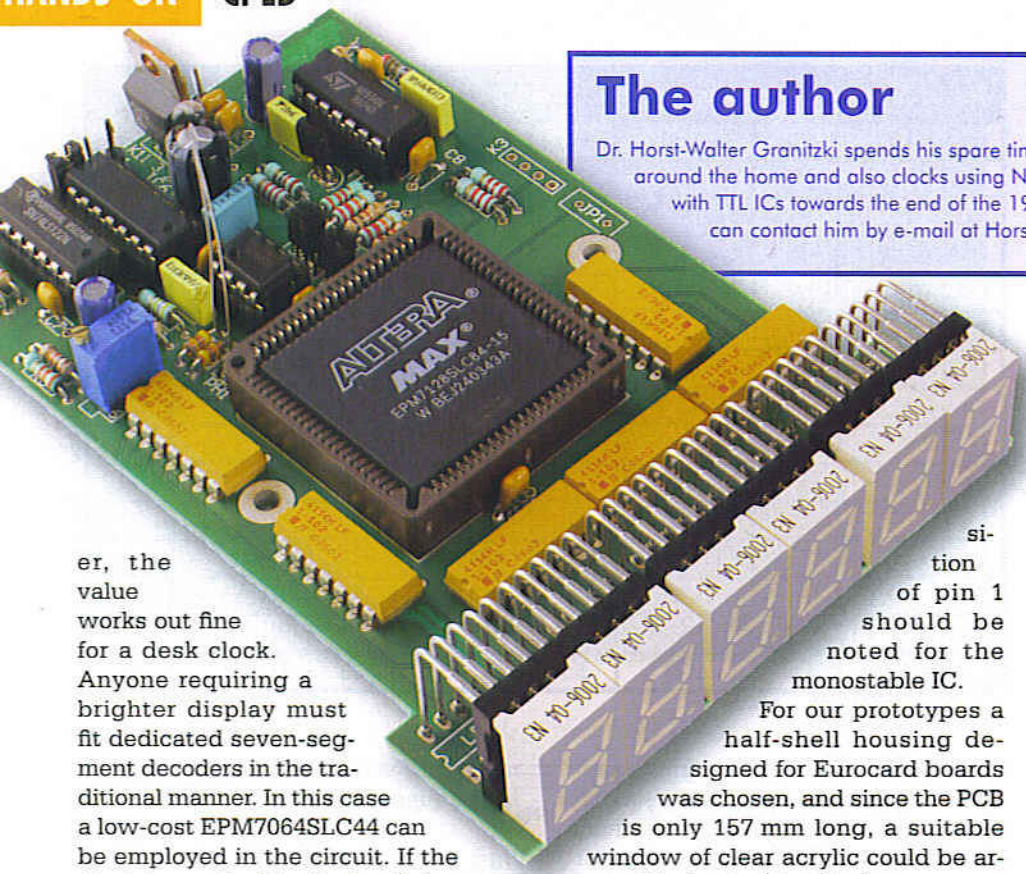
COMPONENTS LIST

Resistors
R1-R4,R22,R23 = 1kΩ
R5,R6 = 33kΩ
R7 = 9kΩ1
R8,R16=100kΩ
R9 = 22Ω
R10,R20,R21 = 2kΩ2
R11-R15,R25 = 1kΩ 7-way SIL array
R17 = 470kΩ
R18,R19 = 22kΩ
R24,R27 = 10kΩ
R26 = 100kΩ multiturn preset
PH1 = LDR 9060

Capacitors
C1,C6 = 10µF 16V radial
C2,C3,C11 = 10nF
C4,C7,C8,C9,C10,C12,C13,C14 = 100nF
C5 = 1nF
C15 = 470µF 16V radial

Semiconductors
D1,D2 = 1N4148
T1 = BC557B
T2,T3 = BC547B
IC1 = 74LS122
IC2 = 74LS14
IC3 = NE556
IC4 = EPM7128SLC84-15, programmed, order code **050311-31**
IC5 = NE555
IC6 = 7805
LD1-LD6 = SA52-11GWA (7-segment display with 90-degrees socket

Miscellaneous
K1 = 3-way SIL pinheader
K2 = 2-way SIL pinheader
K3 = 4-way SIL pinheader
JP1 = jumper
JP2 = 3-way jumper
DCF77 radio timecontrol receiver module (see text)
IC sockets
84-way PLCC socket
Enclosure Eurobox type KGB 13
PCB, ref. 050311-1 from www.thepcbshop.



The author

Dr. Horst-Walter Granitzki spends his spare time on electronics, mainly on gadgets to use around the home and also clocks using Nixie tube displays. He designed his first circuits with TTL ICs towards the end of the 1970s but today he prefers using CPLDs. You can contact him by e-mail at Horst@Granitzki.de

er, the value works out fine for a desk clock. Anyone requiring a brighter display must fit dedicated seven-segment decoders in the traditional manner. In this case a low-cost EPM7064SLC44 can be employed in the circuit. If the clock is required to display the year, month and day of the week as well as the time, at least six more displays will be necessary with then 12×7 = 84 connections in total. This too can be realised with the EPM7128SLC84 on the basis of this project, if the seven-segment decoders are left 'outside' the CPLD.

Construction

The PCB has been laid out intentionally to make soldering simple (see **Figure 6**). Apart from the CPLD itself, which fits into a socket with pins 1.27 mm apart, there are no SMDs. All tracks have been designed to have sufficient width to allow constructors to etch their own single-sided boards (no hair-thin tracks that disappear during the etch!). Take special care while drilling the 84 holes of 0.6 mm diameter for the Plastic Leaded Chip Carrier (PLCC) socket. They must line up exactly, at the correct distance apart, otherwise you will not get all 84 pins to pass through properly.

As wire links are not used it doesn't matter which components you fit first. The ideal power supply is a small 9-V plug-in 'wall wart' device that can deliver 300 mA. If its output is not too high, the heatsink beneath the voltage regulator can be omitted. Do not use a switch-mode power supply as its pulsing could interfere with your reception of DCF!

The seven-segment display blocks are placed in special angled sockets; sockets are recommended for all ICs. The position of pin 1 should be noted for the monostable IC.

For our prototypes a half-shell housing designed for Eurocard boards was chosen, and since the PCB is only 157 mm long, a suitable window of clear acrylic could be arranged in front of the display.

The components around transistors T2 and T3 including the four-pin connector (with the exception of R22 and R23) can be omitted if the serial interface is not required. Provision is made on the board for connectors to the power supply, DCF receiver module and the PC; the actual type of these can be selected according to your own preference.

Commissioning your clock

It's best to test the populated PCB in stages. With the CPLD and display not yet installed the current consumption should be in the region of 30 mA, and around 85 mA with the CPLD. Now plug the display devices into their sockets and link the jumper JP1 (Lamp Test). Each of the displays should now show '8' and the current drawn should not exceed 200 to 220 mA. Experiment a bit with the photoresistor; when it is covered current consumption should go down. Now adjust the spindle trimmer next to the photoresistor so that the display is clearly visible in well-lit surroundings.

Next, connect the DCF module to K1 (check polarity: DCF signal goes to Pin 1 of IC2). Jumper JP2 enables you to select whether the signal is inverted or not. The seconds should now count down. If this does not occur it may be that your receiver module is not delivering a proper TTL-level signal to the input of the 74LS14. In that case the mini-circuit in **Figure 7** will assist (for convenience the components can be soldered directly onto the PCB of the DCF module). Incidentally our CPLD will not be overexerted by the task imposed by this circuit. A practical expansion would be an extra output in serial interface format, for communicating with a PC for example.

(060311)

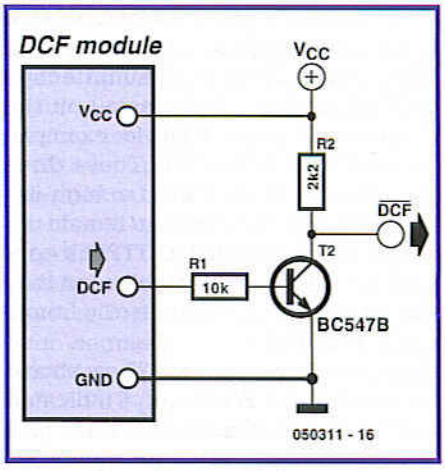


Figure 7. In the event that your module does not produce TTL-level signals, this mini circuit will sort things out.

Web links

[1] www.elektor-electronics.co.uk/Default.aspx?tabid=28&year=2004&month=2&art=51712
[2] www.altera.com/support/software/download/sof-download_center.html
[3] http://focus.ti.com/lit/ds/symlink/sa555.pdf
[4] www.elektor.com
[5] www.elektor-electronics.co.uk/Default.aspx?tabid=28&year=2002&month=9&art=50745
[6] www.altera.com/literature/ds/m7000.pdf
[7] www.hw-server.com/docs/dcfat.html
[8] http://en.wikipedia.org/wiki/DCF77

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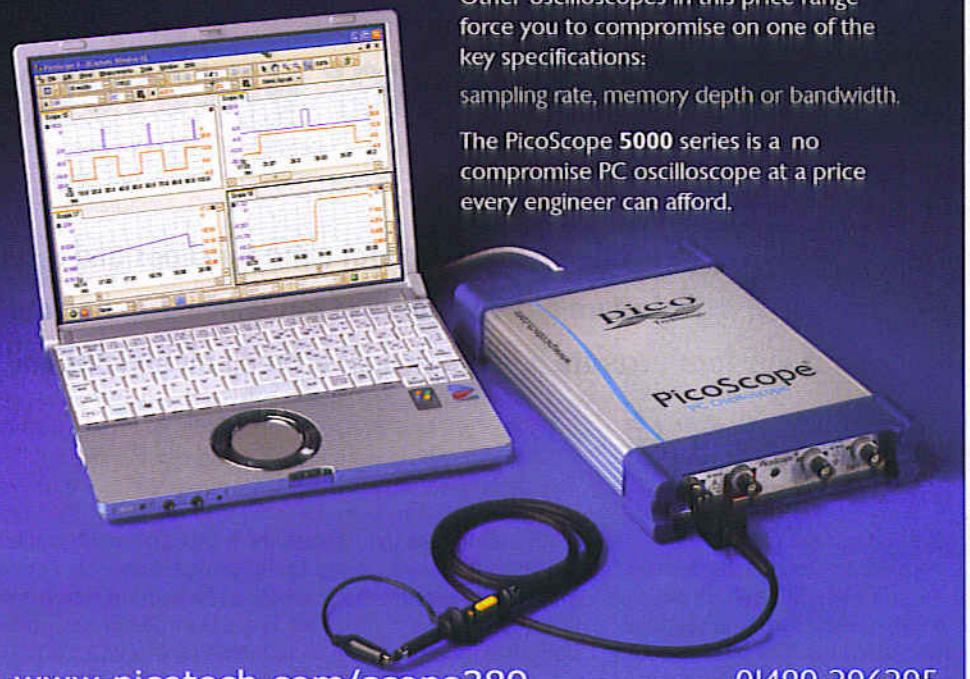

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Accurate Measureme

'Bargain bucket' multimeter uncovered

Fons Janssen – Maxim/Dallas Benelux

It is almost unbelievable: £5 for a digital multimeter with several extra functions and a set of leads. Surely that isn't enough to manufacture a decent piece of equipment? To find out how useful such a multimeter is and how accurate it is, we bought a cheap multimeter and gave it a thorough investigation.

You often see them in the £5 box near the checkout at Wallmart(-ish) outlets and builders' markets: multimeters that appear to be able to measure everything. Voltage, current, resistance, diodes and transistors; and all that for only £5! You can't help but wonder how they manage to sell such an item for so little money. More importantly, it would be interesting to know how accurate such a meter was and if it would be suitable for use in the lab or only for general use around the house. To find the answer to this question the author took a great financial risk and bought a meter in order to examine it closely.

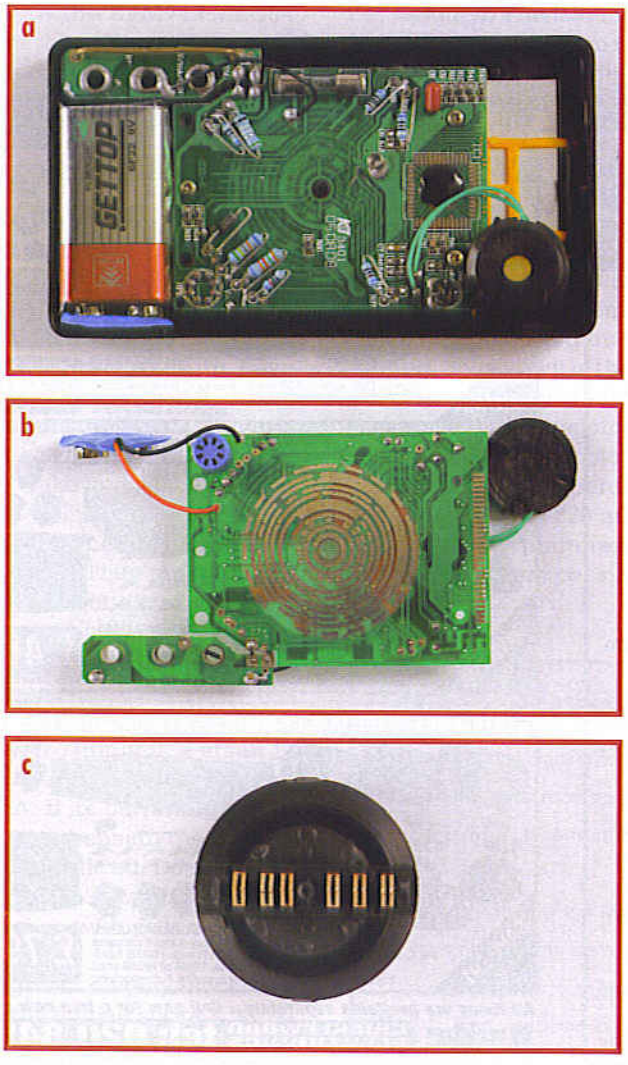


Figure 1.
The hardware of the multimeter:
a) the case with its rear cover removed, b) the PCB from the front, c) the rotary switch with six wipers.

Circuit diagram

At first sight the inside of the meter appears very straightforward. On the component side of the double-sided PCB we see one IC, a few capacitors and resistors, a diode, a fuse, a preset and a buzzer (refer to the photos in **Figure 1**). On the solder side we find the connectors and contacts for the function switch and the LC display (**1b**). The most ingenious part is the rotary switch. This consists of six slide-contacts that are mounted on the underside of a plastic knob (**1c**), and another set of contacts spread along 11 concentric rings on the PCB. This switch is used to select a completely different configuration of the circuit for each of its 20 positions.
The complete circuit diagram for the multimeter is shown in **Figure 2**. Broadly speaking, the circuit can be divided into three sections:

- The function switch that selects the right circuit configuration for the required measurement.
- The voltmeter, built around an ICL7106-type chip, which takes care of the actual measurement and also drives the LC display.
- Two ladder networks consisting of precision resistors, which are used to scale the input signal or act as a reference.

The six slide switches (SW1 to SW6) make up a single rotary switch, which is used to select the different configurations. For each position of the rotary switch the contacts of the slide switches are always in a single line. For current and voltage measurements the input signal is conditioned so that the voltmeter IC receives a maximum voltage of 200 mV (V_{ref} = 100 mV). For a voltage measurement the input signal is first reduced in value by a precision potential divider. For a current measurement the current is converted into a voltage by a second precision resistor network. When measuring a resistor the voltage across the measured resistor is compared with the volt-

nts for a Fiver?

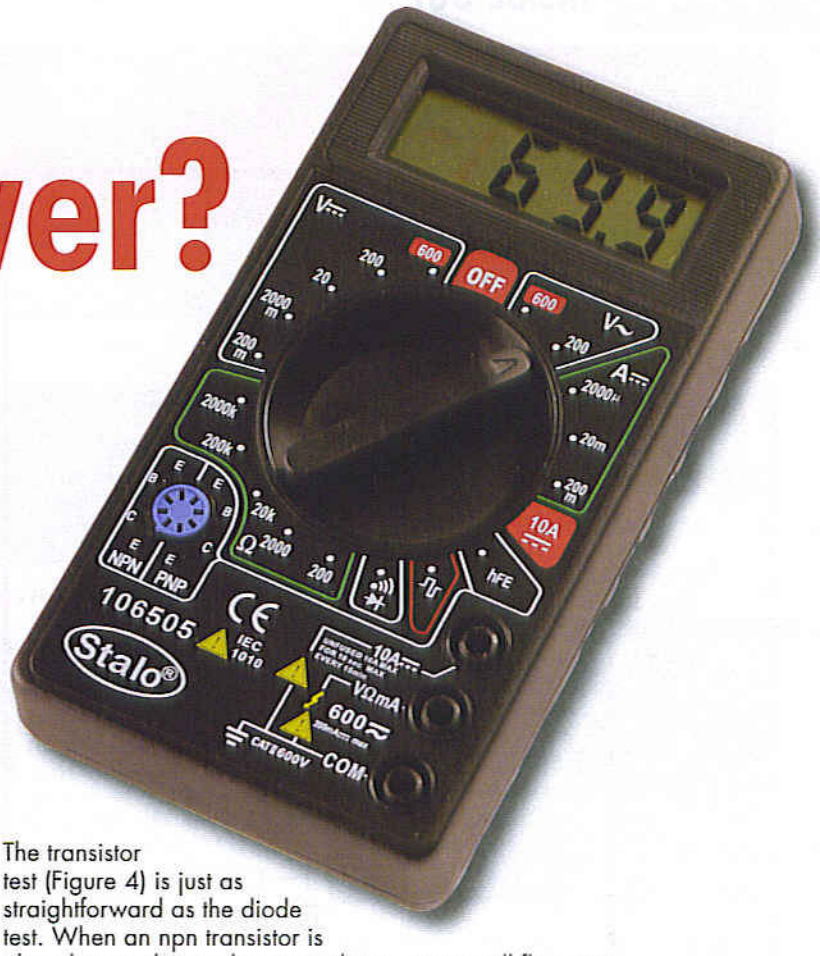
age across a reference resistor that has the same current flowing through it. The voltage across the reference resistor then acts as V_{ref} for the voltmeter IC, which makes the measured voltage directly proportional to the value of the unknown resistor.

Extra functions

The nice thing about this meter is that it also has a diode and transistor test. We'll look into these functions in more detail. The simplified circuit diagrams for these functions are show in **Figure 3 and 4**. For the diode test, IC1 sets V+ about 3.0 V above ground (note that the battery –ve isn't connected to ground). When a diode is connected to the meter a current flows through the series connected R38, R39, R20 and the unknown diode. Assuming a working silicon diode, it will have a voltage drop of about 0.7 V, which leaves 2.3 V across the resistors. The current through these will then be approximately:

2.3 V/(100Ω+900Ω+1300Ω) = 1 mA.

The voltage drop across R38+R39 is then about 1 V, which is used as the reference voltage for the voltmeter. The voltmeter shows the diode voltage using a range of 2 V. If a voltage of about 0.7 V is measured you can conclude that the p-n junction of the diode is still functional. If the meter sees a voltage of less than 100 mV it will sound a buzzer. This continuity check is built into the voltmeter IC.



The transistor test (Figure 4) is just as straightforward as the diode test. When an npn transistor is placed correctly into the test socket a current will flow into the base through R24. The size of this current is:

$(V^+ - V_{be}) / (R^* + R21 + R22 + R24) \approx (3\ V - 0.7\ V) / 220\ k\Omega \approx 10\ \mu A$.

The voltmeter measures the emitter current via resistors R* + R21 + R22:

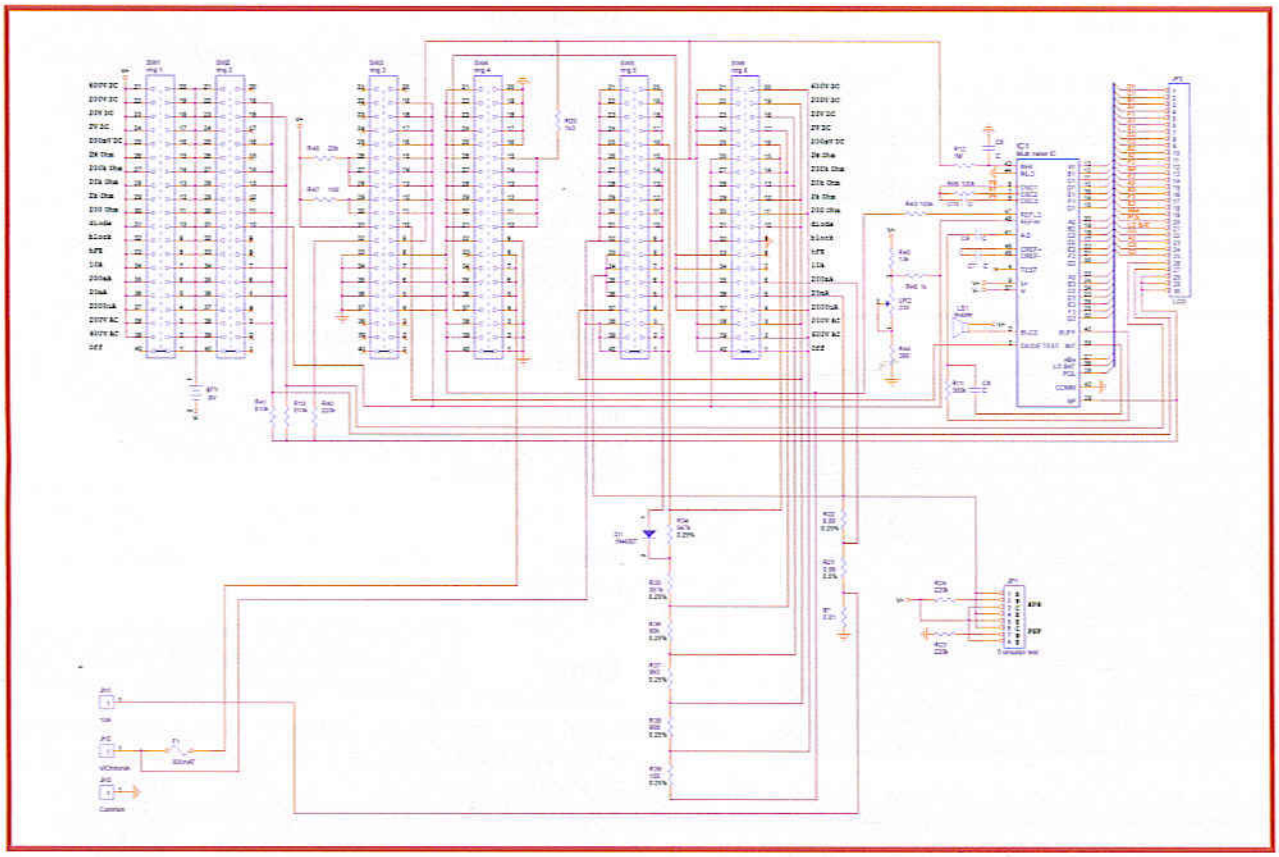


Figure 2.
Circuit diagram for the multimeter.

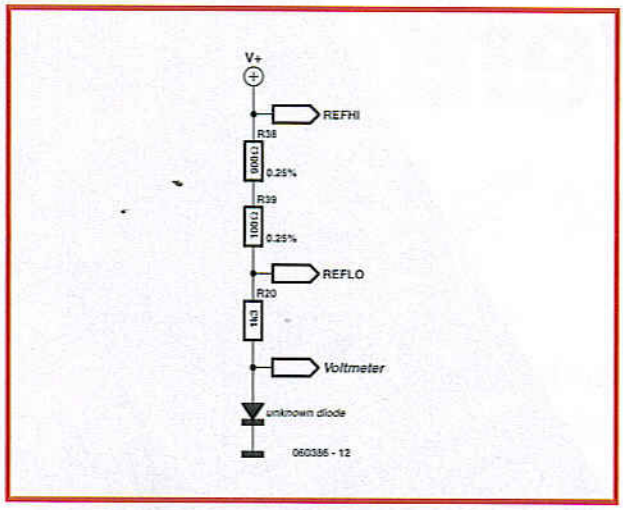


Figure 3. Simplified circuit for the diode test.

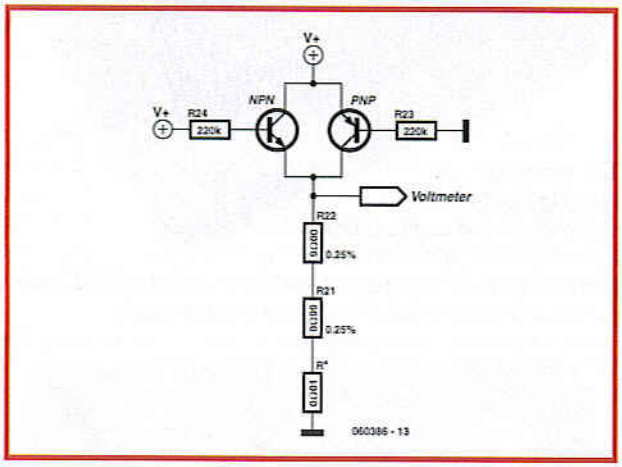


Figure 4. Simplified circuit for the transistor test.

$V_{meas.} = I_e \times 10\ \Omega$

This voltage is measured using a reference of 100 mV and the result is shown without a decimal place. This means that the value shown (X) is equal to:

$V_{meas.} / 0.1\ mV = I_e \times 10\ \Omega / 0.1\ mV = I_e \times 10^5$

Since $h_{FE} \approx I_e/I_b$, it follows that:

$X = h_{FE} \times I_b \times 10^5 = h_{FE} \times 10^{-5} \times 10^5 = h_{FE}!$

For a pnp the calculations are almost identical, except that I_e is replaced by I_c.

Accuracy

The accuracy of measurements is different for each function. According to the manual it is ±0.25% of the full scale at 200 mV ± 2 digits. For the other DC measurements it is ±0.5% of the measured voltage ±2 digits. At first this looks to be fairly accurate, but appearances can be deceptive. Because we have a 3.5-digit meter, the influence of these ±2 digits is much bigger than the percentage of the measured value, especially at lower input voltages (compared to the full scale value). In **Figure 5** is a graph of the measurement error as a function of the measurement voltage. As a comparison we've also shown the measurement errors for a professional 5.5-digit multimeter (34405A), which was made available by Agilent Technologies for use in preparing this article. From the graph it is clear that the effect of the ±2 digits is greatest at the lower end of each range.

That covers the specification. But how does the meter function in practice? To find out, we measured several voltages with both the low-cost multimeter as well as the professional Agilent 34405A multimeter. To keep things simple, we've assumed that the Agilent-meter showed the 'correct' value and that any differences on the low-cost meter were due to the errors of this meter. The results of these measurements are also shown in Figure 5. We can see that the values fall well within the stated specifications.
We obtained similar results for current and resistor measurements. With these the measurement error also stayed within those given in the specifications.

Conclusions

From these measurement results we can conclude that this isn't a bad little meter. For an electronics hobbyist just starting out we would recommend it, especially at this price. However, it isn't clear what happens to the accuracy in the longer term. The specifications stated that the given accuracy is guaranteed for a year, after which you may have to calibrate the meter. If this meter were used in a lab environment we would certainly recommend that it is calibrated on a regular basis. For critical measurements, where accuracy of the figures after the decimal point is important, this meter would be unsuitable and a professional meter is essential.

And finally, we'll show all the advantages and disadvantages in a list, so you can decide for yourself if such a £5 meter is suitable.

Pros:
+ Cheap
+ Versatile

Cons:
– Limited accuracy
– Low input impedance (1 MΩ) for voltage measurements
– Low-cost build quality; e.g. a soldered fuse instead of a fuse-holder
– No facility for computer controlled measurements

(060386-I)

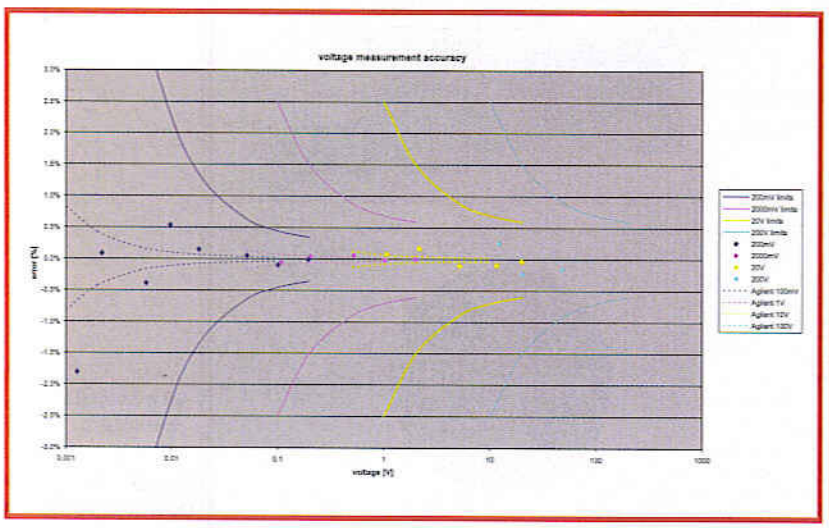


Figure 5. The measurement error as a function of the input voltage for a cheap meter and a professional meter.

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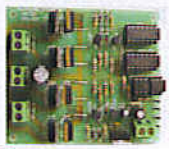

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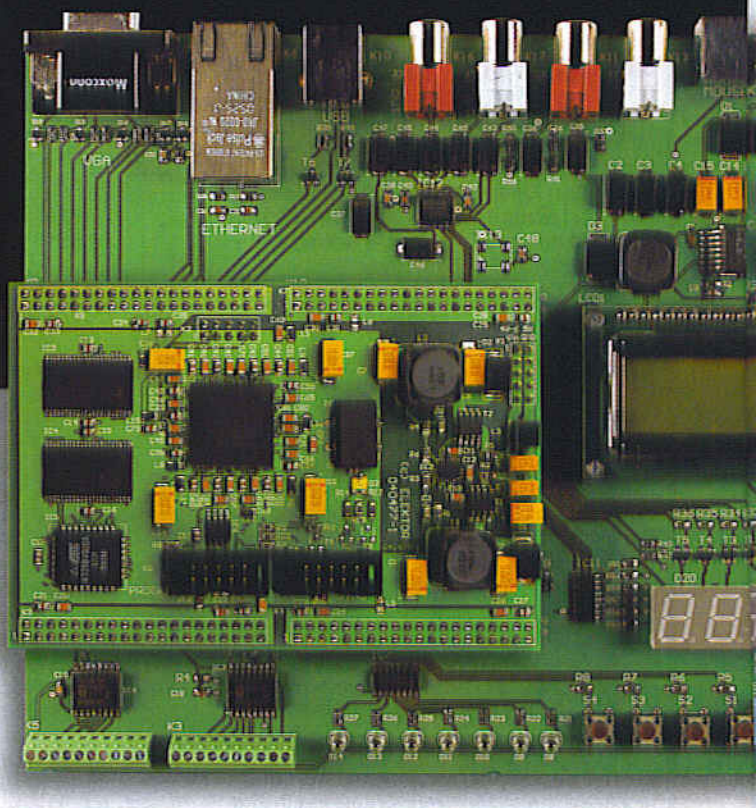
FPGA Course (9)

Part 9 : The final act



Paul Goossens &
Andreas Voggeneder

We've used nearly every I/O port of the prototyping board at least once in this FPGA course. We say 'nearly' because we haven't used the Ethernet port up to now. The final instalment of the course sets this right with a full-fledged webserver application.

The prototyping board has an Ethernet connector and associated Ethernet PHY. This makes it possible to connect the FPGA to an Ethernet network, and ultimately to the Internet.

Ethernet

An Ethernet network can be used to interconnect several computers and other devices. The Internet is the largest and best-known example of an Ethernet network. This article shows you how to connect the FPGA module to an Ethernet network. This can be a small local area network in you home, but it can also be the Internet.

Various sorts of logic in the FPGA module are necessary for this purpose. Although the FPGA prototyping board has an Ethernet connector and Ethernet PHY, it takes quite a bit more than this to make an Ethernet connection. The task of the Ethernet PHY is to transmit and receive data in serial format according to the Ethernet standard.
Besides this PHY, you also need a media access controller (MAC). The functions of the MAC component are:

- automatic data flow control
- detecting data collisions and retransmitting data if something goes wrong (CSMA/CD)
- adding a CRC checksum
- adding a preamble on transmission and deleting the preamble on reception

For the experts among our readers, this is Layer 2 of the OSI model. Layer 1 consists of the combination of the PHY, the transformer and the connector.
You also need a microcontroller with the right software to add the TCP/IP protocol and the application to the system. Just as in the previous instalments, we use the T51 core for this purpose.
The software is based on the software for our MSC1210 webserver. We used the uC51 compiler and associated TCP/IP stack to compile the code. This compiler is available from Wickenhäuser (see inset).

MAC

The media access controller (MAC) comes from www.opencores.com, and it is written in Verilog. The MAC uses a 32-bit data bus, while the T51 works with an 8-bit data bus. The *ethernet_verilog.vhd* file was modified so these two busses can be connected together.
The details of how this MAC works fall outside the scope of this article. In any case, you don't need to understand the details to use the MAC properly. With the help of the software provided with the course, you can quickly write your own applications for the Ethernet port.

First example

Our first example (**ex24**) uses the T51 core, the MAC core, and some peripheral logic. The Ethernet core eats up a fair amount of the scarce memory in the FPGA, so the maximum amount of ROM available to the T51 is 14 kB. This is a rather small amount of memory for a webserver. Among other things, the entire TCP/IP stack, the control logic for the MAC and the PHY chip, and the webserver application must all be fitted into this 14 kB.
The RAM consists of an external SRAM IC that is already present in the FPGA module. This IC is connected to the microcontroller via the wishbone bus. The memory layout is shown in **Figure 1**. The first 52 kB of RAM are provided by the SRAM IC. Addresses 0xD000 through 0xDFFF are reserved for the Ethernet MAC. Finally, the remaining 8 kB is used as buffer memory for transmitted and received data packets.
Now the FPGA prototyping board has to be connected to a network. You can use a router or a switch for this. The TCP/IP address of this application is set to a fixed value of 192.168.0.1. Ensure that your network is configured such that address 192.168.0.1 is valid on the network. If you use a router, the TCP/IP address of the router must be configured such that the first three numbers are 192.168.0, and the last number must **not** be 1 since this number is already used by the FPGA module. If the router has a DHCP server, you will have to adapt it to the new TCP/IP addresses.
If everything goes the way it should, after you program the FPGA you can use the web browser on your PC to view the web pages in the FPGA by entering the following address (URL):

http://192.168.0.1

If this doesn't work, check the network settings of your PC and router.

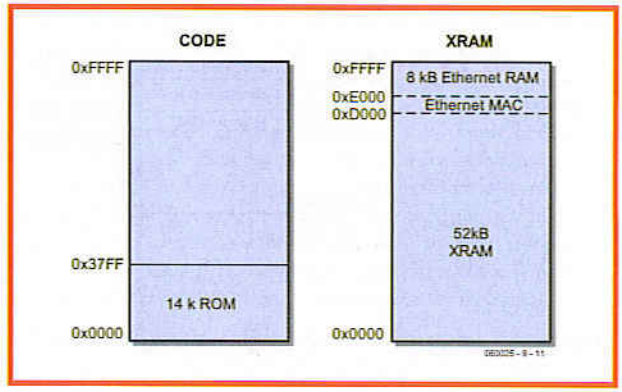


Figure 1. Memory layout for example ex24.

Even more

The webserver of example 24 has just enough oomph to publish a couple of HTML pages using the FPGA module. This is rather on the meagre side, and it certainly isn't what we really want. The limiting factor here is program memory.

If you can expand this memory, you can then write more 'meaningful' applications for the webserver. Fortunately, the FPGA module has some extra RAM and flash memory. If you use the flash memory to store the program code, in theory you can use programs up to 128 kB in size. This brings us up against a problem: you can program the memory in the FPGA using Quartus, but you can't program external memory.

Bank registers

Bank_En (0xF8)

Bit 4: 1 = VGA enabled; 0 = VGA disabled
(0x8000–0xBFFF)
Bit 5: 1 = SRAM always bank 0;
0 = SRAM depends on Bank_Sel
Bit 6: 1 = SRAM enabled; 0 = flash enabled
Bit 7: 1 = Ethernet disabled; 0 = Ethernet enabled
(0xD000–0xFFFF)

Bank_Sel(0xF9)

This register selects the current bank.

Features of example 25

- 8052 controller running at 25 MIPS
- 10/100 Mb/s Ethernet interface
- 256 kB RAM
- 128 kB flash
- VGA interface
- PS/2 interface
- Firmware updating via BOOTP

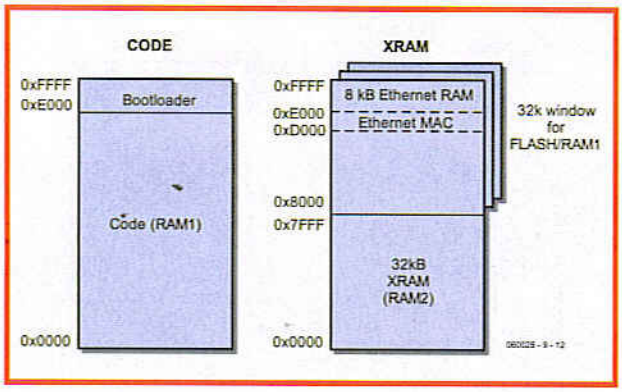


Figure 2. Memory layout for example ex25 when the bootloader is NOT executed.

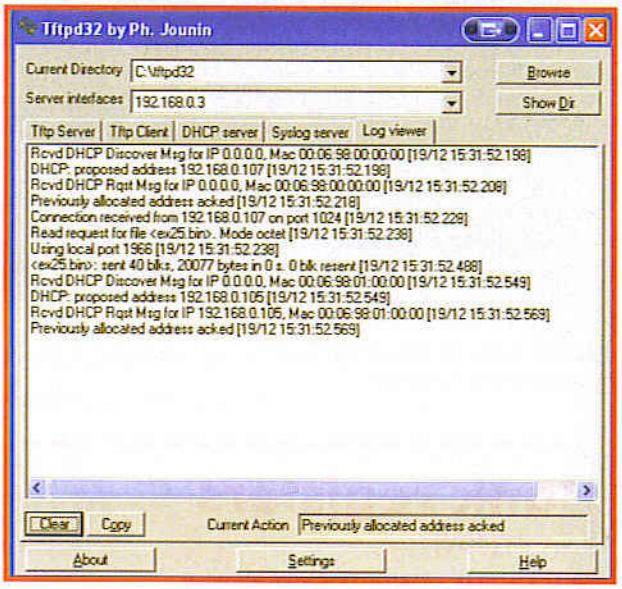


Figure 3. DHCP server settings in the program tftpd32.

µC-51

The software used in examples 24 and 25 was generated using the Wickenhäuser µC51 C compiler (www.wickenhaeuser.de).

We used this compiler on account of the TCP/IP stack that comes with the compiler. The free version of the compiler can generate programs with up to 8 kB of code, which is not enough for our software. If you wish to modify and recompile the software, you will need the full version of the compiler. The price of the compiler was € 84.50 (approx.£ 59) at the time of writing.

Up to now we have not been able to find a suitable TCP/IP stack for SDCC. If at some point we manage to find an open-source TCP/IP stack that is suitable for SDCC, we will make this known via our FPGA forum.

Naturally, we would also be grateful to hear about any suitable TCP/IP stack written by one of our readers or encountered by our readers somewhere on the Internet.

Boot loader

In example 25 (**ex25**), we connect the microcontroller to the flash memory and both SRAM chips. We also place a boot loader program in the internal ROM. If you set dipswitch 6 to the ON position and then reset the circuit by pressing button 1, this program will run.
The boot loader uses the DHCP protocol to try to obtain a valid TCP/IP address, such as the address of the router or PC. If this succeeds, it then uses the BOOTP protocol to request data. The data that the microcontroller receives in response to this request is stored in the external flash memory.

If the system is started up with dipswitch 6 in the OFF position, the content of the flash memory is copied to the SDRAM (IC4 on the prototyping board). The program code in the SDRAM is then executed. The reason for copying the program code is that the flash memory is relatively slow (access time 150 ns). The SDRAM has an access time of 10 ns and is thus much faster. The long access time of the flash memory makes it necessary to insert three wait states for each read instruction. As a result, the microcontroller effectively runs at 6.25 MHz instead of 25 MHz. This restriction is not necessary if the program code is executed from the SDRAM, so the microcontroller is free to operate at full speed.
It is not essential to store the program code directly in the flash memory when you are developing new software. For this reason, we added the option of storing program code in external SRAM (IC4) instead of flash memory. To do so, set dipswitch 7 to the ON position. The program will then be executed from SDRAM after the firmware has been downloaded.

RAM

The RAM memory is also expanded in example 25. To help clarify the following explanation, the memory layout of example 25 is shown in **Figure 2**. This layout is only valid if the boot loader is ***not*** running. A different memory layout is used when the boot loader is running, so that data can be written to the SRAM chip (IC4).
The memory layout can be configured using two SFR registers: Bank_En (0xF8) and Bank_Sel (0xF9).
Bit 4 of Bank_En determines whether VGA memory is addressable. If it is set to '1', VGA memory can be accessed in the address range 0x8000–0xBFFF.
Bit 7 of the same register determines whether the memory of the Ethernet interface is accessible as XRAM in the address range 0xD000–0xFFFF.
Bit 6 selects either flash or RAM for the upper 32 kB. If bit 6 is set to '0', flash memory can be accessed in the memory range 0x8000–0xFFFF. If this bit is set to '1', the content of the SRAM (IC3) is accessible in this address range.

Note that the VGA interface and the Ethernet interface have the highest priority. If either of these interfaces is enabled, the associated addresses cannot be used for the SDRAM or flash memory.
Bank-switching capability
is also provided to enable using the entire SDRAM and flash memory. You can use the Bank_Sel register to choose which part of the flash memory or SDRAM is selected. In case of the flash memory, this register determines which of the 32-kB blocks is currently in use. With the SDRAM, this register determines which 64-kB block is currently in use.

Down to work

That's enough explanation – now let's try example 25 in practice! Besides the usual software, you need one more program file for this, which is named *tftpd32*. It can be downloaded from the Internet free of charge (http://tftpd32.jounin.net). This program file contains a DHCP server and a BOOTP server. You need both of them in order to load software into the flash memory.
To start off, you have to ensure that your PC uses a fixed IP address. As already mentioned, we selected address 192.168.0.1 for this.

If you router has a DHCP server, you must disable it, since only one DHCP server is allowed in a network. If you use a router, it must also be configured with a fixed IP address (in our case, we used address 192.168.0.2 for the router).
After starting up *tftp32*, you have to configure the right DHCP server settings. In our example (**Figure 3**), we reserved addresses 192.168.0.105 through 192.168.0.115 for dynamic addresses. We also selected file *ex25.bin* as the BOOTP file.
The next step is to use Quartus to configure the FPGA. Make sure that dipswitch 6 is ON and dipswitch 7 is OFF. After the configuration is completed, the boot loader will start running and request an IP address. It will then use BOOTP to ask for a program. You can see this in the Log Viewer of the *tftp32* window.
If everything goes the way it should, the IP address of the FPGA will appear on the LCD screen. In our case, the FPGA was assigned address 192.168.0.107. Now you can locate the FPGA module in your web browser at address http://192.168.0.107. If your FPGA module is assigned a different address, simply enter the corresponding address in your web browser.

Pitfalls

The file that is sent vial BOOTP (the firmware for the microcontroller) must be a binary file. The µC51 compiler will generate a binary file automatically if you use the 'make' files provided with the course.
If you want to use software generated by a different compiler, make sure that it generates a binary output file. Most compilers can generate binary files. If you compiler can't do this, there are several freeware programs available that can convert hex files into binary files.

Conclusion

You can refine and extend the final embedded system of example 25 to generate your own applications. The features of this system are quite impressive, especially considering that the complete source code is available in VHDL. You can use this source code to enlarge your knowledge of VHDL.
We hope this course has helped you carry out your first practical experiments with programmable logic and VHDL.
The course is naturally far from complete – the subject of FPGAs and VHDL is so broad that you could easily write a whole set of books about it. Nevertheless, we think the course provides enough material – in part because of the numerous examples – to enable you to start developing your own designs in VHDL.

We have set up a separate topic in the forums section of our website so users of the FPGA module can share their experience. There's a good chance that you can pick up new ideas there, and you can also ask other readers for help with any problems you may encounter.
In any case, we hope you have a lot of fun (and learn something) with the FPGA module!

(060025-9)

DHCP and BOOTP

The DHCP protocol can be used to assign dynamic addresses to devices with Ethernet ports. Each device in a network requires a unique IP address so it can communicate with other devices. This can be achieved by manually assigning each PC or device a unique address. However, people quickly realised that it would be convenient to have IP address configuration be handled automatically by a server.

The protocol for this is called the DHCP protocol. It requires a DHCP server. Most routers for home use have built-in DHCP servers.

Another protocol that has been developed is the BOOTP protocol. This protocol makes it possible to boot PCs from a network if they do not have internal hard disks. If a BOOTP request is sent to a server, it uses the same protocol to send a small program back to the PC. The PC runs this program after receiving it. This program usually enables the PC to continue starting up from the server. This makes it a lot easier for system managers to supply new software to all PCs on the network in a single operation or install updates.

In our example, we use BOOTP to send new firmware to the FPGA module. This firmware is loaded into flash memory or SDRAM (depending on the position of dipswitch 7) and then executed.

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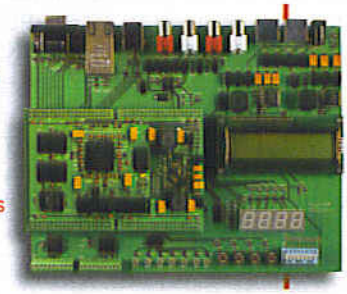


The basis of this course is an FPGA Module powered by an Altera Cyclone FPGA chip, installed on an FPGA Prototyping Board equipped with a wealth of I/O and two displays (see the March 2006 issue).

Both boards are available ready-populated and tested. Together they form a solid basis for you to try out the examples presented as part of the course and so build personal expertise and know-how in the field of FPGAs.

Further information may be found on the shop/kits & modules pages at www.elektor-electronics.co.uk

I-Q: a Highly Intelli Quality Radio

First steps in Software Defined Radio (SDR)

Burkhard Kainka

Until now panoramic display and selectable bandwidth were features found only on top range (and fearfully expensive!) shortwave receivers. Realising these functions in software makes it possible to create a receiver for ridiculously little money using barely any hardware components. SDR and I-Q Mixers are the new watchwords…

This receiver is so cheap it's an absolute bargain — but with the inevitable qualification. If (such a small word!) you use a freeware program for the software radio, if you build the minimalist hardware yourself and if the PC (or notebook computer) used is already paid for, then yes, you really can have a new radio with all the luxury trimmings for virtually nothing. Naturally the time spent creating it is not work, just sheer pleasure…

SDRadio

It's the Italian radio amateur Alberto (callsign I2PHD) whom we must thank for the downloadable freeware program SDRadio [1]. This PC program teams up with the computer's sound card and a simple RF front end to create a magnificent shortwave receiver for all modes from AM to SSB. Using the mouse alone, a range of up to 48 kHz can be tuned without even altering the oscillator frequency. You can see what's going on either side in the adjacent frequencies and react flexibly to interference, altering the receiver passband as required.

The hardware we need is a so-called I-Q mixer (also known as a quadrature mixer), which in principle is a direct mixer but enhanced to be a dual-stage mixer with phase-shifted oscillator signals. In this article we shall use one of these mixers in an experimental circuit of our own design.

Theory (just a little!)

As well as the desired frequency, all simple mixer stages also produce an 'image signal' (mirror image) that frequently requires a lot of effort to filter out and remove. However, this is not the case for the I-Q mixer, which in principle comprises two mixer stages and looks after image signal suppression itself. The concept can be applied to very simple receivers and is particularly valid for software-based receivers.

The three most commonly used receiver types are the 'straight' receiver, the superhet and the direct mixer. In the straight receiver a tuned circuit at the input looks after all selection issues. An example is the Audion, which employs active absorption in the input circuit to improve tuning selectivity. A straight receiver of this kind does not suffer from image signal problems but offers rather weak suppression of adjacent signals. The superhet is different; here we have several intermediate frequency (IF) circuits achieving good selectivity and adjacent signal suppression. Unfortunately the image

igent Approach to

signal still creates problems for us. A superhet with an IF of 455 kHz has, in principle, some secondary response at twice the intermediate frequency (2 * 455 kHz = 910 kHz). On medium wave a preselector circuit is sufficient to suppress this undesired response quite adequately. However, many shortwave radios exhibit a significant image frequency response.

The direct mixer is an ideally simple receiver. Without the complication of an intermediate frequency it mixes the RF signal straight down to the audio frequency stage. The process is used not just with simple amateur radio receivers but also for equally simple DRM receivers, in which the 'audio' signal is in fact a 12 kHz IF. In both situations the image frequency is so close to the wanted one that we no longer have any chance of filtering it out.

Figure 1 illustrates this problem in a worked example. A signal on 3990 kHz is to be mixed down to 12 kHz. The mixer oscillator operates at 3990 kHz + 12 kHz = 4002 kHz. In the process an image response arises at 4002 kHz + 12 kHz = 4014 kHz. We can only hope that there is no strong signal present at the 'wrong' frequency.

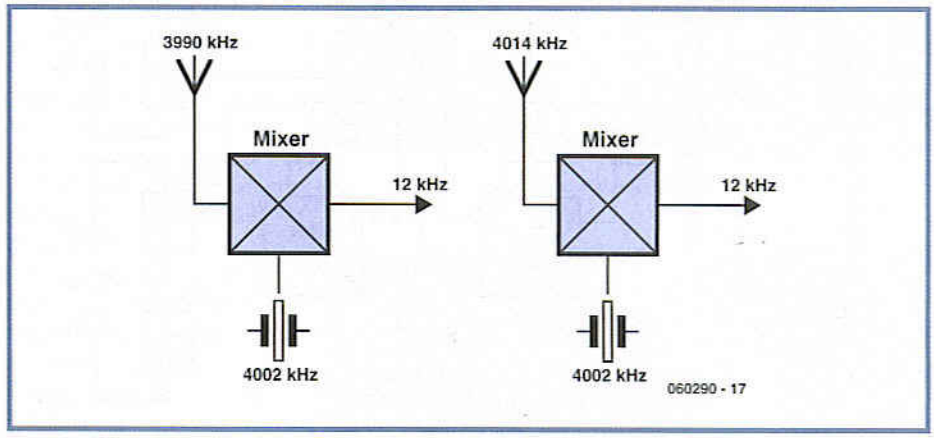


Figure 1. Image frequencies.

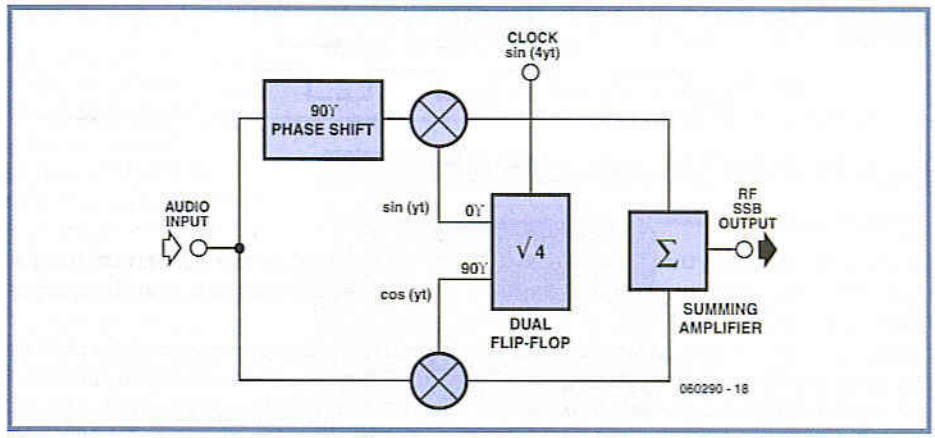


Figure 2. SSB generation using the phase method.

I-Q Mixer

The solution to this problem is to use two identical mixers instead of just one. These are driven using the same oscillator frequency but 90 degrees out of phase. The same input signal then produces outputs from the two mixers that are phase-shifted 90 degrees apart. The signals must then be phase-shifted one more time (in **Figure 2** this happens in the phase shifter in the upper branch ahead of the mixer) and then summed together. This is where the image frequency signals are cancelled out, whilst the desired signal is amplified. This technique, seen here in the I-Q mixer, is actually old hat and has been employed, in the reverse direction, for a long time for producing SSB signals. In that situation too the issue is all about mixing signals without generating an image frequency (corresponding in that case to the other sideband). In amateur radio for instance this technique is known as the phase method

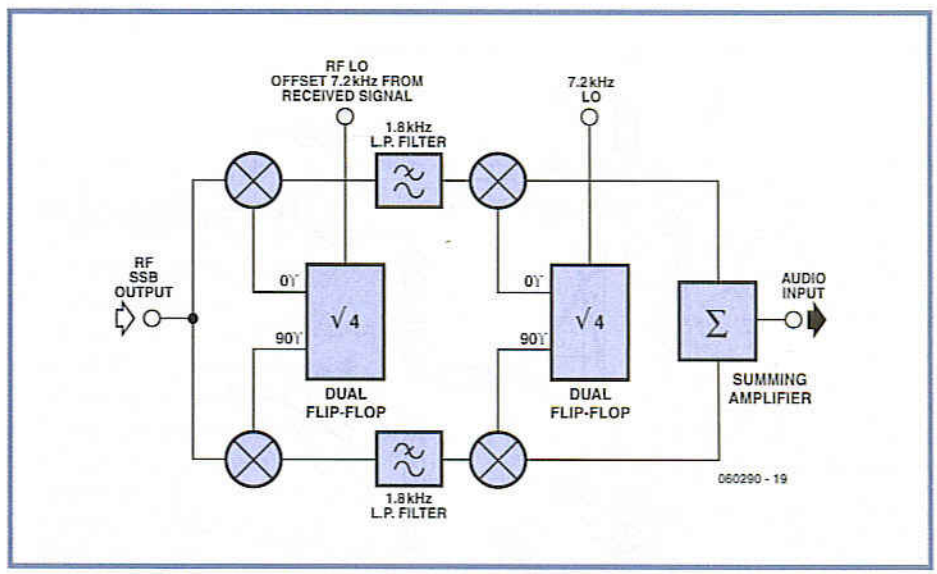


Figure 3. Reception path in the third scheme.

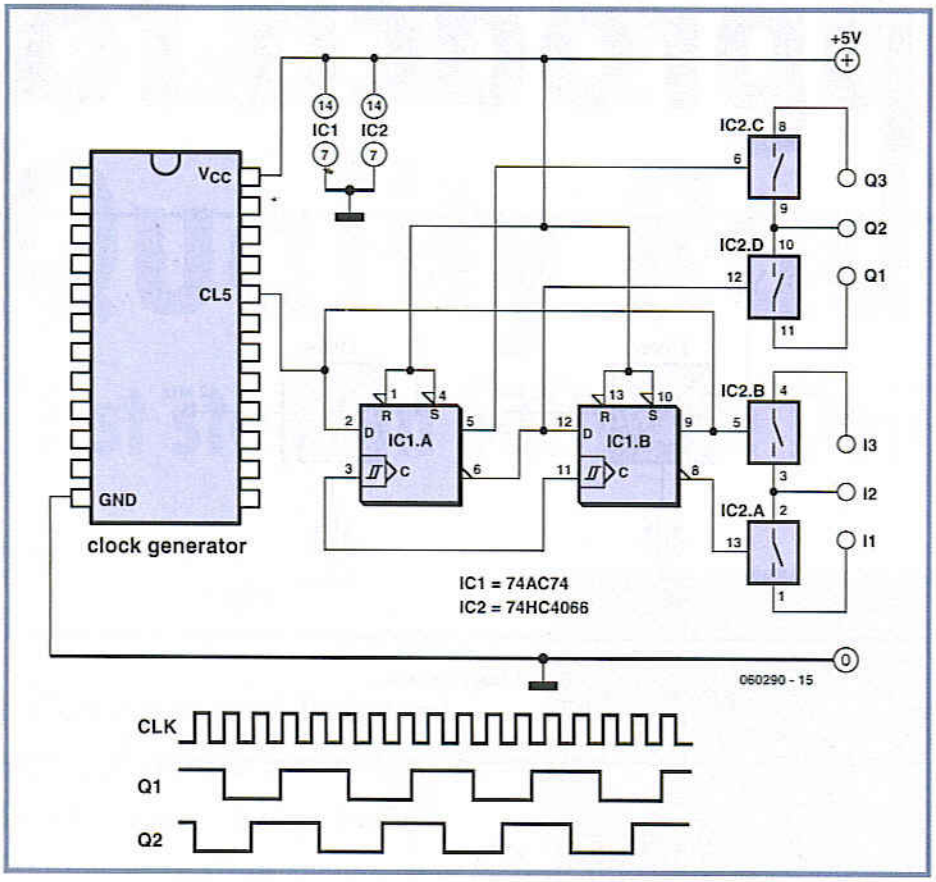


Figure 4. The I-Q mixer.

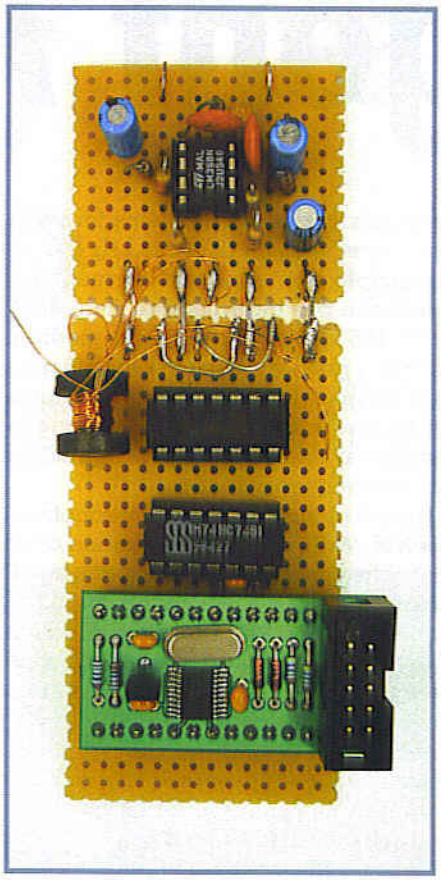


Figure 6. Test build of the complete receiver.

and the problem with the phase method is the difficulty of maintaining an entire frequency band from 300 Hz to 3000 Hz in phase to the same degree. In Weaver's so-called 'third method' two further mixers are employed to sustain or conserve the phase-shifted oscillator signals (**Figure 3**). This method would for example enable the construction of a complete SSB transceiver without crystal filters [2].

Meanwhile the prerequisites for the I-Q mixer look ever more attractive, as signal processing in software has made significant progress. For our first experiments there are some great programs such as SDRadio and DREAM. All we need do is provide two mixer signals, phase-shifted 90 degrees apart, to the left and right channels of the PC sound card. The software handles everything else.

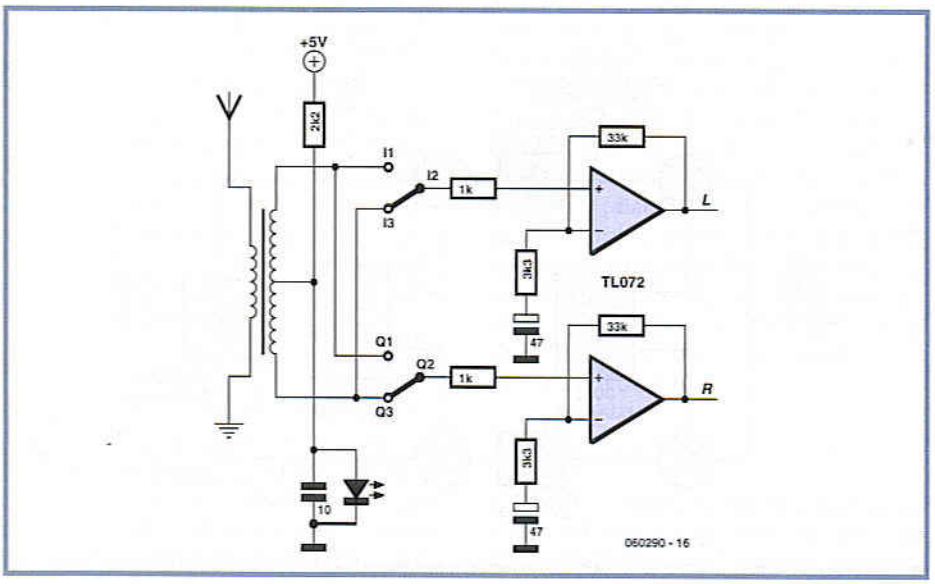


Figure 5. A broadband receiver.

Circuitry

The simplest way of achieving the phase shift required in the oscillator signal is by digital circuitry (**Figure 4**). Two D-type flip-flops in a 74AC74 divide the input frequency by four and simultaneously produce output signals phase-shifted by exactly 90 degrees.

Our clock source is the Serially Programmable Crystal Oscillator from the March 2005 issue. In principle we could also use a free-running oscillator on the four-times receive frequency but then greater effort would be required to achieve adequately good stability.

The mixer employed comprises four analogue switches in the 74HC4066 chip, which guarantees good synchronism between the two channels and displays good signal integrity. Two analogue switches are combined to form a changeover switch, so as to create a balanced mixer. **Figure 5** shows an I-Q direct mixer for the frequency range

from around 500 kHz to 30 MHz.
A broadband transformer with 10 : (20+20) wire turns was wound on a small ferrite core. The mixer itself is followed by a low-pass filter. After this a 20 dB amplifier increases the sensitivity of the receiver. **Figure 6** shows a test makeup of the circuit (source: www.elexs.de/iq2.htm).
The I-Q mixer provides image frequency suppression of up to around 40 dB. If we link just one of the two channels to the sound card the result is typical for a simple direct mixer, as seen in **Figure 7**. A signal of 11 kHz appears at both +11 kHz and −11 kHz. With the two input signals phase-shifted by 90 degrees the desired signal is boosted and the image signal suppressed (**Figure 8**). With software alone a band of 48 kHz can be tuned in this way.
This simple receiver demonstrates astoundingly good reception results on medium and short waves, in particular high sensitivity and good frequency stability, as well as amazingly sharp selectivity of the kind that only software can achieve.

Even greater improvements are possible. In order to avoid unwanted secondary response it's vital to use a good sound card with an effective anti-aliasing filter. In very basic sound cards we have observed that at a sampling rate of 48 kHz signals above the theoretical limiting or boundary frequency of 24 kHz are processed with almost no attenuation. A signal of 26 kHz then appears at 22 kHz. With the I-Q mixer this leads to stations outside the receive range popping up as phantom signals. In this situation the only solutions are a better sound card or a separate anti-aliasing filter (the single-pole low-pass filters used in the present circuit will not be adequate). You could install for example four-pole Butterworth filters with a limiting frequency of 12 kHz but both filters would have to be equalised very accurately, which can be achieved only by using individually selected capacitors.
A secondary weakness of the simple circuit is that the mixer also operates on the odd multiples of the oscillator frequency. Since a switching mixer also exhibits principally overtone mixing, using an input band filter or preselector would be sensible.

DRM reception

The circuit described here is also suitable for use as a simple DRM receiver, since DREAM makes it possible to extract an I-Q signal (**Figure 9**). For this the parameter -C 3 must be entered. Using this simple circuit and a long wire antenna numerous stations can be decoded error-free in the medium and shortwave bands [3]. DREAM offers an analogue mode as well and works as a full-function software defined radio for AM, FM, SSB and CW.

060290-1

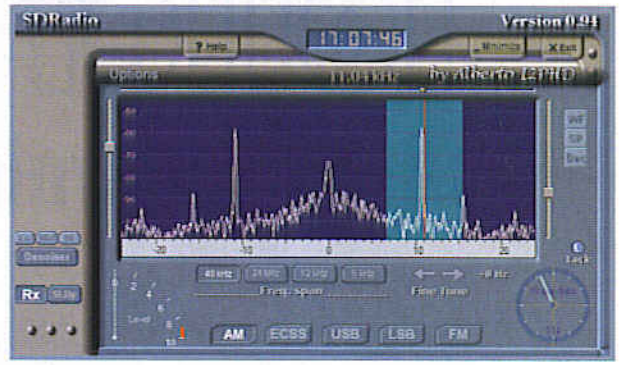


Figure 7. Image frequency with only one mixer.

Figure 8. Suppressed image frequency with two mixers.

Figure 9. A DRM signal from the I-Q mixer.

Web links
[1] http://digilander.libero.it/i2phd/sdradio/
[2] www.b-kainka.de/drm.htm#dritte
[3] www.elexs.de/iq2.htm

Information sources
Figures 2 and 3 are taken from Philips Application Note AN1981 New low-power single sideband circuits.
Further information on this subject can be found here and also at www.analog.com/library/analogDialogue/archives/34-03/upconversion/index.html

Weatherfax

The receiver is suitable not just for AM und DRM but also for HF-FAX. As an experiment the Weatherfax transmitter DDH3 of the German meteorological service was received on 4855 kHz. As decoder we used a test version of the universal receiver program JVComm32 (www.jvcomm.de). The oscillator frequency was altered to 3875.5 kHz.
The illustration shows an extract of the weather map received.

Toilet Guardian

Biogas warning prevents unpleasant s

Jeroen Domburg & Thijs Beckers

If we are to believe the Americans we should be prepared at all times for a terrorist attack. In Europe we are heading the same way, as can be seen from various news flashes. The UK has also adopted a threat level system, which indicates how worried the population should be. This is all very well, but these types of indicator should really be utilised where they are most effective: in the toilet.

Although the average European doesn't normally suffer from bomb attacks in the toilet, other types of attack seem to be more common, mainly using biological gases. It would be nice if there was an indicator that prevented you from opening the toilet door soon after somebody else's visit, when you would be met a mixture of rather unpleasant gasses. The purpose of the Toilet Guardian is to figure out what's been happening and on the basis of this give a visual indication of the current terror level.

Terror level assessment

How can the air quality in the toilet be determined reliably? Smell detectors do exist, but they aren't cheap and very difficult to obtain, especially for the average hobbyist. We therefore need to acquire this information in a different way. A light sensor turns out to be quite suitable: Assuming that people turn off the light after their visit to the toilet, it should be possible to make a good estimate of the pong level from the time that the light has been switched on. A time-out can be incorporated to deal with those cases when people forget to switch off the light. What is the best way of showing the state of the terror level? The Americans decided they needed five levels, represented by the colours green, blue, yellow, orange and red. Three colours are enough for a toilet, for which the traditional colours green, orange and red come to mind.

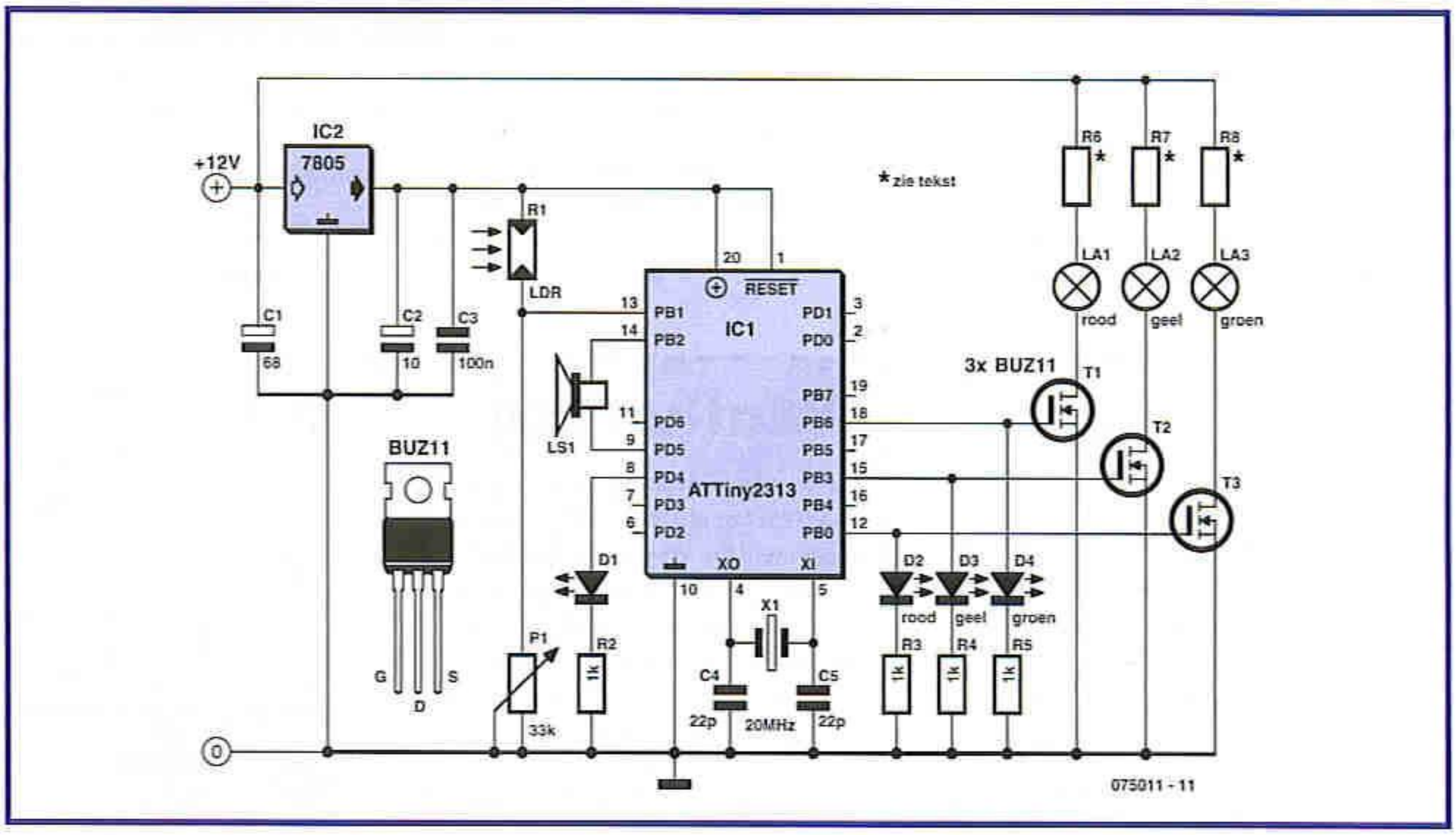


Figure 1. The circuit remains very simple, due to the use of a microcontroller.

surprises

About the author

Jeroen Domburg is a student at the Saxion Technical University in Enschede, the Netherlands. Jeroen is an enthusiastic hobbyist, with interests in microcontrollers, electronics and computers.

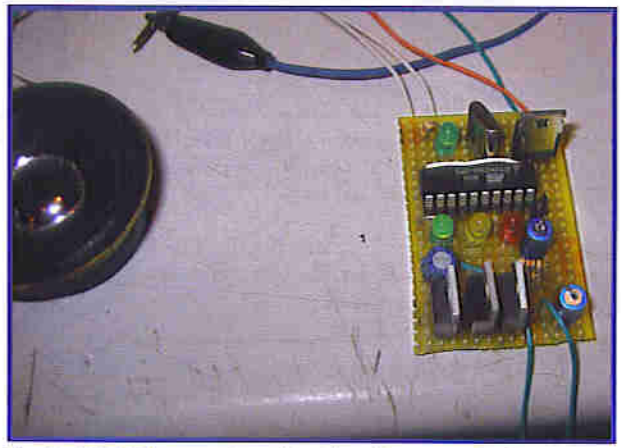
In this column he displays his personal handiwork, modifications and other interesting circuits, which do not necessarily have to be useful. In most cases they are not likely to win a beauty contest and safety is generally taken with a grain of salt. But that doesn't concern the author at all. As long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

Spider in the web

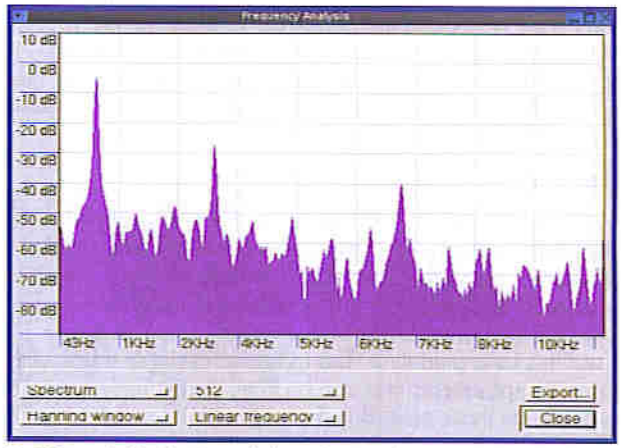
The circuit is controlled by a microcontroller (ATTiny2313). This keeps the circuit very simple, as can be seen from **Figure 1**. The circuit requires a 12 V supply, for which a standard mains adapter could be used. A 7805 provides the 5 V for the logic.
The microcontroller is the spider in the web of this circuit. It uses three MOSFETs to turn the lights on and off. The loudspeaker is connected directly to two pins of the µC, without the use of either an amplifier or D/A converter. An LDR is connected to the analogue comparator input of the µC. A preset is used to set the sensitivity. D1 shows whether the microcontroller thinks that the toilet light is turned on or off, and is therefore useful when adjusting the preset. You should be aware that the LED could have a delayed response of up to four seconds, which should be kept in mind when you're adjusting the preset.
At first sight the loudspeaker doesn't appear to be very useful. Without the use of a D/A converter or a processor that can hold a decent sound sample it surely can't produce anything better than simple square-wave beeps? However, you'd be surprised. The firmware can make the loudspeaker produce a nice 'Ping!' whenever the terror level changes. We can compensate for the lack of a D/A converter via the use of the PWM hardware that resides inside the µC. The PWM frequency is set for several hundred kilohertz. The membrane of the loudspeaker can't move that fast and will therefore take the average of the PWM value. In this way we've implemented a componentless D/A converter.

Simulation trick

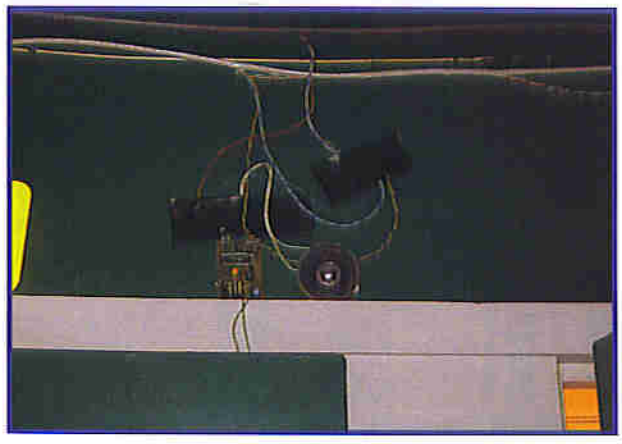
We first need to find a way in which to generate the sound. A simple square wave is out of the question because it doesn't sound right and the 2 KB of Flash memory isn't enough to store a sample of a decent 'Ping!' sound. We therefore need to resort to a few tricks to get the required output. If you open a wave file of a 'Ping!' sound with a wave editor (in our case: Audacity [1]) and look at its spectrum, you'd see that a major part of the sound is made by two frequencies: 771 Hz and 3136 Hz. It comes in very useful that the higher frequency is about four times the lower one. The sound itself gradually declines in amplitude over time.
Using this information we can write a compact program that creates a sound very similar to the original, analogue ping. The PIC program generates 32 samples for the two sine waves and it outputs these from within a loop. An additional routine uses some clever shift instructions to reduce the amplitude of the signal in 16 steps in half a second. The resulting output produced by this code is quite pleasing to the ear.
The rest of the firmware doesn't really do much. The main part consists of a counter that increments once every two



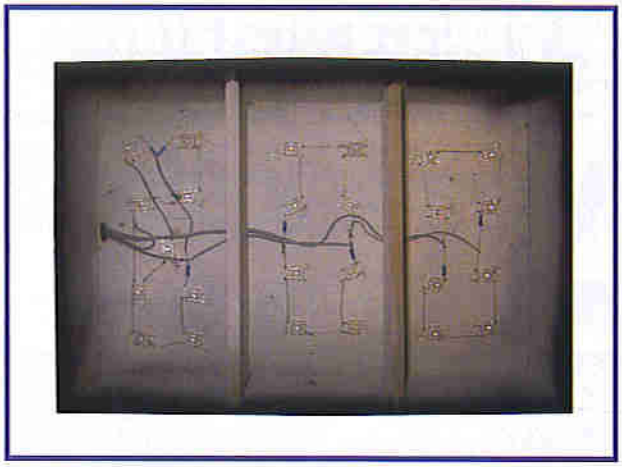
The circuit is built onto a piece of stripboard because only a few components are used.



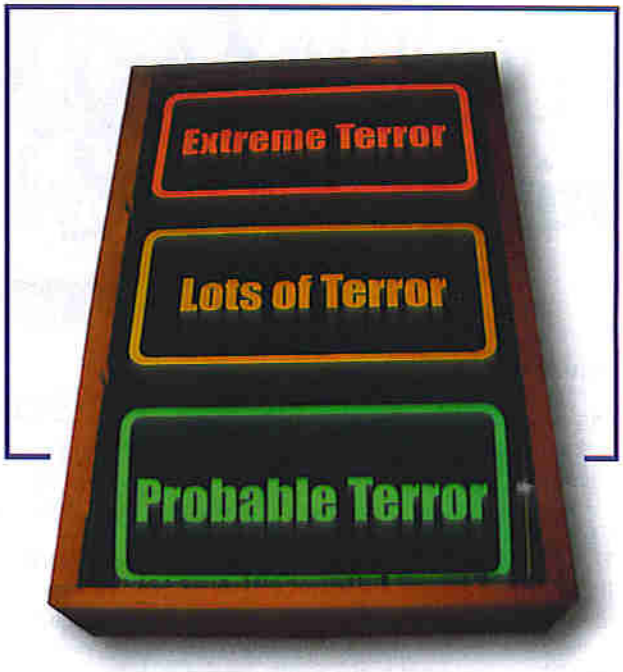
An FFT graph of a 'ding' sound shows the contribution made by all frequencies. There are three prominent peaks. Using sine waves for just the first two peaks produces a good imitation of the sound.



As an interim measure, the prototype was fixed to the wall using duct tape, making it easier to check that the concept worked.



The lighting is provided by a number of bright LEDs, which have been fixed to the case using a hot glue gun. It is of course also possible to use a CCFL or even a 12V incandescent lamp.



This is what the finished indicator looks like. There are three separate compartments inside the MDF box. The front is made out of plastic with the printed lettering just behind it.

seconds when the light is on, or which is decremented every four seconds when the light is off. The times at which the terror level changes from one level to the next are stored as constants in the source code. This makes it very easy to change the behaviour of the circuit to your own preferences. As usual, the firmware can be downloaded free of charge from the author's website [2] or the *Elektor Electronics* website [3].

The box

We used Google to find inspiration for the construction of the indicator hardware. We came across a fairly recent adventure game that also had a 'bathroom terror alert indicator' as part of the game. We quite liked the wording and the general look of this virtual indicator, so we used this as a guideline. The indicator requires a box with three compartments that can be lit up individually, revealing the text that's placed in front of them.
The box itself is made from MDF, with the front covered by a piece of Plexiglas and an A4 transparency sheet, with the text printed by a colour laser printer. A number of bright LEDs provide the lighting. It is of course also possible to use incandescent lamps or fluorescent lights instead. Due to the popularity of PC case modding, the cost of the latter has dropped substantially. The current limiting resistors are only required when you use LEDs. You will have to determine the values of these resistors yourself because they depend on the type of LED used. The MDF case can also be used to hold the loudspeaker.

(075011)

Web links

[1] audacity.sourceforge.net

[2] sprite.student.utwente.nl/~jeroen/projects/wcterror

[3] www.elektor-electronics.co.uk

This is the final result. The electronics have been mounted inside the toilet to keep them out of sight.

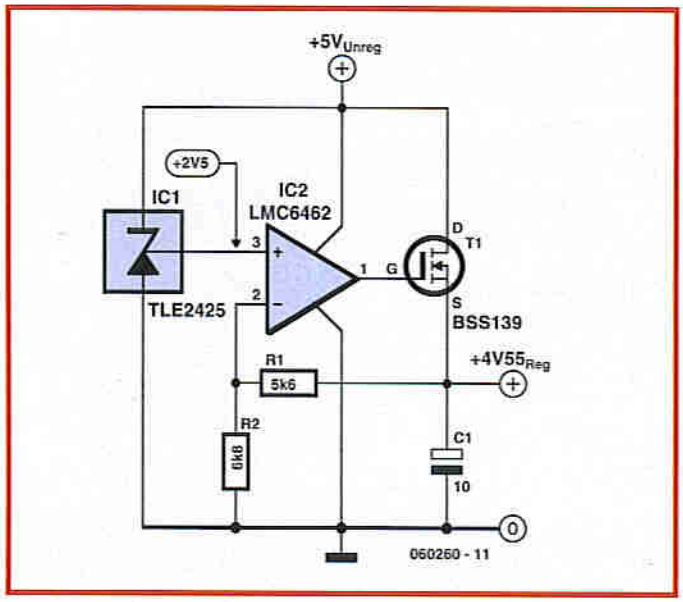
The controller could also drive other devices than the terror indicator lights. You could for example hook up a fan in parallel with the red, which helps to remove the offending smells from the toilet even quicker.

LDO Regulator

Stephen Bernhoeft

Recently the author had to adapt a standard circuit configuration (which often uses an npn bipolar) so as to operate as a low-dropout (LDO) regulator. The circuit shown here uses that rarity, a depletion-mode MOSFET to implement the LDO function.

What to do when you have to derive an analogue supply voltage (close to +5 V) from an existing 'digital' 5-volt rail, ensuring sufficient decoupling between the two? One answer is to step up and then use a linear regulator to step back down. However, if around 4.5 volts will suffice then an alternative is a home-made LDO regulator. The circuit is usually a fairly standard shape — typically an npn transistor (with base-current limiting resistor) is used. Initially, it would appear that this design suffices — after all, the textbooks say the saturation voltage is around 0.2 V. Unfortunately, this is no longer true when the collector is tied directly to the positive supply. An enhancement-mode MOSFET suffers similar disadvantages: with the drain tied High you need greater than drain potential at the gate to achieve low $R_{DS(on)}$. Enter that seldom-used beast — the depletion-mode MOSFET!



Depletion-mode MOSFETS are 'on' even when $V_{gs} = 0$, and you have to back-bias the gate to achieve an increase in channel resistance.

In the circuit shown the BSS139, an NMOS depletion device, operates with the gate forward-biased. With a load of 10 mA, the measured FET resistance was 38 ohms.

(060260-I)

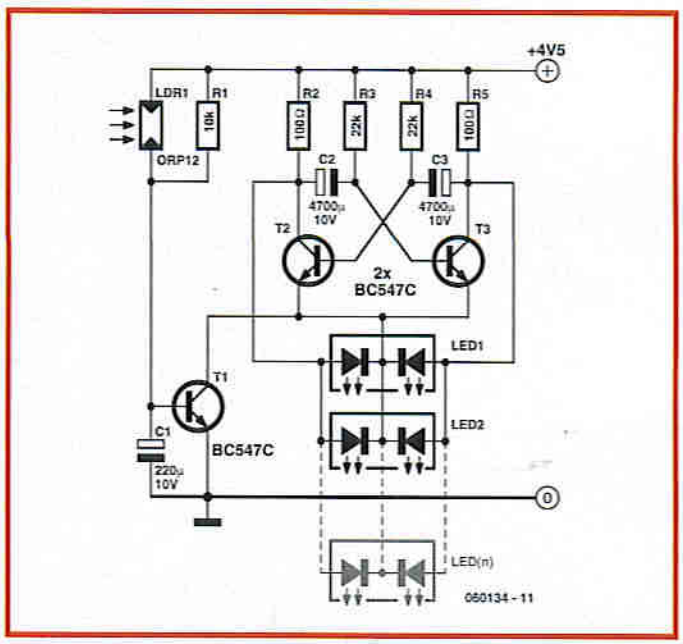
Bi-colour LEDs operated by LDR

Ken Barry

The author thought it be nice to render a number '4' (his house number) using a slowly changing two-colour LED display.

The display shown here employs an LDR which causes the LEDs to dim during the dark hours, and light at slowly increasing brightness with daylight. The function ensures the house number would always be visible day or night. The circuit diagram shows an astable multivibrator T2-T3 combined with switchable potential divider T1. The latter is switched on and off by an LDR and a capacitor.

Assuming a supply voltage of 4.5 volts the circuit consumes about 80 mA to light 37 bi-colour LEDs of the three-pin common-cathode type. The LEDs used in the prototype were supplied by CPC/Farnell (http://cpc.farnell.com), order code LP00362. All LEDs are connected in parallel as shown in the schematic by the dashed outline.



A 10-kΩ resistor is connected in parallel with the LDR (a type ORP12) to govern the threshold level to a degree. You may want to experiment with the value.

(060134-I)

Pin Pitch	2.54mm
PIV Max.	5
View Angle	24°

LP00360 LP00361 LP00362 LP00363 5mm (T1) tri-colour LEDs

5mm untinted clear lens LEDs • Common cathode • Both diodes connected gives third intermediate colour • Low power consumption

Colour	Lum. Intensity (mcd) @ 20mA		If (mA) Max.
	Min.	Max.	
HE Red/Green	100/50	300/200	30/25
HE Red/Yellow	100/30	300/80	30/30
Green/Yellow	50/30	200/80	25/30
Ultra Red/Green	300/80	700/200	30/25

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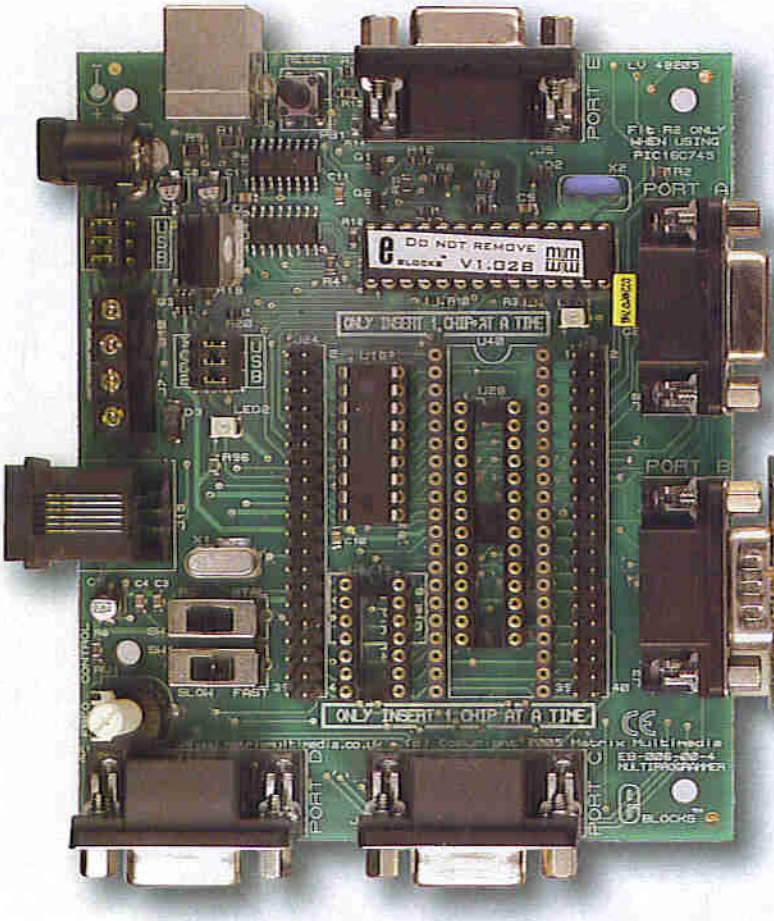


E-blocks L

Flowcode from the

Jean-Paul Brodier

As many of you have already discovered, E-Blocks, along with programming tool Flowcode, open up enormous possibilities, though you still have to start somewhere. The problem is — where? The Flowcode CD-ROM contains a very accessible course called Flowcourse. Now's the time to really make a start in programming and transferring a project from the E-blocks environment into the real world!

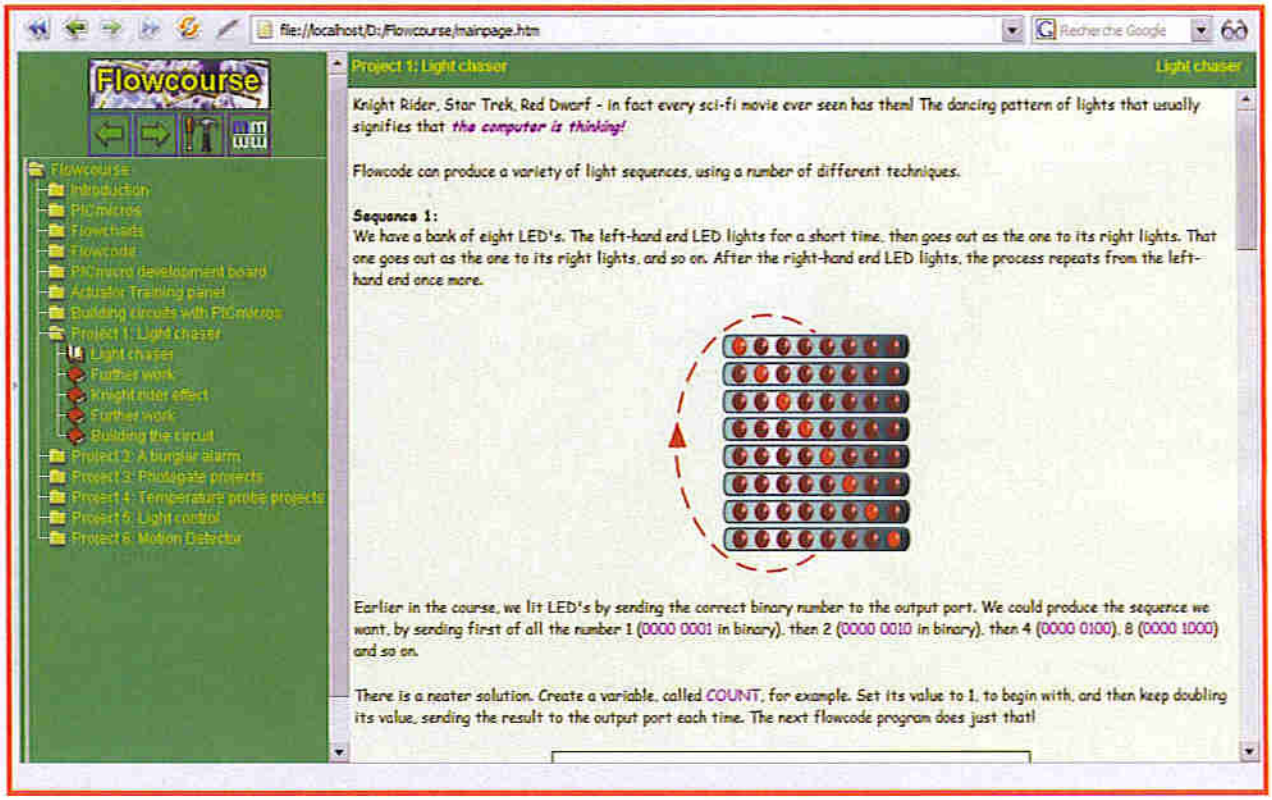


Figure 1. Description of the light chaser in Flowcourse.

ED Chaser

ground up

Hot plugging

The Windows XP operating system copes perfectly with E-blocks thanks to the USB link.

We can also be thankful to the designers of E-blocks for powering the MULTIPROGRAMMER's interface via the USB bus. This avoids problems with disconnection/reconnection with the PC when the power is removed and applied again in order to insert or remove the microcontroller or an extension card.

Install the software on the CD-ROM, accepting all the default options offered. In addition to Flowcode itself, you'll be installing MPLAB, Microchip's assembler and C compiler. You will hardly notice these programs, since Flowcode takes care of the interface 'transparently', as they say.
Assuming drive D: is the CD-ROM drive on your computer, use your system browser to go to the directory D:\flowcourse (). Open the page *mainpage.html*.
From this point on, we will assume that you've already followed the beginning of the course, so you know roughly how a microcontroller works and, in theory at least, how it can be programmed to turn an LED on and off.

The Light Chaser project

Open the page *Project 1: Light chaser* (**Figure 1**).
Here you'll find the description of one of the simplest demonstration applications: an LED light chaser. We're no longer talking about just turning on or off a single LED, but a whole set of eight LEDs.
As soon as we start to bring this application into the real world using *Flowcode*, prompts and questions will pop up, so instead let's take look at the answers: no, there is no bridge provided between this demonstration application and the files in the *Tutorials* directory; no, the numbers used as filenames don't relate directly to an application; and no, there isn't a file in the directory corresponding to the application we're interested in.
So we're going to use the *Flowcode* Editor to create, from scratch, an application to match the description. Let's get into swing by reproducing the first flowchart — the one in **Figure 2**.
Click on File, then New; after entering the type of microcontroller used (here, a PIC 16F88), you'll get an Editor page with a program that has just two labels, BEGIN and END (**Figure 3**).
To add symbols between the beginning and the end, all you have to do is left-click on the selected symbol in the left-hand column, then hold the button down and drag the symbol into position (**Figure 4**).
Right-clicking now opens a box where you can enter the properties for the object under the cursor.
Here, we'll use English for the labels, though except for keywords it doesn't matter what language you use (**Figure 5**). The software automatically sets the loop end tag and gives it the same name as the start tag.

Onwards to the micro

To check the operation of our first program, we'll have to transfer it into the microcontroller's program memory. But before we get to that point, the flowchart first has to be converted into a C-language program. Next, we need to compile this C program into a form accepted by a program assembler. Next, the assembly code is translated into machine code (PIC in this case), which is finally loaded into the Flash memory of the chip. The good news is that you, the user, need not worry about the detail of these operations, as the Flowcode program automatically performs them in the correct order when you click on *Compile to PIC* (**Figure 6**).

The programnming phase

The programmer used to copy the machine code into the microcontroller memory is the MULTIPROGRAMMER card from Elektor's E-Blocks range.
It is automatically recognised by the software installed earlier. The microcontroller used here is the PIC 16F88, which is more than adequate for the job.
The programmer reports that the operation was successful, and the program runs immediately (**Figure 7**). The report tells us that the program only takes up 115 out of the 4096 program words available, i.e., less than 3%!
After this check on the PIC programming sequence, you continue to drag boxes into the flowchart (and sometimes out again!) until the complete program is produced. The finished flowchart for the last example looks like **Figure 8**.

Some more program details

The 'Shift' box (icon) may require a little explanation. The action performed is actually no more than multiplication or division — there is no physical shifting as such. It's just an arithmetical operation, because that's all a microcontroller can do! In any number system, multiplication or division by the base itself is equivalent to a shift-right or shift-left by one order of magnitude. The binary system is no exception to this — hence by multiplying the number COUNT by 2, we shift the LED that's on to the left, whereas by dividing by 2, we shift it to the right.
You will note that the delay between the steps is different from the example, and that the 'rise' time is different from the 'fall' time. Sliding down the greasy pole is usually faster than climbing it!
You're quite free to reduce or increase the lengths of the delays to suit your own preferences.

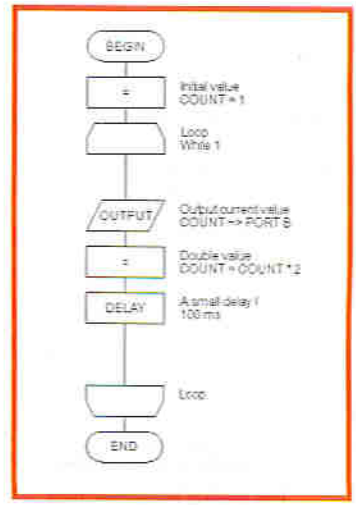


Figure 2. The elementary program in the Flowcourse tutorial. We're going to be reproducing this step by step, before adding further functions to it.

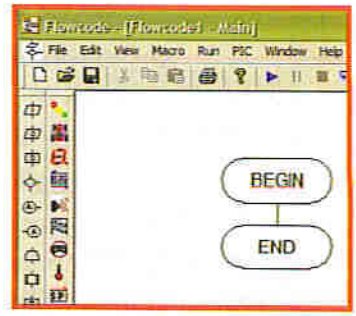


Figure 3. At the outset, the flowchart has no more than these two tags, between which we're going to be insert a series of instructions.

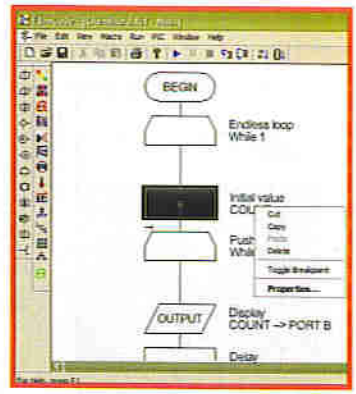


Figure 4. A right click lets us access the Properties of the box we've just added.

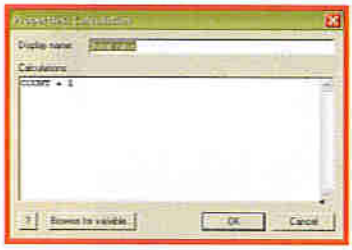


Figure 5. The Properties entry box — in practice, these are arithmetic operations.

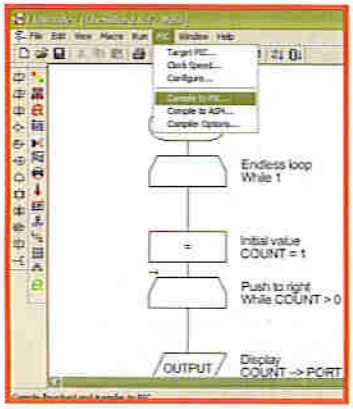


Figure 6. The Compile to PIC command starts the process of transferring the flowchart into the microcontroller's program memory. All assuming that the type of microcontroller has been specified using the Target PIC option.

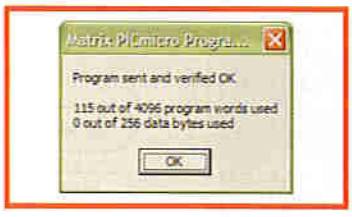


Figure 7. Programming takes only a few seconds. The chip memory still has plenty of space left. As soon as this message pops up, your program starts running.

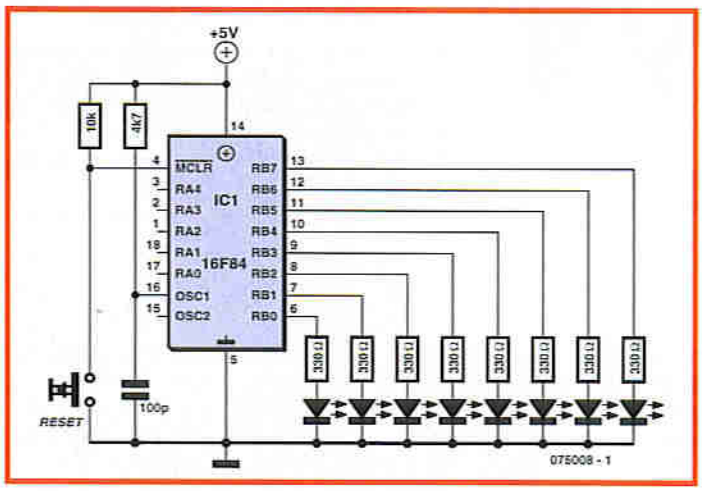


Figure 9. The application circuit involves just a few components.

Undressing the E-blocks project

Now that we've accomplished the program writing, debugging and chip programming, it's time to transfer the project from the E-blocks environment into the real world, where it will function 'stand-alone', hopefully! Your general method of working should be to use E-blocks to do all the program writing, testing and debugging, and then 'move' the finished lot to a completely separate board. As part of the approach, simply revert to your E-blocks system if errors are found in the standalone hardware (and they *will* be found!), or if users require improvements, tweaking, extensions, etcetera. In this context, the program simulation abilities of E-blocks will be particularly valued. You may also find that some E-blocks modules like the switch board or the led board are only required for

In line with this method of working, we're going to breadboard a self-contained circuit so as to free off the MULTIPROGRAMMER and E-Blocks LED BOARD for their original purpose of testing and developing programs.

The programmed microcontroller is part of the target circuit shown in **Figure 9**. The breadboarded circuit may be produced on prototyping board, a.k.a. 'perfboard', 'stripboard' or 'Veroboard'. The author's prototype is shown in **Figure 10**. Track breaks are made using a 4-mm drill bit fitted into a spare drill chuck to act as a handle.

Naturally, the PIC microcontroller is not soldered in, but simply plugs into its socket. The light chaser is powered from a 5 V supply.

(075008-I)

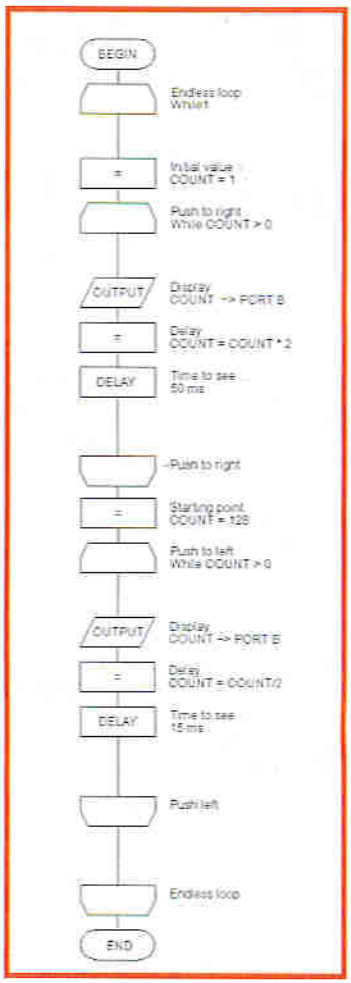


Figure 8. The light spot of our chaser goes back and forth in Knightrider fashion, instead of doing the single sweep of the original program. To do this, it sequences together a 'Push right' loop with a 'Push left' loop, then goes back to the start.

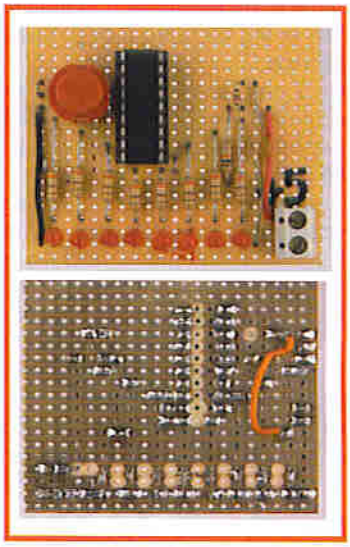
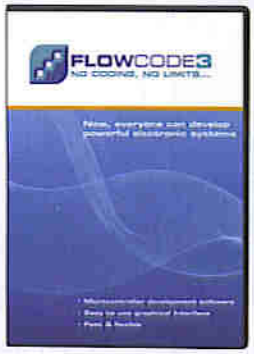


Figure 10. The layout of the components on the prototyping board largely follows the positioning in the circuit diagram. The horizontal lines are formed by the copper strips of the board, the vertical lines by the component leads or pieces of insulated wire.



Flowcode 3

Registered users of Flowcode 2.x versions are advised that Flowcode 3 is now available from Matrix multimedia or Elektor Electronics. Flowcode 3 is described in the December 2006 issue of Elektor Electronics. The product may be ordered from the SHOP pages at www.elektor-electronics.co.uk

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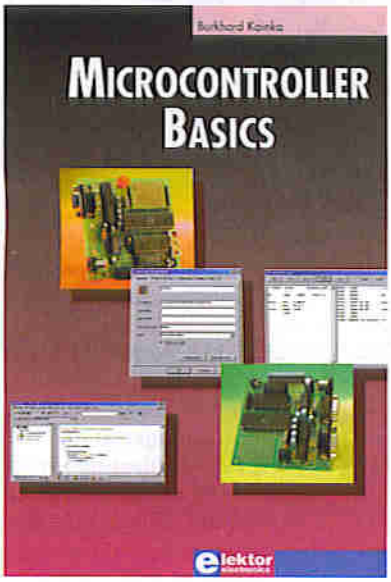

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Burkhard Kainka

Microcontrollers have become an indispensable part of modern electronics. They make things possible that vastly exceed what could be done previously. Innumerable applications show that almost nothing is impossible. There's thus every reason to learn more about them, but that raises the question of where to find a good introduction to this fascinating technology. The answer is easy: this Microcontroller Basics book, combined with the 89S8252 Flash Board project published by Elektor Electronics. This book clearly explains the technology using various microcontroller circuits and programs written in several different programming languages. In the course of the book, the reader gradually develops increased competence in converting his or her ideas into microcontroller circuitry.

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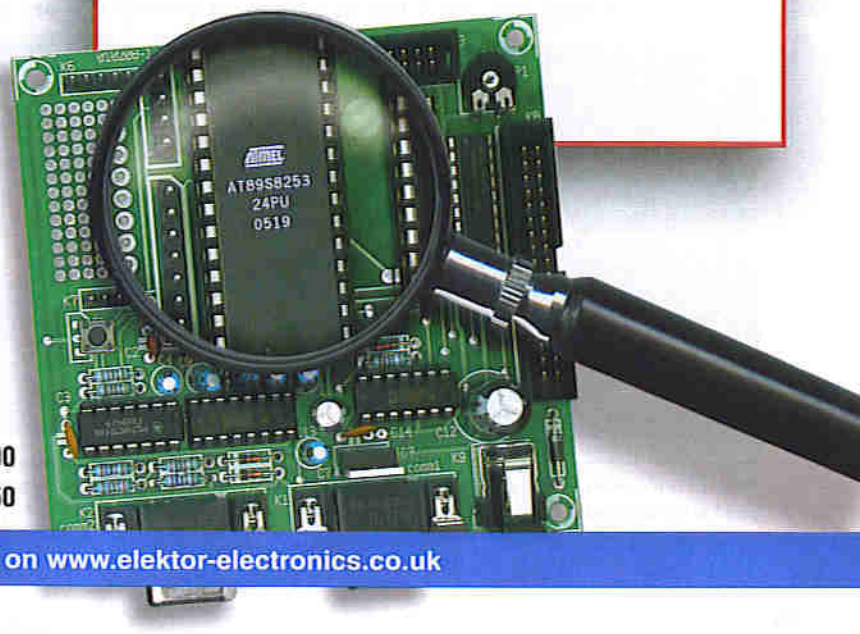

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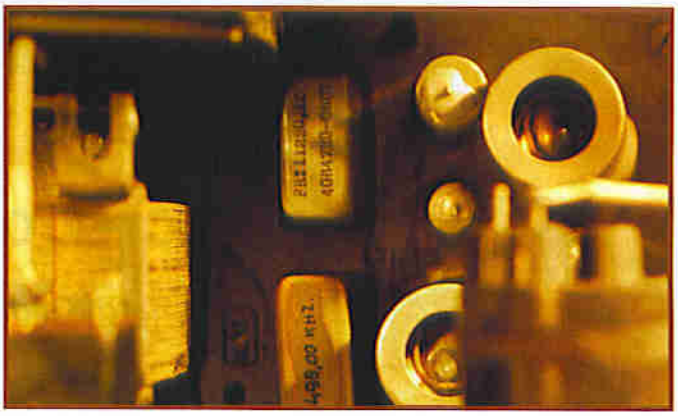
Philips SFM114/00 Wobbulator (1952)



Jan Buiting

'Wobbulator', apart from a funny word that will earn you not only a good score but also fierce discussions when playing Scrabble, refers to a test instrument for visualizing the frequency response of filters and IF (intermediate frequency) amplifiers in receivers.

According to manual, the instrument I hauled down from my attic for this month's Retronics was designed by Philips Telecommunication to "adjust intermediate frequency amplifiers operating at 1.5 MHz or 9.72 MHz". Whereas most of today's personal mobile radio (PMR) equipment have first IFs of 10.7 MHz or 21.4 MHz, the use of 1.5 MHz and 9.72 MHz was common practice in the 1950s and 1960s. Crystal filters for these two frequencies being unavailable as well as unaffordable at the time, it was essential for the IF passband to be properly tuned as it determined to a large extent the receiver's selectivity and FM discriminator response.

Most PMR equipment of these years was supplied with 'stagger-tuned' multi-stage IF amplifiers. Each L/C network in a filter or amplifier was adjusted a little below or above the centre frequency to create a flat passband with the desired width (usually 100 kHz or so). In practice, the IF amplifier in the engineering prototype was very carefully set up to the highest standards by adjusting the dozen or so cores in the tuned L/C networks, all with the help of a wobbulator and an oscilloscope. The approved filter response was then declared the 'standard' and the relative depth of each ferrite core in its coil former carefully noted. Next the cores positions were visually and manually 'copied' on to the L/C boxes in mass-produced amplifiers. In other words, none of the IF amplifiers that left the factory had been individually tuned for optimum response — they were assumed to function as closely as possible to the standard, which can only be upheld if you can rely on fairly close tolerances on production and components used (in particular, the silver-mica tuning capacitors). Poor show? Philips got away with this quite well for more than 20 years.

The SFM114/00 shown is complete, original and works a treat. I hooked up an old oscilloscope and attacked the stagger-tuned 1.5-MHz IF amplifier in my 1953 SDR314 portable (see Retronics, November 2006) to see if improvements could be achieved. Adjusting this 6-stage IF amplifier is great fun. To set up a virtually flat passband of about 130 kHz wide (± 66 kHz) with steep edges (80 dB selectivity) takes about half an hour to get absolutely right. The improvement over the stagger-tuned settings is dramatic on the scope screen. In practice, there's a higher and steadier FM noise level as well as slightly less distortion of the received signal (probably due to the discriminator being properly driven now).

The SFM114/00 also generates marker pulses 20 kHz either side of the centre frequencies. On the first ten or so pages of the user manual, the writer (or typist) insists that an ECL80 valve is configured as a 'flip-flap' for this purpose. Then a text correction is seen on page 12 and we read 'flip-flop' in the remainder of the book.

This wobbulator employs an unusual method of generating the swept-frequency output signal at 9.72 MHz. Basically, it is obtained from subtractive mixing of 11.22 MHz and 1.5 MHz quartz-generated signals rather than straight frequency variation of an oscillator. The reason I guess is that it was difficult to produce sufficient 'pull' (of the order of ±100 kHz) on a 9.72 MHz crystal without running into harmonics or undesirable amplitude variations.

(075013-II)

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

Hexadoku

Puzzle with an electronic touch

The Hexadoku puzzle for this month is yet again the perfect prompt to start thinking about other things than transistors, microcontrollers or software. Juggling hexadecimal numbers not only stimulates the brain but may also win one of the prizes we've on offer. Join Hexadoku this month, send us your solution and enter the prize draw.

The instructions for this puzzle are straightforward. In the diagram composed of 16 x 16 boxes, enter numbers such that **all** hexadecimal numbers 0 through F (that's 0-9 and A-F) occur once only in each row, once in each column and in each of the 4x4 boxes (marked by the thicker black lines). A number of clues are given in the puzzle and these determine the start situation. All correct entries received for each month's puzzle go into a draw for a main prize and three lesser prizes. All you need to do is send us the numbers in the grey boxes.

The puzzle is also available as a **free download** from our website (Magazine → 2007 → February).

Participate!

Please send your solution (the numbers in the grey boxes) by email, fax or post to:

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Subject: hexadoku 1-2007.

The closing date is
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The competition is not open to employees of Segment b.v., its business partners and/or associated publishing houses.

Prize winners

The solution of the December 2006 Hexadoku is: **87E46**.

The **E-blocks Starter Kit Professional** goes to:

Tim Parsonson, Brandon (UK).

An **Elektor SHOP voucher worth £35.00** goes to:

Dmitry Kuznichov, Haportim (ISR);
Isolde Tietz, Darlington (AUS);
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Congratulations everybody!

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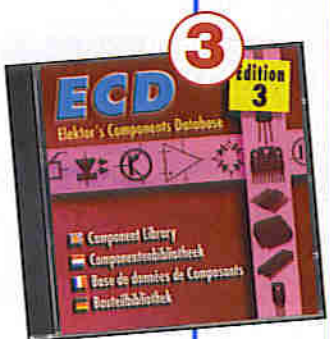

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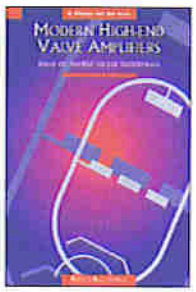

Valve amplifiers are regarded by many to be the ne plus ultra when it comes to processing audio signals. The combination of classical technology and modern components has resulted in a revival of the valve amplifier. The use of toroidal-core output transformers, developed by the author over the past 15 years, has contributed to this revival. This book explains the whys and wherefores of toroidal output transformers at various technical levels and offers innovative solutions for achieving perfect audio quality.

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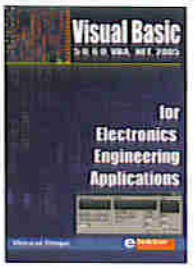

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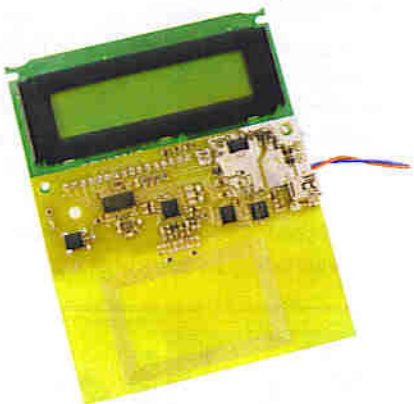

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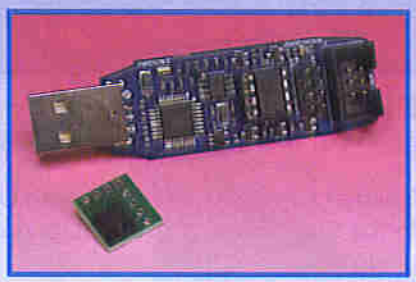
New micros on the block: Freescale MC9S08

In this article we introduce you to Freescale's MC9S08 range of microcontrollers. Relatively new to the market and not covered yet in Elektor, these devices fit perfectly in the 'all-microcontrollers' theme we've set ourselves for the March 2007 issue. The article goes to show that these low-cost micros are remarkably easy to use thanks to ingenuous software and hardware tools called Code Warrior and Spyder respectively. The article will culminate in the April 2007 issue with the description of a 4-direction acceleration/deceleration indicator.



Mobile Phone LCD Recycling

We're sure many of you have a discarded mobile phone somewhere in a drawer. You'll like to hear that many parts from these mobiles can be reused for electronics projects, the LC display being the most interesting item. In this article we show how the LCD salvaged from an Alcatel OTE db mobile can be driven from a small ATMega16 board or a PC RS232 port.

Also...

Explorer-16 (3);
Fairchild 30-Year Anniversary Project;
Wireless ATMega/USB transceiver*;
Very Simple Clock*; Mini Project;
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* we regret that these articles could not be accommodated in the February 2007 issue as planned.

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Showcase		78, 79
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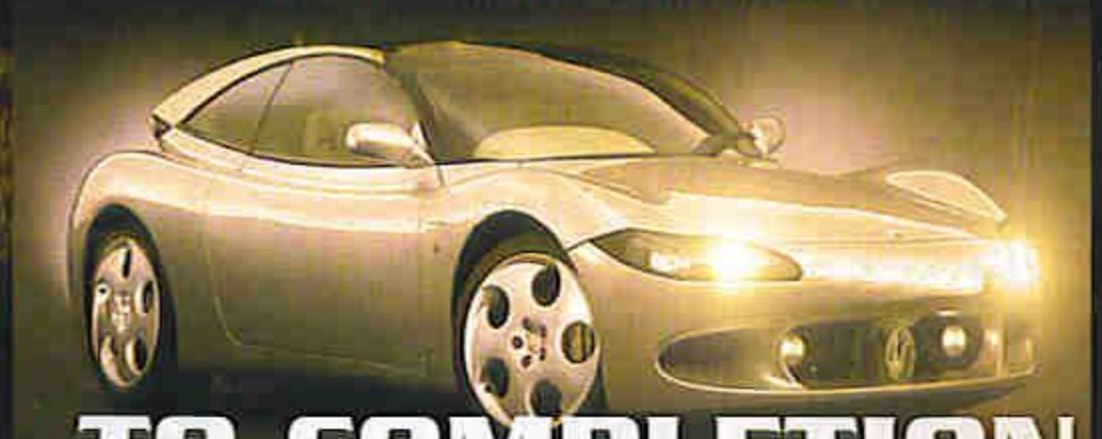

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