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June 2014

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Control by Tablet and Smartphone

FT311D-based Android User Interface Builder

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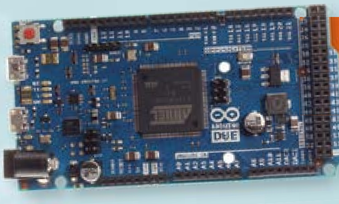

ARDUINO DUE

32-bit power thanks to an ARM processor

Features

Microcontroller	AT91SAM3X8E
Operating Voltage	3.3V
Input Voltage (recommended)	7-12V
Input Voltage (limits)	6-20V
Digital I/O Pins	54 (of which 12 provide PWM output)
PWM Channels	12
Analog Input Pins	12
Analog Outputs Pins	2 (DAC)
DC Current per I/O Pin	130 mA
DC Current for 3.3V Pin	800 mA
DC Current for 5V Pin	800 mA
Flash Memory	512 KB (all available for the user applications)
SRAM	96 KB (two banks: 64KB and 32KB)
Clock Speed	84 MHz

£46.95 • € 52.90 • US $72.00

ARDUINO MEGA

Like the Uno but with more memory and I/O

Features

Microcontroller	ATmega2560
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limits)	6-20V
Digital I/O Pins	54 (of which 15 provide PWM output)
Analog Input Pins	16
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	256 KB (of which 8 KB used by bootloader)
SRAM	8 KB
EEPROM	4 KB
Clock Speed	16 MHz

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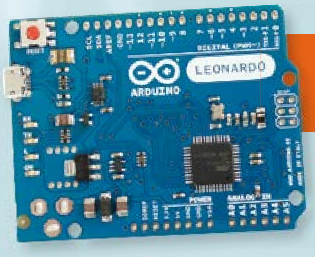

ARDUINO LEONARDO

Especially good for USB applications

Features

Microcontroller	ATmega32u4
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limits)	6-20V
Digital I/O Pins	20 (of which 7 provide PWM output)
PWM Channels	7
Analog Input Pins	12
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB (of which 4 KB used by bootloader)
SRAM	2.5 KB
EEPROM	1 KB
Clock Speed	16 MHz

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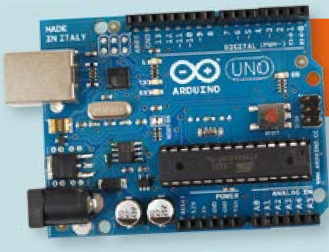

ARDUINO UNO REV.3

The most popular board with its ATmega328 MCU

Features

Microcontroller	ATmega328
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limits)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
PWM Channels	6
Analog Input Pins	6
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB (of which 0.5 KB used by bootloader)
SRAM	2 KB
EEPROM	1 KB
Clock Speed	16 MHz

£23.95 • € 27.50 • US $38.00

ARDUINO ETHERNET

Networking has never been easier

Features

Microcontroller	ATmega328
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limits)	6-20V
Digital I/O Pins	14 (of which 4 provide PWM output)
Arduino Pins reserved	10 to 13 used for SPI 4 used for SD card 2 W5100 interrupt (when bridged)
Analog Input Pins	6
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB (of which 0.5 KB used by bootloader)
SRAM	2 KB
EEPROM	1 KB
Clock Speed	16 MHz

£46.95 • € 53.90 • US $73.00

ARDUINO YÚN

Two processors

Features AVR Arduino microcontroller

Microcontroller	ATmega32u4
Operating Voltage	5V
Input Voltage	5V
Digital I/O Pins	20
PWM Channels	7
Analog Input Channels	12
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB (of which 4 KB used by bootloader)
SRAM	2.5 KB
EEPROM	1 KB
Clock Speed	16 MHz

Features Linux microprocessor

Processor	Atheros AR9331
Architecture	MIPS @400 MHz
Operating Voltage	3.3V
Ethernet	IEEE 802.3 10/100Mbit/s
WiFi	IEEE 802.11b/g/n
USB Type-A	2.0 Host/Device
Card Reader	Micro-SD only
RAM	64 MB DDR2
Flash Memory	16 MB

PoE compatible 802.3af card support

£60.95 • € 69.95 • US $95.00

ARDUINO

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Further Information and Ordering at www.elektor.com/development/arduino

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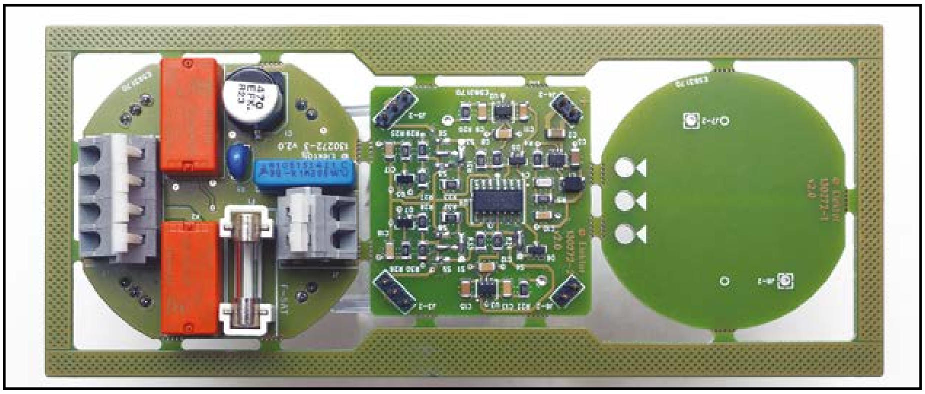

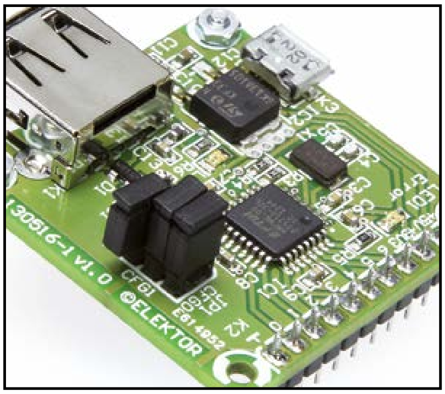

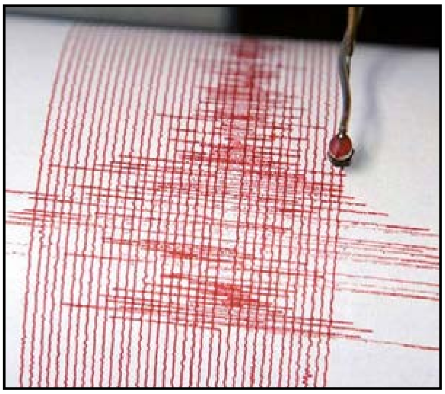

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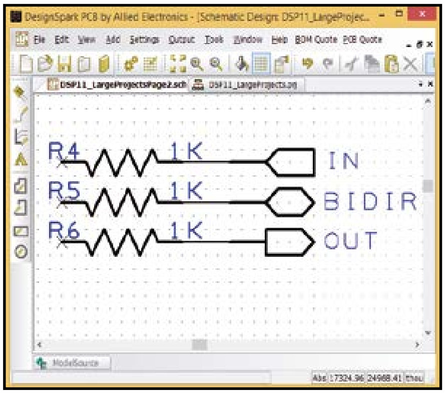
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R5 1K BIDIR
R6 1K OUT
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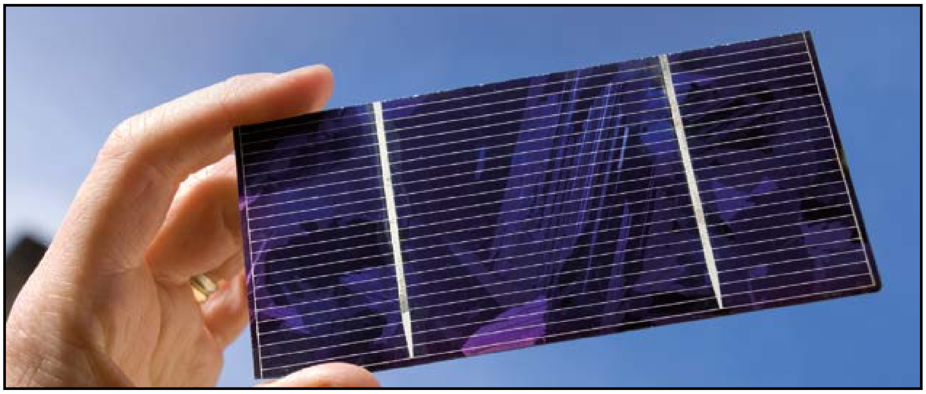

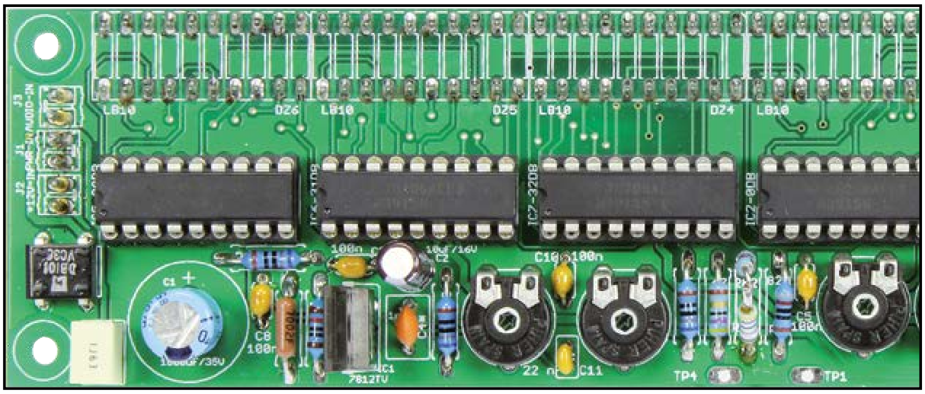

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Volume 40, No. 450
June 2014

ISSN 1947-3753 (USA / Canada distribution)
ISSN 1757-0875 (UK / ROW distribution)
www.elektor.com

Elektor Magazine is published 10 times a year including double issues in January/February and July/August, concurrently by

Elektor International Media
111 Founders Plaza, Suite 300
East Hartford, CT 06108, USA
Phone: 1.860.289.0800
Fax: 1.860.461.0450

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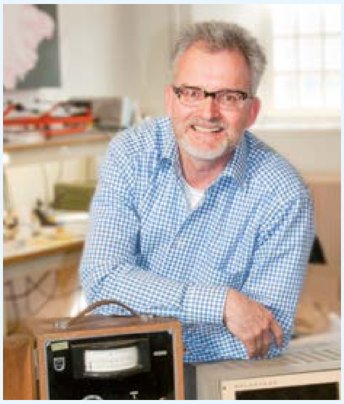

A www Guide to Elektor

This space being remarkable for intensive reading (even by my CEO) but drawing little response overall, I will venture to present a condensed what-where-why (www) guide to Elektor magazine within the constellation called Elektor International Media. You may have noticed that Elektor is no longer at a single .com website but divided across Magazine, Store, Labs and Forum. All are intensely online driven to serve our 300 K audience around the globe.

- **Elektor Magazine** at *www.elektor-magazine.com* is a service website where our valued Green and Gold Members find their digital copies and the archive of past editions, and are able to renew or change their membership. It is also home to the famous free software downloads with published articles, as well as all "Project" editions of Elektor.POST. Status: Okay; Up For Revision 2015.
- **Elektor Store** at *www.elektor.com* is our online retail activity as well as the portal to all of EIM's websites and publications. Use it to shop around for books, PCBs, semikits, DVDs, and PCB fabrication equipment. Create and manage your Store account, track orders, find special offers, get in touch with Customer Services, view legal stuff. Status: Under Construction.
- **Elektor Labs** at *www.elektor-labs.com* showcases Elektor's wide open kitchen, where the editors taste and select the dishes to refine and serve out in the printed magazine, with the help of authors, graphics people and the Elektor lab crew. Status: Okay; Lively.
- **Elektor Forum** at *http://forum.elektor.com* was relocated and restyled recently. It's amazing what help you can find there, like for the recent 500 ppm LCR Meter. Good for older projects. Status: Okay; login procedure provisionally shared with Elektor Labs.

A grand operation is currently underway as our web staffers are harmonizing all login data. After all, Magazine, Store, Labs can be browsed freely to an extent, but logging on is required at some point to place an order or reach content. Or, in case of the forum, reply to, create and write topics.

When lost aim for www.elektor.com as our portal site. Bookmark it. When utterly lost aim for www.eimworld.com. When interested in hands-on electronics, start on page 8.

Enjoy this edition of Elector (page 17),

Jan Buiting, Editor-in-Chief

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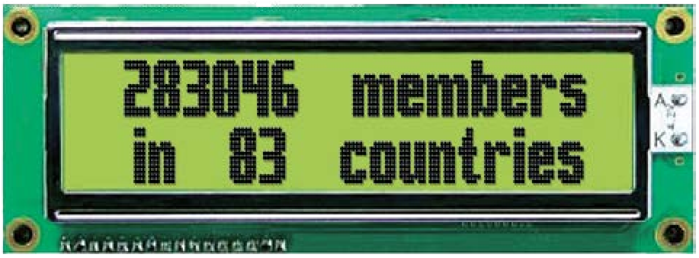

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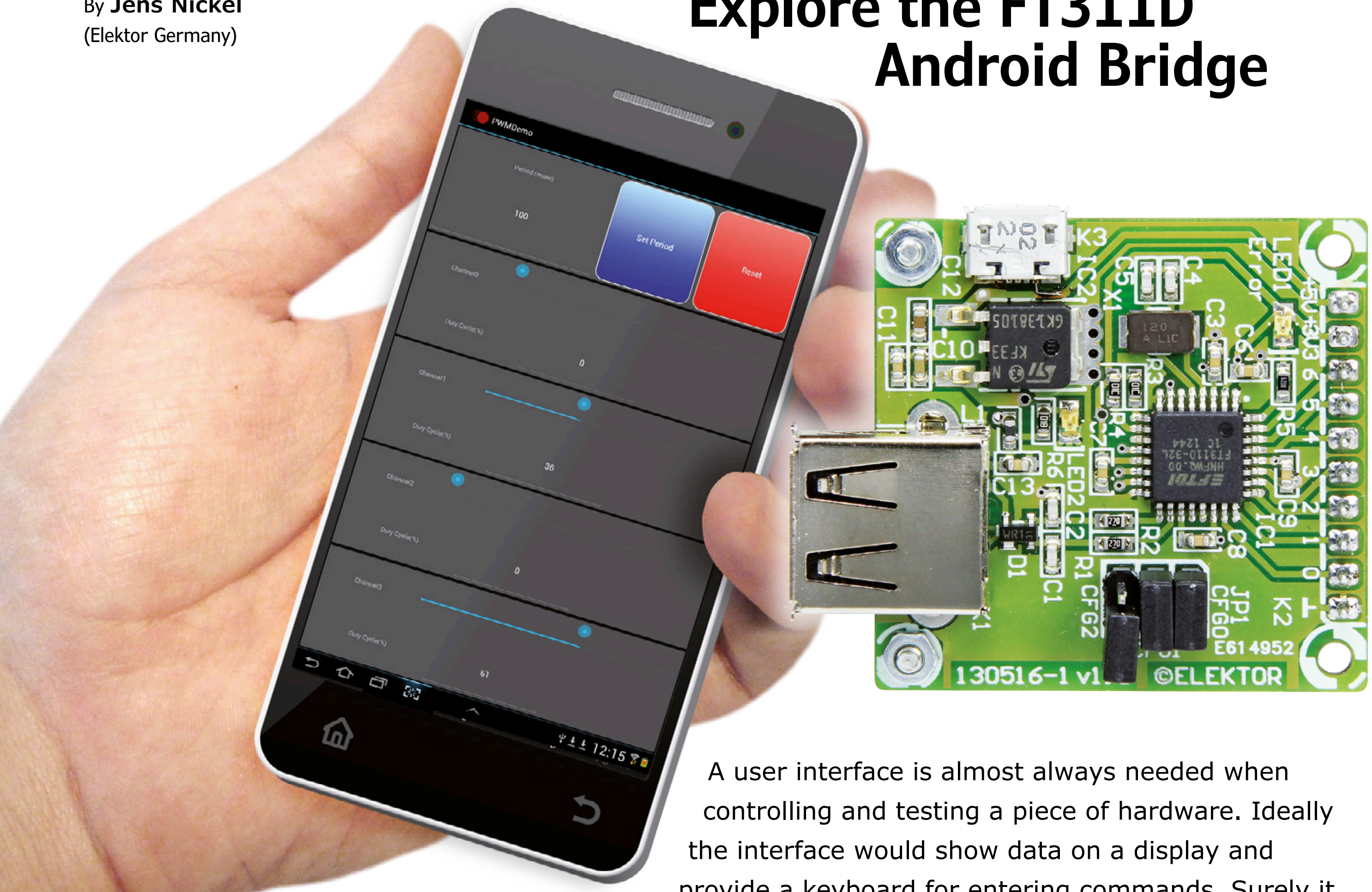
Android User Interface Builder

Explore the FT311D Android Bridge

By **Jens Nickel**
(Elektor Germany)



A user interface is almost always needed when controlling and testing a piece of hardware. Ideally the interface would show data on a display and provide a keyboard for entering commands. Surely it should be possible to use a smartphone for the job? The FTDI FT311D is a flexible bridge that can interface your circuit to an Android smartphone or tablet. It offers options for seven digital outputs, four PWM outputs, asynchronous serial and I²C and SPI interfaces. To make things simple we have designed a small board to carry the chip: introducing the 'Elektor Android breakout board'.

A large proportion of electronics projects, including those published in Elektor magazine, includes a serial interface over which readings are transmitted and commands are received, typically in the form of ASCII strings. A terminal program, running on a PC, is normally used for testing and sometimes even in normal operation. However, even in laptop form such a computer can be cumbersome to use as well as noisy and expensive. Smartphones and tablets offer a more convenient alternative, and their touchscreen displays allow a pleasant control interface to be provided for the user.

On the technical side the main obstacle to this idea is that the only usable interface to the outside world offered by smartphones and tablets is a USB slave port. This means that our circuit must include a microcontroller implementing a USB host interface and we have to get involved in writing the firmware to handle the interface protocol. We also have to make sure that the operating system running on the mobile device is capable of sending and receiving bytes over USB under the control of a user-written application.

Open accessory

Fortunately the last problem at least has been solved for all modern Android smartphones and tablets. Google, the company responsible for developing the majority of Android, already has its finger on the pulse: recognizing the demand for an interface to RGB LED light shows, servo-controlled robots and other such 'maker' projects, it introduced in version 3.1 of Android the so-called 'Android Open Accessory', or AOA, mode. This offers the possibility of simple communications with external hardware over USB [1], with no need to write or install special USB drivers in the operating system. Internally two USB bulk endpoints are provided (for input and output), allowing data to be transmitted and received at up to 12 Mbit/s (USB Full Speed). For more information on how USB works see the Elektor article 'Inside USB' [2]. The external hardware must provide USB host functionality and the mobile device can also be charged over the USB port. When a board with suitable hardware (called an 'accessory') is plugged in, an AOA-enabled Android device will recognize it from its USB descriptors [3]. If the developer so wishes, an specified application can be launched automatically when the hardware is connected.

Support is of course available to Android developers working on such hardware and software [4]. Nevertheless, designing hardware to provide USB host functionality and writing the corresponding firmware will be a daunting prospect for many, as the USB standard is rather complex, particularly when it comes to making 'plug-and-play' work reliably.

A neat device

Taking the complexity out of designing USB interfaces is something that Scottish chip designer FTDI has been working on for many years. Its best-known product is perhaps the FT232, an easy-to-use USB-to-serial converter. More recently the company introduced a programmable device with USB host functionality (the 'Vinculum'), which makes it easy to design hardware that, for example, is capable of accepting USB memory sticks.

Around two years ago FTDI brought the FT311D [5] on to the market. Like the Vinculum, this device provides a USB host port and a number (seven, in this case) of spare pins for controlling other hardware. To make it easier to use the chip FTDI supplies it ready-programmed with firmware to implement the whole USB communications stack including the AOA protocol: see the block diagram in **Figure 1**. The bridge chip has a range of different interface modes. In the simplest case the seven pins of the FT311D can be used as digital inputs and outputs (GPIOs). Other modes provide for the output of PWM signals, asynchronous serial communications, and I²C and SPI bus interfaces (both as master and slave). The I²C option alone opens up the possibility of connecting a huge range of special purpose devices to the FT311D, from port expansion chips and A/D converters to real-time clocks. Practically any project, therefore, can be connected to an Android device using the FT311D bridge. The interface mode is simply selected by the

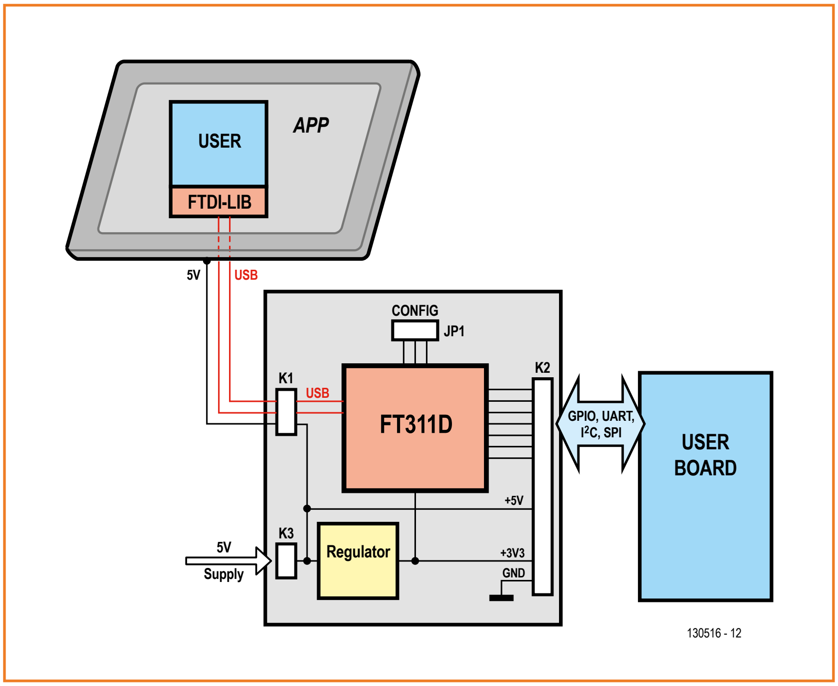


Figure 1.
Block diagram of the Android breakout board. The FT311D and the FTDI library in the Android app handle the USB communications protocol: external hardware can be controlled (for example over an I²C bus) by calling simple functions such as 'WriteData()'.

level on three digital input pins. For flexibility these can be connected to jumpers or switches (see the text box 'Interface modes'). It is not possible to configure the device using a PC program or similar.

The simple route to an app

The manufacturer has designed a simple protocol for each of the interface modes. Packets containing a couple of bytes of payload data flit back and forth over the USB connection to instruct the FT311D how to set its outputs and read back its inputs. In each case the first byte in a packet from the smartphone or tablet to the device represents the command: in GPIO mode there are three different commands to configure the pins as inputs or outputs, to set or clear the outputs, and to read back the inputs. In PWM mode a different command sets the mark-space ratio from 5 % to 95 %, the byte immediately after the command specifying the PWM channel (from 0 to 3). Further commands configure the I^2C, UART and SPI interfaces and read and write data over them. The commands are fully documented in the 'FT31XD Programmer's Guide', which can be downloaded from FTDI's website [5].

This protocol is of course handled inside the FT311D by its pre-programmed firmware. On the Android device side the main jobs are to assemble the command packets and to handle the protocol requirements of AOA mode on the USB interface. When an app is launched it can determine whether an FT311D-based accessory is in fact connected.

Fortunately FTDI supplies a suite of Java library files, one corresponding to each mode of the chip, to handle these tasks, and given a basic knowledge of Android programming it is easy to integrate these libraries into your own program. In the case of GPIO mode, for example, the library file FT311GPIOInterface.java provides the functions ResetPort, ConfigPort, WritePort and ReadPort. The library files are also embedded in small Android demonstration programs, each of which provides a graphical user interface on the smartphone or tablet. The GPIODemo app (see **Figure 2**), for example, displays seven buttons to control the outputs and seven 'LEDs' to indicate the status of the inputs. These demonstration projects, eight in all, not only provide a way to test the chip and its connections, but can also

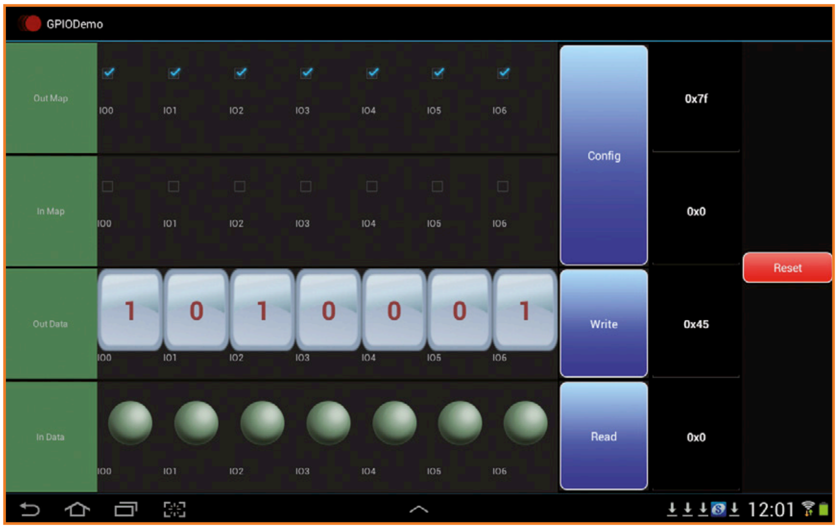
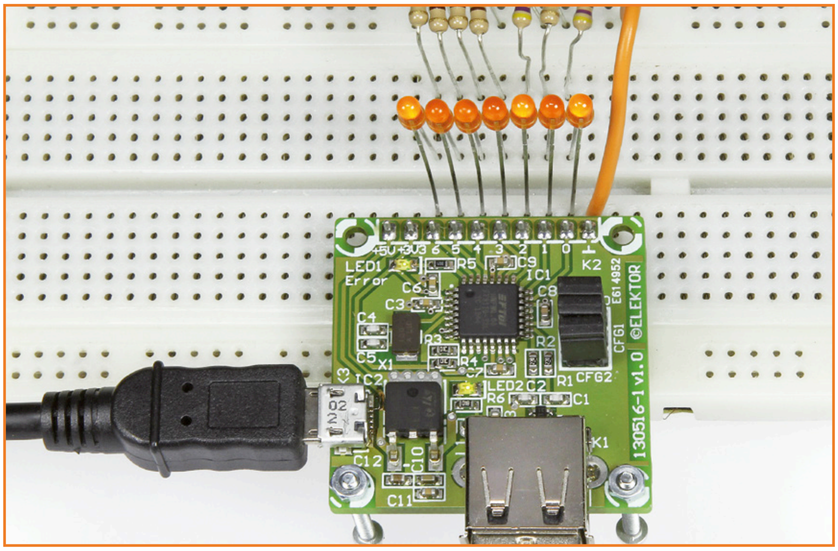

GPIODemo
Out Map
☑ IO0 ☑ IO1 ☑ IO2 ☑ IO3 ☑ IO4 ☑ IO5 ☑ IO6
Config
0x7f
In Map
□ IO0 □ IO1 □ IO2 □ IO3 □ IO4 □ IO5 □ IO6
0x0
Reset
Out Data
1 0 1 0 0 0 1
IO0 IO1 IO2 IO3 IO4 IO5 IO6
Write
0x45
In Data
IO0 IO1 IO2 IO3 IO4 IO5 IO6
Read
0x0
12:01

Figure 2. FTDI provides demonstration Android apps: this example allows control of digital inputs and outputs.



Compatibility

All Android devices running version 3.1 (Honeycomb) or above support Android Open Accessory mode. Your device can tell you which Android version it is running: on our Samsung Galaxy Tab it is under 'Settings', 'About device'.

Some devices running version 2.3.4 and above of Android also support AOA mode: devices vary depending on whether the manufacturer happened to include AOA support when customizing the operating system.

For older Android devices an alternative possibility for connecting to external hardware is the Elektor Andropod module, which uses a preprogrammed Vinculum device to communicate using the Android Debug Bridge (ADB). The module is available from Elektor [10].

Figure 3. The board (not including the screws) can be purchased from Elektor ready-built and tested.

form a basis for further app development. The demonstration projects and the libraries are in the Android.zip archive: this can be downloaded from FTDI's website.

Breakout board

To make it easier for our readers to try out this neat device, Elektor Labs staffer Ton Giesberts has designed the 'Elektor Android breakout board', a small board available ready-built from Elektor (**Figure 3**). The circuit diagram is shown in **Figure 4**. Ton was (in part) inspired in his design by an article on the FT311D by Jeff Bachiochi published in our sister magazine *Circuit Cellar* in December 2013.

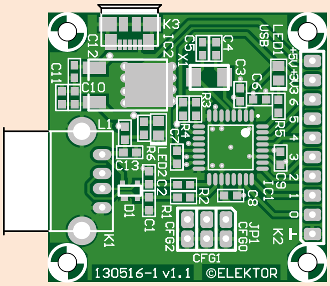
The Android tablet or smartphone is connected to K1, a USB A socket, on which a charging voltage VUSB (nominally 5 V) is also provided. The Android device, the FT311D and any other connected hardware are powered over K3, a micro USB socket. This choice has the advantage that the power adapter supplied with the smartphone or tablet, which normally uses the corresponding type of plug, can be repurposed.

Low drop-out regulator IC2 produces the 3.3 V supply required by IC1, the FTDI chip. External hardware is connected to K2, which carries the relevant signals from the FT311D as well as power at 5 V and 3.3 V. It is also possible to power the board and the Android device over the 5 V pin on this header.

Pins CFG0 to CFG2, which set the interface mode of the device, can be pulled to ground using jumpers. If a jumper is omitted, an internal pull-up in the device pulls the input high.

FTDI suggests connecting an LED to the /USB_ERR output, which it calls the 'Error LED'. However, this is misleading: the LED will light continuously when the FT311D has successfully established a connection with an AOA-compati-

Component List



Resistors

R1,R2 = 27Ω, 0.1W, 1%, 0603
R3,R4 = 10kΩ, 0.1W, 1%, 0603
R5 = 620Ω, 0.1W, 1%, 0603
R6 = 1kΩ, 0.1W, 5%, 0603

Capacitors:

C1,C2 = 47pF, 50V, 5%, C0G/NP0 0603
C3,C6–C9,C11,C13 = 100nF, 25V, 10%, X7R 0603
C4,C5 = 27pF, 50V
C10 = 4.7µF, 6.3V, 10%, X5R 0603
C12 = 10µF, 10V, 20%, X5R 0603

Inductors

L1 = 600Ω @100MHz, 0.38Ω/0.5A, 0603, Murata BLM18AG601SN1D

Semiconductors

D1 = PRTR5V0U2X TVS diode
LED1,LED2 = LED, 0805
IC1 = FT311D-32L1C-R
IC2 = KF33BDT-TR, LDO

Miscellaneous

K1 = USB-A socket, PCB mount
K2 = 10-pin pinheader, 0.1" pitch; round pins for plugging onto a breadboard (e.g. Harwin D01-9923246)
K3 = Micro-USB-B socket, SMD
JP1 = 6-pin (3x2) pinheader, 0.1" pitch, incl. 3 jumpers
X1 = 12MHz quartz crystal, 20ppm, 18pF, 5x3.2mm
PCB # 130516-1 v1.1 [6]
or
Elektor Android Breakout Board, ready assembled and tested, Elektor Store # 130516-91 [6]

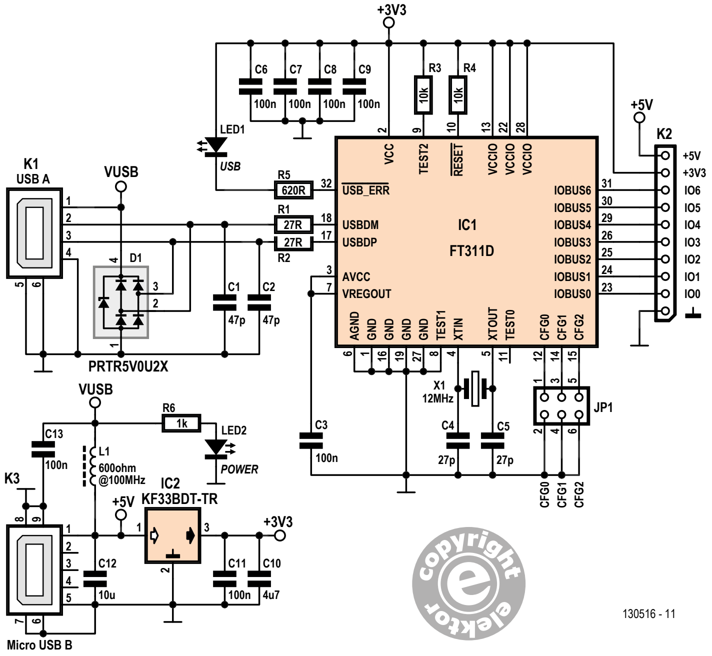


Figure 4. The circuit is built around the FT311D. The 5 V supply is provided over micro USB socket K3.

Interface modes

JP1 allows one of the six available interface modes to be selected: GPIO (digital inputs and outputs), PWM (mark-space ratio from 5 % to 95 %), I^2C master, asynchronous serial, SPI master and SPI slave. Pins IO0 to IO6 on K2 change behavior depending on the interface mode selected: the table also shows the pin numbers for the FT311D chip.

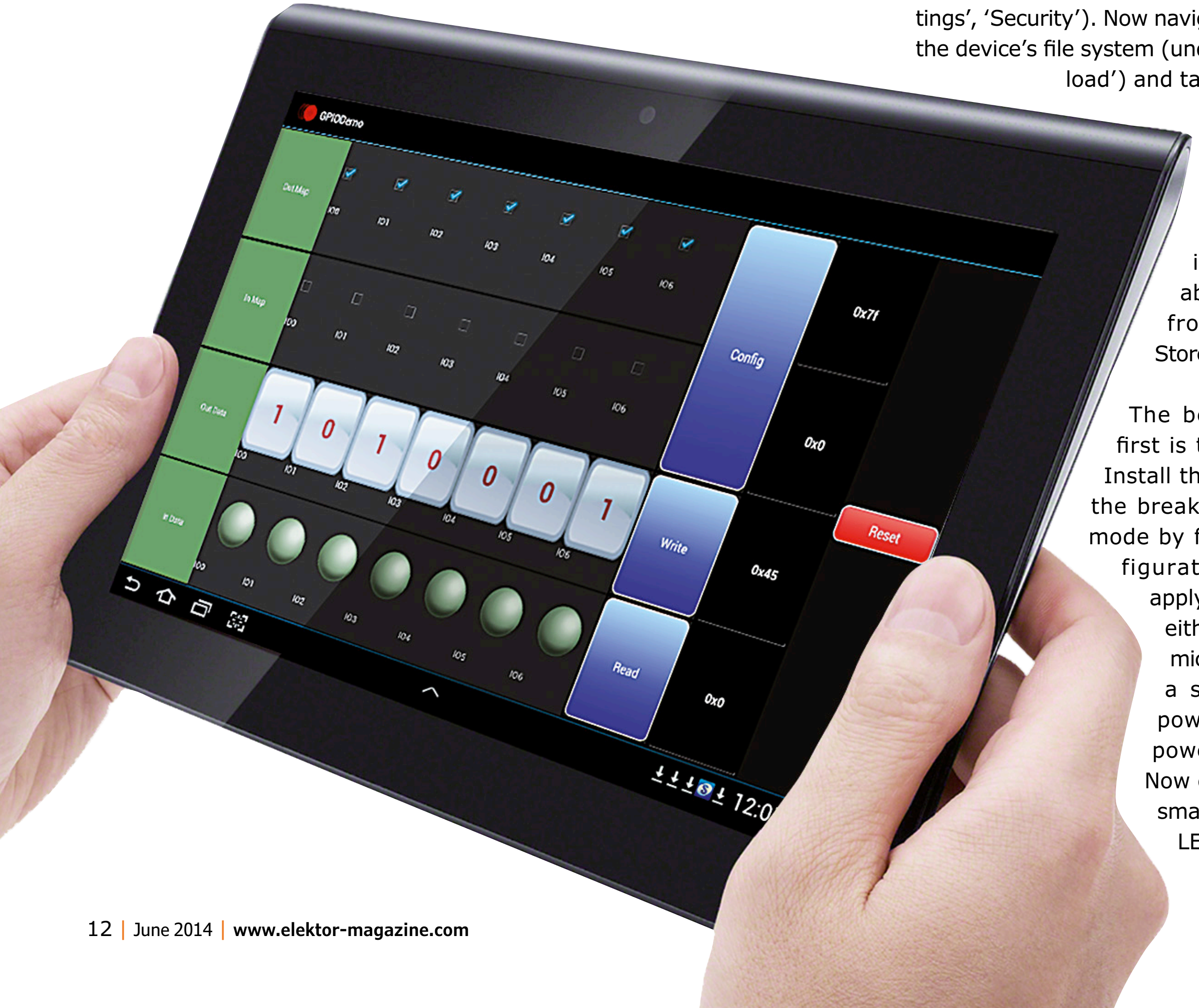
Modue		GPIO	PWM	I^2C	Serial	SPI Master	SPI Slave
CFG2	**15**	GND	GND	GND	GND	open	open
CFG1	**14**	GND	open	open	GND	GND	GND
CFG0	**12**	GND	GND	open	open	open	GND
IO0	**23**	IO0	PWM0	SCL	TXD		
IO1	**24**	IO1	PWM1	SDA	RXD		
IO2	**25**	IO2	PWM2		RTS		
IO3	**26**	IO3	PWM3		CTS	CS	CS
IO4	**29**	IO4			TXEN*	CLK	CLK
IO5	**30**	IO5				MOSI	MOSI
IO6	**31**	IO6				MISO	MISO

TXEN = transmit enable for RS-485 line driver

ble Android device, and so Ton felt it was more appropriate to label it simply 'USB LED' in the circuit diagram. The LED flashes when an error occurs; if an Android device that does not support accessory mode is connected, it remains dark. The Elektor Android breakout board can be purchased ready-built and tested [6]. A header is soldered at K2, making it easy to plug the unit into a breadboard. It is a good idea to fit two spacers or bolts to the holes on the opposite side, as shown in **Figure 5**.

Test and demonstration

For initial testing download the demonstration projects from the FTDI website [5]. In each case inside the /bin directory there is a .apk file: this is roughly the Android equivalent of what would be a .exe in the Windows world. Connect the smartphone or tablet to the PC and copy the .apk file into the Android device's file system, for example into the Download directory. The smartphone or tablet now has to be configured to allow such downloaded applications to be installed. In the case of our Samsung Galaxy Tab this involved ticking the 'Unknown sources' box (under 'Settings', 'Security'). Now navigate to the .apk file in the device's file system (under 'My Files', 'Download') and tap on it. Normally the Android device will ask if you wish to install the application. If this does not work, one of the installer apps available for free download from the Google Play Store may be able to help.



The best example to try first is the GPIODemo app. Install the app and configure the breakout board for GPIO mode by fitting all three configuration jumpers. Next apply power to the board, either from a PC using a micro USB cable or using a suitable micro USB power adapter, and the power LED should light. Now connect the tablet or smartphone to the board. LED1 should now light, and simultaneously a dialog box should appear on the Android device asking whether the GPIODemo app should be launched automatically in the future whenever the hardware is connected.

When the app is running the user interface appears as shown in Figure 2. The upper area allows you to select whether each GPIO pin is an input or an output: on touching the ‘Config’ button the appropriate command is sent to the breakout board to put the settings into effect. The levels on the outputs can be toggled by touching the white buttons and then touching ‘Write’. You can verify the results using a multimeter or more conveniently by plugging the FT311D board into a breadboard and wiring the outputs to ground or the 3.3 V supply via LEDs with series current-limiting resistors, as shown in the picture at the beginning of this article.

More information on all the demonstration apps and corresponding test circuits can be found in the ‘FT311/FT312D Demo APK User Guide’, which can be downloaded from the FTDI website [5]. In the Elektor Labs we tried out the I²C mode of the device by connecting the I²C communications pins to a Gnublin relay board [7][8]: see **Figure 6**. Note that in the demonstration app the field labeled ‘Device Address’ must be filled in with the address of the target I²C device omitting the least-significant bit (which is used to distinguish between read and write commands on the bus).

We also carried out some interesting experiments with two FT311D boards, one configured as an SPI bus master and the other as an SPI bus slave. We connected the two boards and then found we could send bytes from one Android device to another: data sent from the master app when ‘Write’ is touched are immediately displayed by the slave app. And conversely, data entered in the slave app with ‘Write’ will be read into the master app when it is given the ‘Read’ command. We hope that the above has given you a glimpse of the possibilities that this board opens up and we are sure you will think up lots of exciting new projects using it.

(130516)

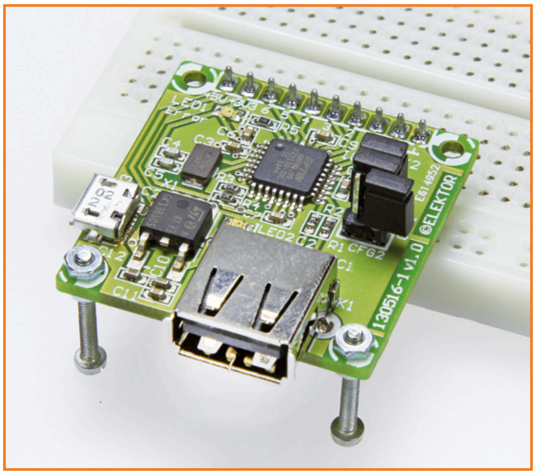


Figure 5.
A breadboard is the ideal foundation for experimenting.

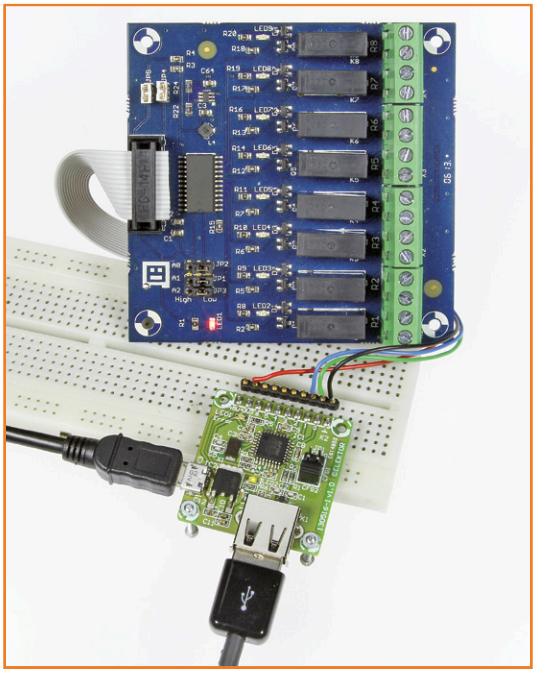


Figure 6.
The Gnublin relay board can be controlled over its I²C bus.

Web Links

[1] http://source.android.com/accessories/custom.html

[2] www.elektor-magazine.com/090992

[3] http://source.android.com/accessories/aoa.html

[4] http://developer.android.com/tools/adk/adk2.html#src-download

[5] www.ftdichip.com/Products/ICs/FT311D.html

[6] www.elektor-magazine.com/130516

[7] www.elektor-magazine.com/130157

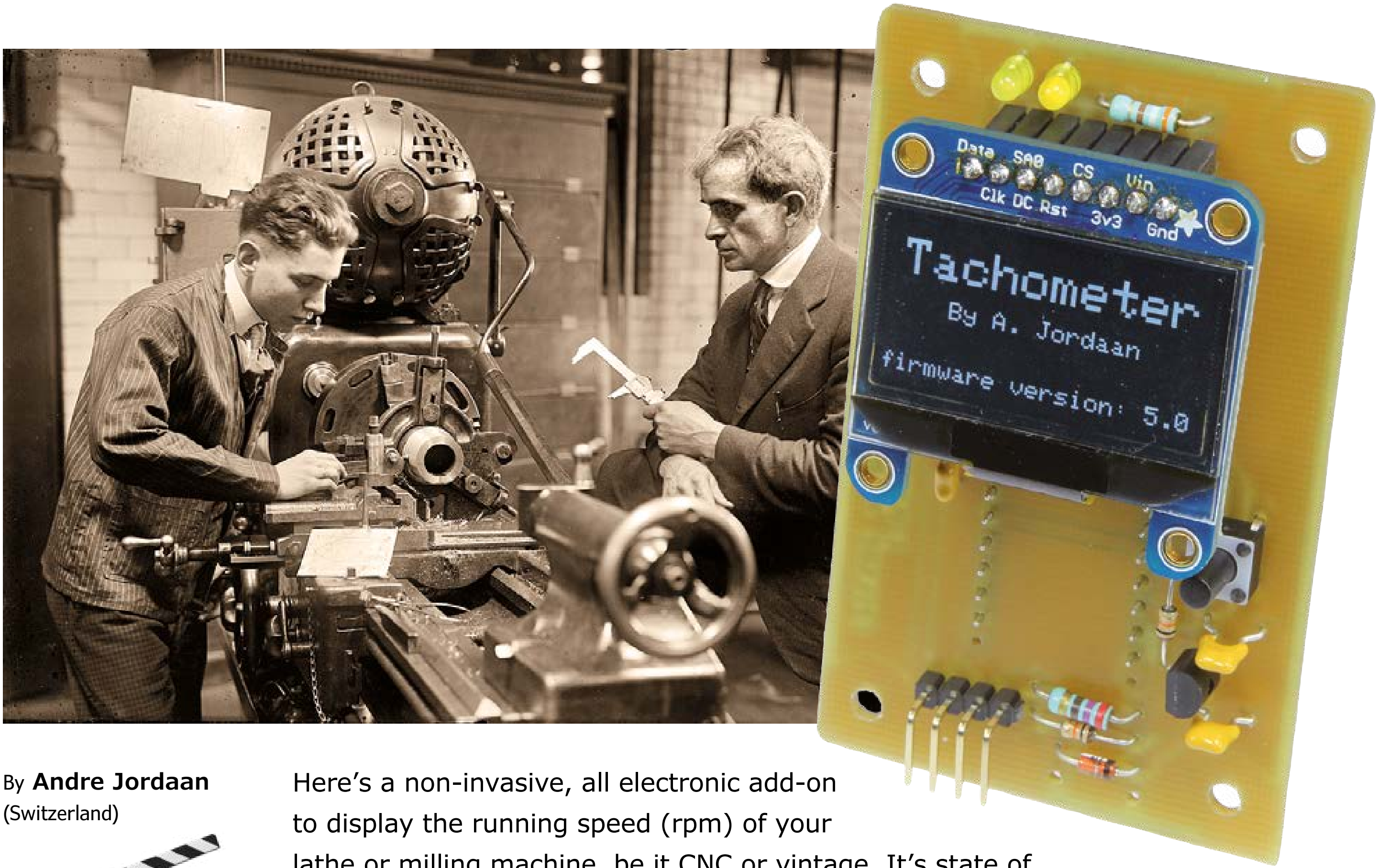
[8] www.elektor.com/gnublin-relay-module-130212-91

[9] www.elektor-magazine.com/110405

[10] www.elektor.com/110405-91-andropod

Lathe Tachometer

Feat. Arduino Micro & OLED



By **Andre Jordaan**
(Switzerland)

Here’s a non-invasive, all electronic add-on to display the running speed (rpm) of your lathe or milling machine, be it CNC or vintage. It’s state of the art—witness the use of an Arduino Micro board and a .96 inch OLED display for instantaneous readout. The little instrument also has a clock displaying the equipment running time.

Attention Bridgeport lathe and milling machine users; get in touch with an electronics geek and have him build this circuit for you.
Attention Arduino users: build this circuit for a nearby Bridgeport lathe owner and get access to his prize machinery.

In this project a reflective IRED / phototransistor device is used as a sensor to produce a retrofit readout of the number of revolutions of a spindle (or “shaft”) on a lathe, a milling machine or a similar piece of equipment in the metalworking toolshop.

Without even scratching the surface of elementary metalworking and finishing, electronicz people should know that the turning speed is crucial for anything that cuts, drills, mills, finishes or polishes metal, wood, glass, and recently, hard plastics, Teflon® and rubber too. In the case of a round steel bar being milled to end size, the turning speed used to do the first couple of rough passes using toolbit ‘A’ at angle *x* may differ considerably from that applied much later for an ultra-smooth surface finish using toolbit ‘B’ at angle *y*. In both cases, the shaft speeds have to be set and verified by the operator using whatever gears or reduction drives are available on the machine.

To the metalworker, the *turning speed* his prized machine is running at equals the *supply volts* and *amps* to the electronics engineer. Get the turning speed (≡voltage) wrong and you risk destroying your precious stock material (≡64-bit ARM MPU), object being created (≡Linux dev system) and/or $50K Bridgeport lathe (≡128-bit LeCroy logic analyzer). ≡You don't want that to happen.

Where we write spindle or shaft in the remainder of this article of course we mean chuck, 3-claw head, 4-claw head, boring head, end mill, polish pad, drill, tap, *etcetera*, since all of these tools are fitted eventually to the powered shaft or spindle of the lathe or milling machine.

How it works

As with most applications of embedded technology the schematic in **Figure 1** does not reveal a lot about the workings or aim of the circuit. In fact, you could be looking at NASA's latest alligator counter for use at Cape Canaveral. One of the reasons for the happy scarcity of components in the schematic is the use of an Arduino Micro board in position MOD(ule)1, resulting in all manner of things being controlled and decided by software rather than discrete parts. The Arduino Micro is first programmed with the project firmware of course via its micro USB connector.

The unregulated supply voltage from a 9-V 6LR22 alkaline battery (or a 7 V to 9 V power adapter) enters the circuit on K1, and gets reduced to 5 volts by stabilizer IC1. LED1 acts as a Power On indicator.

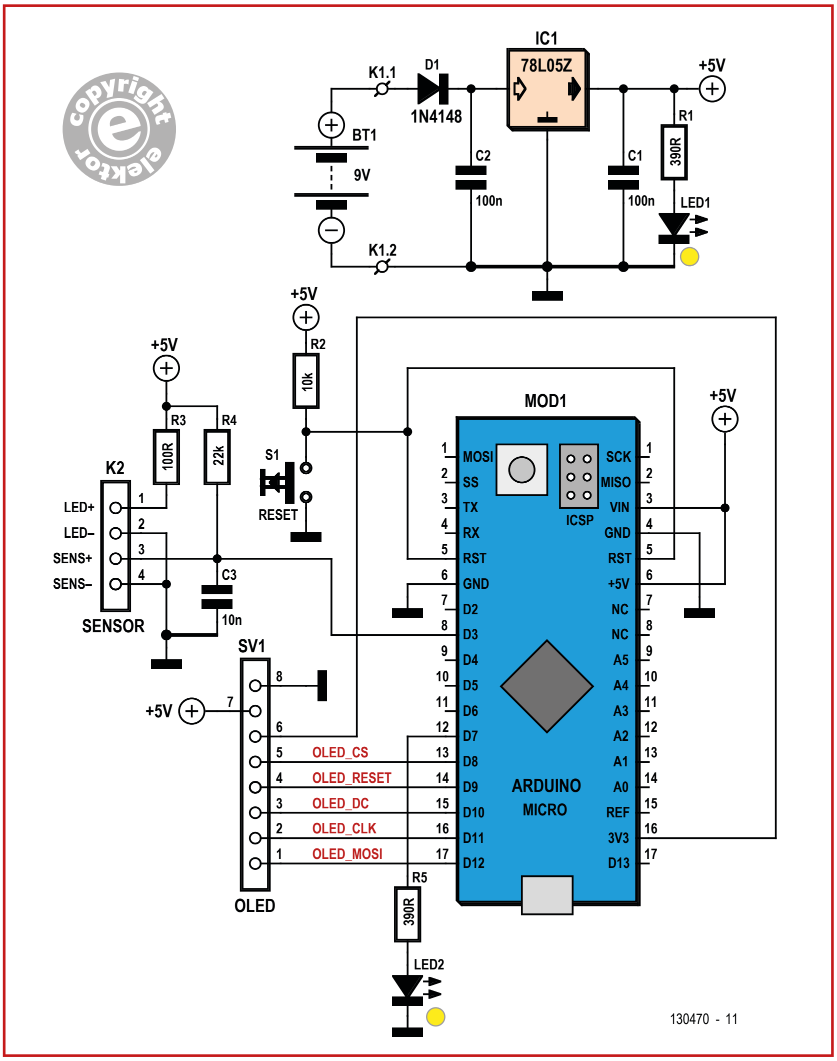
The Adafruit OLED (organic light emitting diode) display module [1] is connected straight onto 8-pin connector SV1. The OLED module with its monochrome, 128 x 64 graphic display gets its 5-volts supply voltage from the same regulator as the Arduino Micro. Other OLED modules may be used but be sure you match their pinout to the board.

The only input device to the circuit, a reflective IRED / phototransistor ("reflective optical sensor" device) like the one at Yourduino [2], is connected on K2. The LED inside the device is again powered from the +5 volts rail via R3. It is on as long as the 5-V supply voltage is present. The phototransistor's SENS+ pin is pulled to +5 volts by R4, and the signal fed to the INT/D3 line of the Arduino Micro board. A piece of matt black adhesive tape or similar is secured around the lathe's shaft, leaving a narrow gap (of about 3 mm). Whenever the light emitted by the LED reflects off the shaft at the position of the gap, it illuminates the internal phototransistor, causing the SENS+ line to drop logic Low, and High again when the LED light is not reflected. Hence the speed of the rising edges of SENS+ signal indicates the shaft speed. Note that due to reduction gears being present in the lathe or milling machine the shaft speed is *not* the motor speed.

The Arduino Micro can be reset to force it to start executing its firmware from scratch by pressing S1.

Finally, the function of LED2 on Arduino Micro line D7 is free to assign by the programmer—like over rev or call keith [4].

Figure 1. Schematic of the precision rev counter for CNC lathes and milling machines. All measurement and control functions are handled by an Arduino Micro plug-on board.



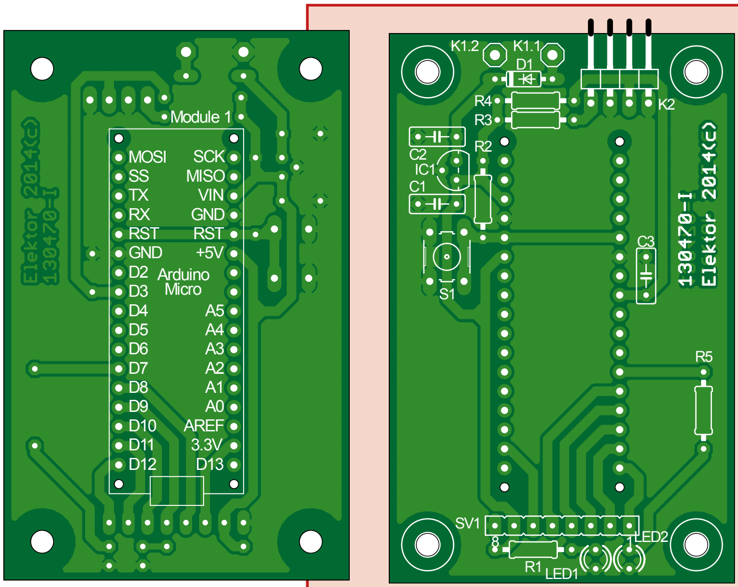


Figure 2. Printed circuit board layout designed by Elektor Labs for the project.

Component List

Resistors
R1,R5 = 390Ω 5%, 0.25W
R2 = 10kΩ 5%, 0.25W
R3 = 100Ω 5%, 0.25W
R4 = 22kΩ 5%, 0.25W

Capacitors
C1,C2 = 100nF 10%, 100V, 5mm pitch
C3 = 10nF 10%, 100V, 5mm pitch

Semiconductors
IC1 = 78L05Z
LED1 = LED, yellow, 3mm
LED2 = LED, 3mm, color t.b.d., optional, see text

Miscellaneous
MOD1 = Arduino Micro, Farnell/Newark # 2285194
S1 = pushbutton, PCB mount, 6x6x9.5mm
SV1 = 8-way pinheader receptacle
K2 = 4-way pinheader receptacle
K1 = 9V battery connector clip + wires
Reflective Optical Sensor, like TCRT5000
Monochrome 0.96” 128x64 OLED graphic display, Adafruit # 326 (UG-2864HSWEG01)
34-pin DIP socket for Arduino Micro (DIY from SIL pinheader receptacles)
PCB # 130470-1

Listing 1. Excerpt from Firmware.ino

```
//to be done when when sensor is interrupted:
void interrupt_rpm_time()
{
  // current_interrupt_time = micros();
  // if (micros() - previous_interrupt_time > (1/fMax))
   {
    current_interrupt_time = (micros() - previous_interrupt_time);
    previous_interrupt_time = micros();
   //  Serial.print("+");
   //   Serial.println(current_interrupt_time);
    //  digitalWrite(ledPin, HIGH);
   }
}


 void calc_run_Time()
{
  //calculating running time
  unsigned long elapsed;
  unsigned long over;
  elapsed=millis();
  h=int(elapsed/3600000);
  over=elapsed%3600000;
  m=int(over/60000);
  over=over%60000;
  s=int(over/1000);
  ms=over%1000;
}
```

Software

The program “Firmware.ino” is recommended educational reading if you want to understand all the ins and outs of the control program, and how it got developed and tweaked. The program is richly commended by the author.

Arduino users will know how to transfer the file to their Arduino Micro board, starting from file 130470-1.zip, which can be downloaded free of charge at [3].

The Arduino program waits for a rising edge at its INT1 input and uses five rising edges to compute the average time between them. Using some math the rpm (revolutions per minute) is calculated and sent to the OLED display.
A snippet of the program code is printed in **Listing 1**. Here we see how the interrupt produced by the sensor gets handled, and the Tachometer’s internal clock is ticking to display the “up” time.

Build it, use it

The printed circuit board designed by Elektor Labs has through-hole parts only and its component overlay is given in **Figure 2**. Let the electronics people handle the programming, board stuffing, soldering and wiring, and the mech people do the mounting of the board in a case, and the

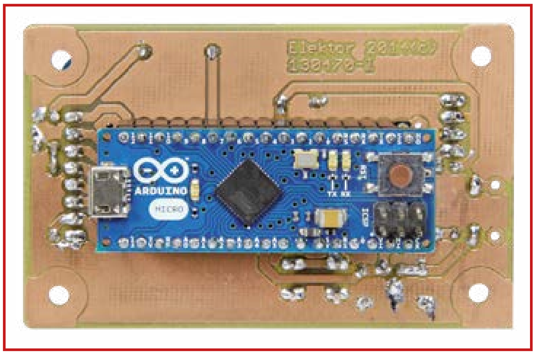


Figure 3. The Arduino Micro board secured on to the solder side of the tachometer board (early prototype).

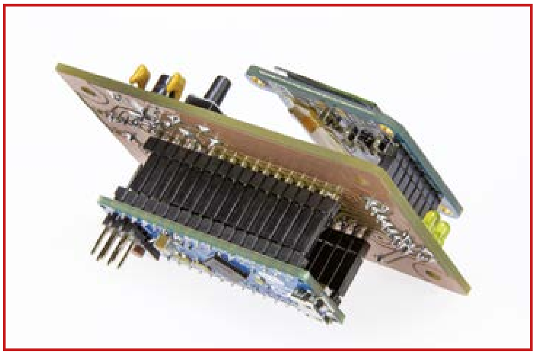


Figure 4. The Lathe Tacho board has boards fitted at either side: an Arduino Micro at the solder side, and a .96″ OLED display at the front. Note the use of SIL pin strip receptacles to ensure the correct mounting distance.

mounting of the reflective sensor close to the powered shaft of their lathe or milling machine. If you are a mechatronics fan you do both jobs with ease, in the proper sequence.

A slotted optocoupler and a vane fitted at a suitable place on the machine shaft may also be suitable but the assembly is more intricate to mount—if not invasive. If your machine shaft is not reflective, stick a small piece of paper on it to do the light reflection.

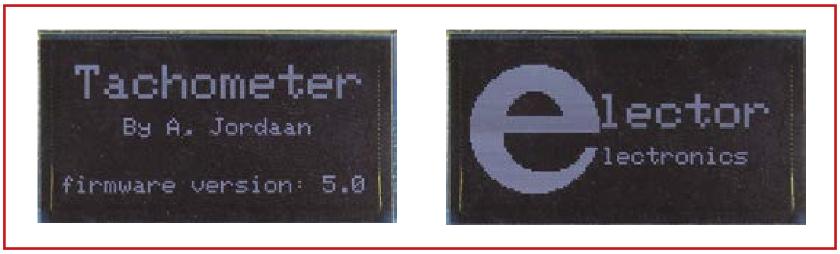
The Arduino Micro is plugged on to the rear (solder) side of the Tachometer board **(Figure 3**); the OLED unit, on to the front (component) side (**Figure 4**).

After switching on, the Arduino Micro initializes, then displays the Elektor logo and “Elector Electronics” (*sic*), then “Tachometer by A. Jordaan” and the firmware number (**Figures 5a; 5b**). Next, the current rpm value is displayed, and the ‘up’ time of the tachometer (so you can bill your customers and come across serious).

Over to you

The project being open in terms of hardware and software, there should be nothing in your way to do custom adaptations like getting that *k* right. It will be insightful for sure. The hardware for example may be adapted to support different types of sensor types like Hall effect. Other possible applications include a step counter, a rev counter for model planes, a PWM percentage meter, or a simple event driven animation on the display. It should also be easy to add more channels and other controls like relays etc. One wish of the author is send the count pulse on to Mach 3—the control software for his CNC machine.

(130470)



Tachometer
By A. Jordaan
firmware version: 5.0

Figure 5. The Lathe Tachometer startup screens. The OLED readout should blend in beautifully with all manner of tech info and lights that can be seen in a 21^{st} century metalworker’s toolshop.

Web Links

[1] OLED display: www.adafruit.com/product/326

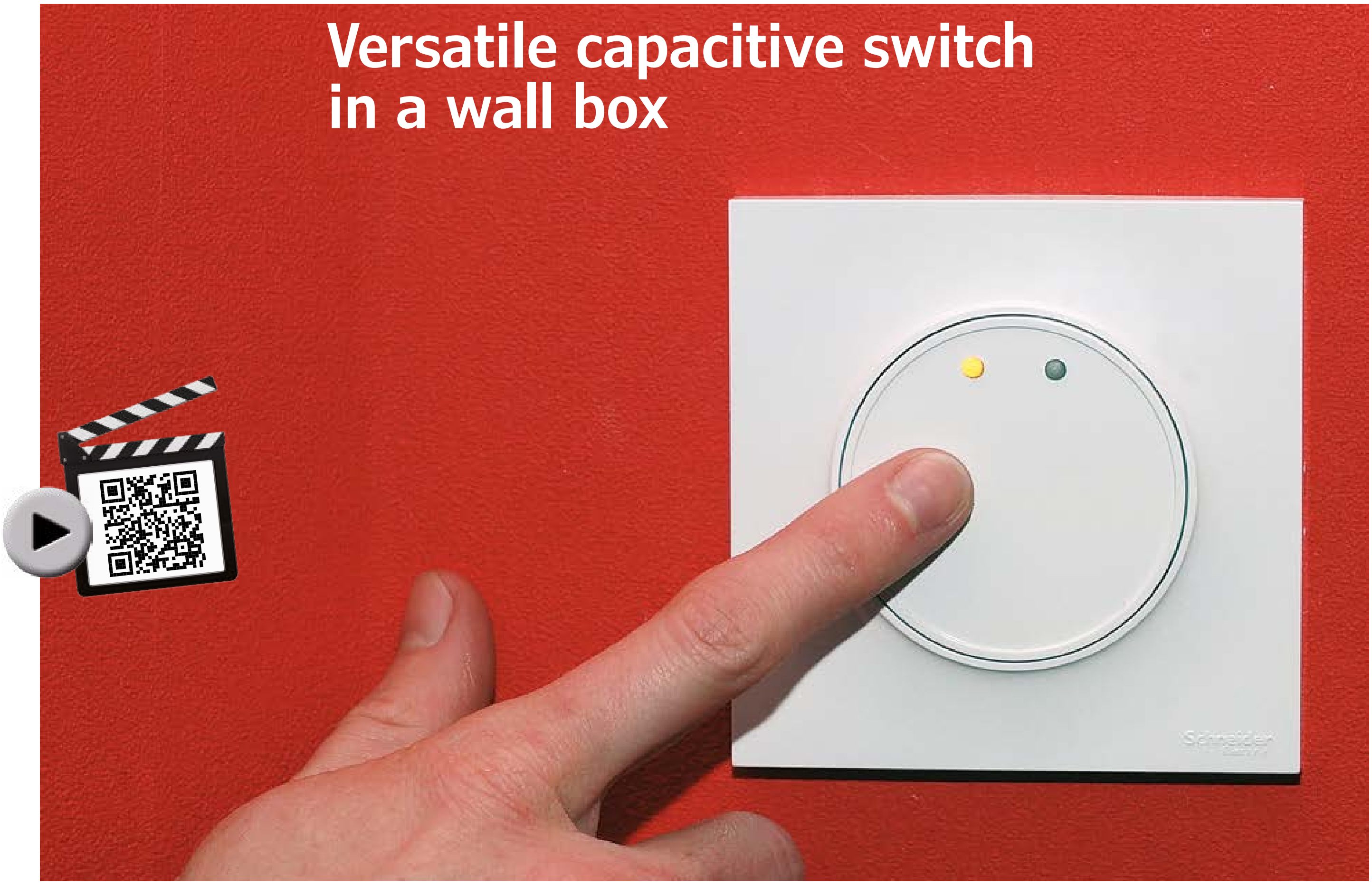
[2] Reflective Infrared Sensor: http://yourduino.com/sunshop2/index.php?l=product_detail&p=217

[3] Arduino Micro firmware: www.elektor-magazine.com/130470

[4] Keith Fenner’s Turn Wright Machine Works on Youtube: www.youtube.com/user/KEF791

Touch-2-Switch

Versatile capacitive switch in a wall box



By **David Ardouin**
(France) [2]

This capacitive-detection dual wall touch-switch, designed to fit into domestic electric wall-boxes, uses analog technology throughout. A single multi-purpose version that you can configure as you wish to function as a simple on/off switch, a 2-way switch, or momentary button, on two independent channels. At low cost, modernizing your home electrics has never been so tempting.

Specifications

- changeover, 2-way, or momentary switch
- replaces a standard mechanical switch in a wall box
- choice of controlling one or two separate lighting circuits
- configurable illuminated indicator
- modern appearance, easy to reproduce, 230 V/50 Hz or 120 V/60 Hz
- no programmed devices
- configurable using just a soldering iron

In these times of home automation and smart electrical installations, the big manufacturers are vying with each other in ingenuity. It seems to be a ferocious fight, judging by the proliferation of models of wall switch on offer, from the simple white changeover switch to automatic systems of controlling lighting for any home by phone or touch tablet—and not forgetting the silent, round, square versions you can customize to your heart’s content. I’d always dreamt of bringing my home electrical installation up to date using touch switches, but couldn't quite bring myself to spend a fortune on this sort of accessory. So that's why I decided to design one that would exactly meet my requirements. The new touch switch will:

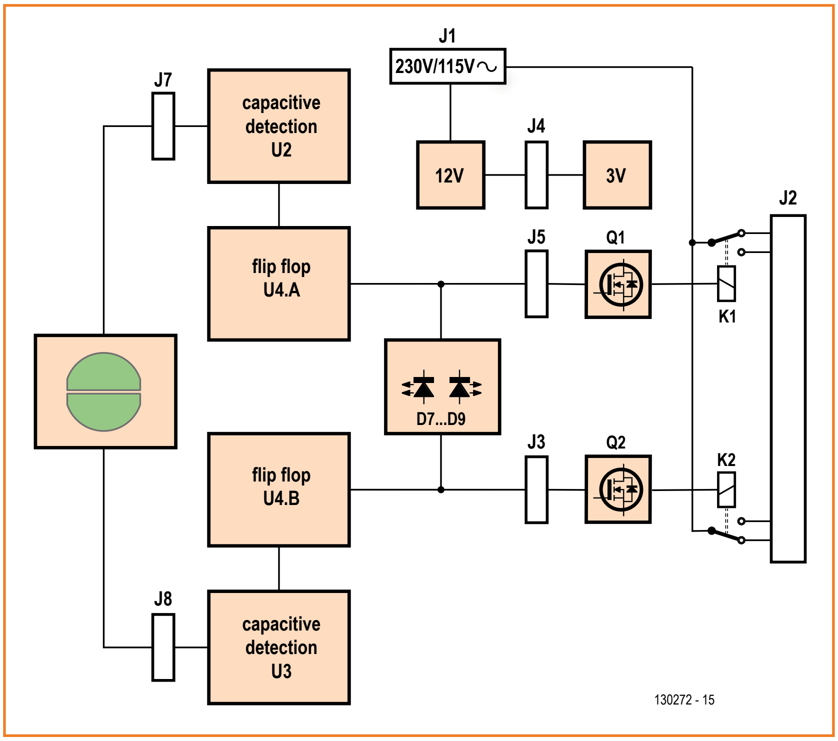
- replace a mechanical switch and fit into a standard flush-mounting wall-box, attractive and modern in appearance, yet easy to reproduce;
- give the choice of controlling one or two separate lighting circuits and operate as a simple changeover switch, a 2-way switch, or as a momentary push-button;
- have an indicator configurable as either a constantly-illuminated pilot light or as an output state indicator.

Look as hard as you like, even with the major names in this field, but you won't find any product with these specifications.

I must admit, however, that changing to an electronic version inevitably implies the switch is going to consume some power all the time—but I've kept this to the strict minimum. It does also require the presence of a Neutral (cold) wire—which may not be present in lighting circuit boxes.

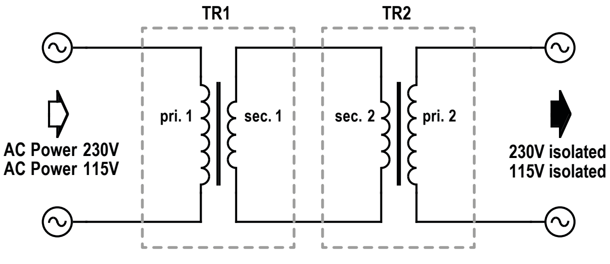
Tips

I suggest exploring the circuit diagram (**Figures 1a and 1b**) by following the line of thinking that led me to this solution. The first crucial choice was picking a technique for switching a power of a hundred or so watts. Exit the triac because of instability at low loads and a monstrous consumption of several tens of milliamps. Using a MOSFET transistor and diode bridge promised minimal losses, but though it worked fine for a single channel, it caused me unacceptable problems running two channels in parallel. What's more, the diode bridge would mean the low-voltage supply could no longer be achieved using a classic capacitive dropper; it would have been necessary to revert to a power resistor with deplorable efficiency. No question either of using a relay, because of its holding current. A conventional relay, no—but maybe a bistable relay? Much less common than their monostable counterparts, latching relays use power only at the moment of changing state. A pulse of just a few



SAFETY

As there's no transformer, this sort of power supply has the advantage of being very compact—but it does not provide voltage isolation. As the internal ground of the circuit is directly connected to the Live (hot), it is strictly forbidden to handle the circuits, including the capacitive part and the electrodes, when the supply voltage is present. User safety is only ensured once the switch is enclosed within its back box. For testing and for any handling in the presence of hazardous voltage, get into the good habit of disconnecting the circuit to be tested before connecting your measuring instruments to it, then powering it back up to read the measured value, and lastly, disconnecting the power again before moving on to the next step.



Example of isolation transformer created by hooking up two 12-V power transformers back-to-back.

For the testing, I recommend making up an isolating transformer from two 230 V/12 V (US: 115 V / 12 V) transformers rated at a few VA wired back-to-back. A dangerous voltage will still be present on the output, but only across the two end terminals. This accessory will make it easier and safer for you to check the circuit is working properly. You will be able to switch the relays, but not connect up an actual load.

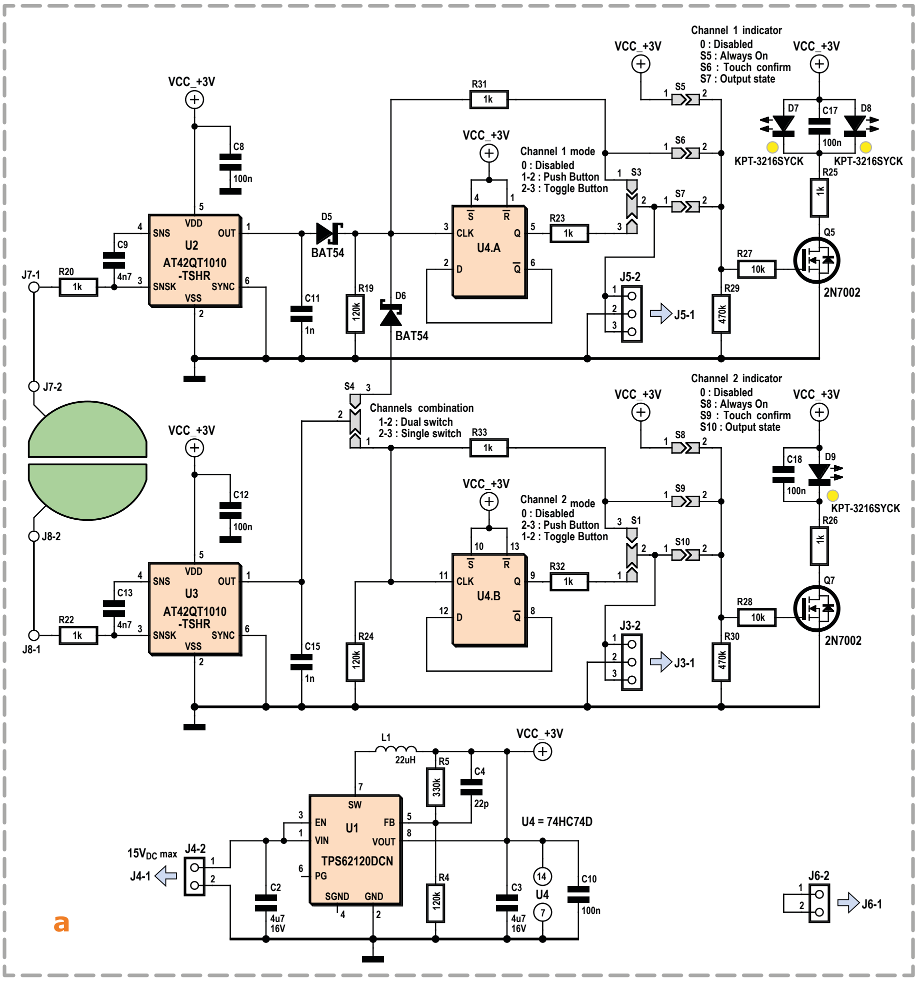


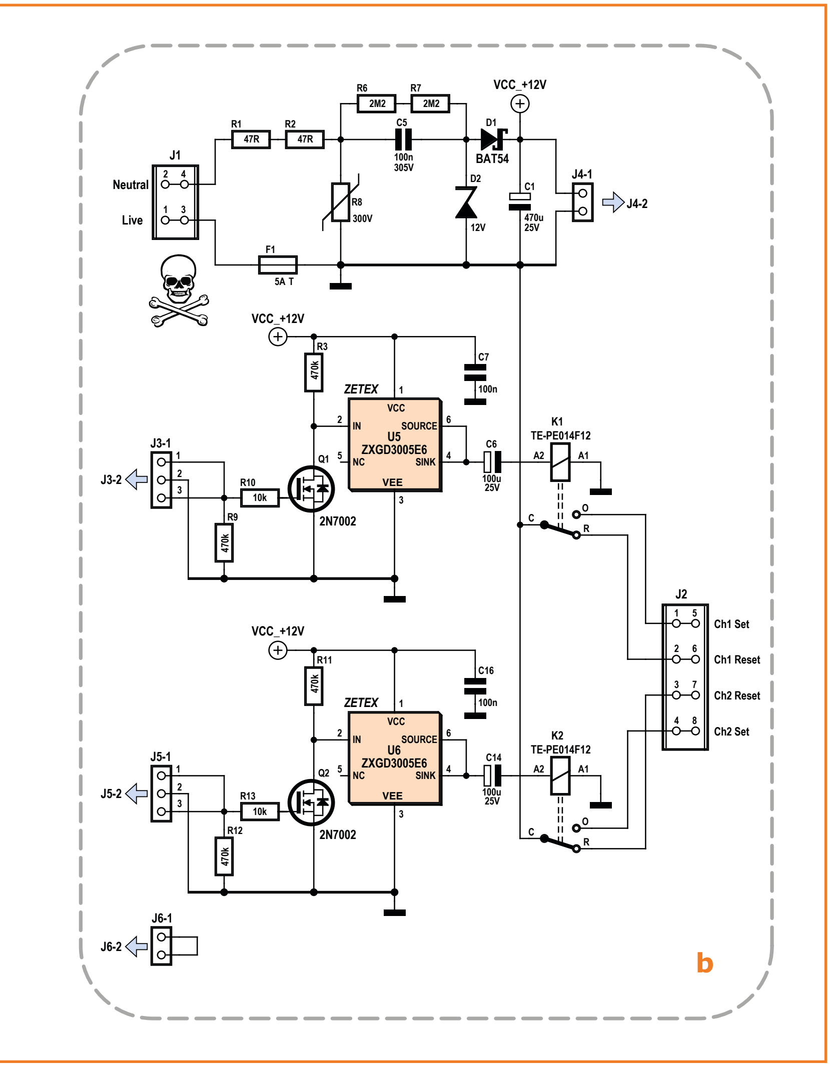
Figure 1a & 1b:
Circuit diagram in two sections: right, the high-voltage circuit; left, the low-voltage circuit. Unless electrically isolated from the power line supply, all the conducting parts of this circuit are live! Despite their high values, C2 and C3 are non-polarized capacitors.

Guaranteed microcontroller-free!

tens of milliseconds is enough to make them switch over; then they don't consume anything at all until the next time they switch. *Perfect!* In the 12-V version, relays K1 and K2 (**Figure 1 b**) draw a current of 18 mA for 20 ms when switching. A "luxury" solution would have been to drive the coil via an H-bridge. But I preferred to store the energy needed for switching in capacitors C6 and C14, which provide the polarity inversion depending on the sense of the edge applied by U5 and U6.

These latter, helped by Q1 and Q2, form level-shifters to amplify the drive signal voltage and supply the current needed by the relays. These devices are normally used to drive MOSFET gates, but they fulfill their role marvelously here for a derisory cost.

The AC powerline supply (J1) makes use of the impedance of a capacitor (C5) to drop the voltage to the required value, with minimal losses. The choice of this component depends on what powerline voltage you have; choose the 150 nF for 115-120 V/60 Hz or 100 nF if your domestic grid is 230 V/50 Hz. A rectifying diode (D1) and zener (D2) then provide regulation to 12 V. Unfortunately, this kind of circuit always draws



some power, whether the rest of the circuit is powered or in stand-by. Now it was clearly out of the question that, to supply the 20 or so milliamps needed to operate a relay for very short periods of time, I would let such a circuit dissipate some 240 mW in heat all the rest of the time. Since the relays only consume power when they are being driven, I deliberately under-rated their supply by a factor of six. It charges at its own speed the large reservoir capacitor C1, which is used as a buffer when power is drawn; in practice, this reserve is enough to withstand even the most frenetic pressing!

When the circuit is powered down, R6 and R7 discharge C5 rapidly, so as to avoid this capacitor holding a potentially lethal charge. For working voltage reasons, two resistors have deliberately been used in series; under no circumstances must they be replaced by a single resistor! This remark applies equally to R1 and R2, which limit the current surge when the circuit is powered up. Varistor R8 protects the circuit from any spikes. Fuse F1 is a 5-A type that will protect against possible overloads or wiring errors; it corresponds to the maximum current relays K1 and K2 can take. Go for a slow-blow type (T), which will be more robust against the surge current from high-power filament lamps. The input and output connectors are spring terminals—much more reliable than traditional screw terminal blocks. Always remember that any work involving the mains supply must be done with the power off.

Details

Now let's take a look at the control circuit (**Figure 1a**). Surprise: there's no microcontroller here! It's my deliberate policy, a bit of nostalgia… The capacitive detection is provided by two half-moon-shaped electrodes, positioned behind the switch front panel and connected to J7-1 and J8-1. U2 and U3 are specialized ICs for capacitive detection. Although at first sight deceptively simple, in fact they include several sophisticated algorithms that are essential for guaranteeing faultless detection over time. Their outputs have one specific feature that gave me a bit of a headache: in order to confirm the device is working correctly, regardless of its logic state, the output regularly goes briefly high-impedance, which produces pulses of erratic logic levels. In order to filter these out, I've added C11 and C15, the values for which are not arbitrary; they are just enough to filter the pulses without degrading the rise-time too much, as that would be hinder proper switching of the flip-flops in U4. Capacitors C9 and C13 directly define the reactivity of the capacitive

Listing

None!

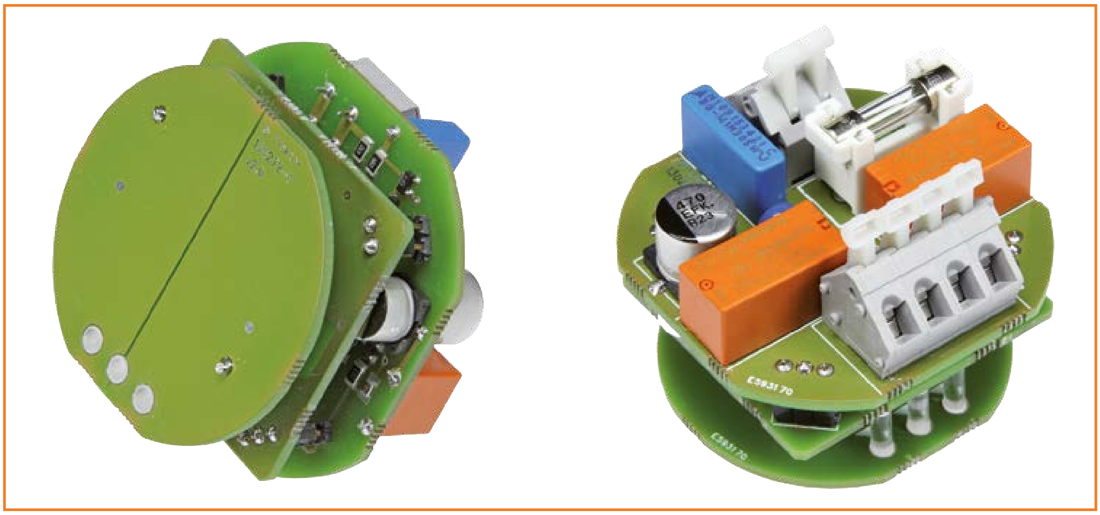


Figure 2.
The dual switch assembled.

button. To make the detection more sensitive, you can increase their value up to 10 nF; on the other hand, if you experience unwanted triggering, you can reduce the value down to 1 nF. Diodes D5 and D6 form a logic OR which, depending on the configuration of solder bridge S4, will allow the outputs from both capacitive detectors to be combined so as to form a single electrode driving just the first output. A solder bridge between its pads 2 and 3 will activate the “single switch” mode, while bridging 1 and 2 give you two independent channels. In the same way, S1 and S3 let you choose between the momentary contact operating mode (bridge across 1 and 2 for S1 and across 2 and 3 for S3) or latching contact mode at the flip-flop output (bridge across 2 and 3 for S1 and 1 and 2 for S3). The first mode is useful for an installation where there are a number of buttons all operating a remote-controlled switch or timer in the electrical distribution board. The drive signals then go on to the power board via connectors J3 and J5.

The behavior is configured using just a soldering iron by applying (or not) blobs of solder on bridges S1–S10.

Channel 1:		
S3	1-2	momentary mode
S3	2-3	two-position switch mode
S5 bridged; S6 & S7 open		indicator 1 always lit (pilot light)
S6 bridged; S5 & S7 open		indicator 1 lit while pressing
S7 bridged; S5 & S6 open		indicator 1 follows output state
S5, S6, & S7 open		indicator 1 disabled
Channel 2:		
S1	1-2	two-position switch mode
S1	2-3	momentary mode
S4	1-2	Channels 1 & 2 independent
S4	2-3	Channel 1 only
S8 bridged; S9 & S10 open		indicator 2 always lit (standby light)
S9 bridged; S8 & S10 open		indicator 2 lit while pressing
S10 bridged; S8 & S9 open		indicator 2 follows output state
S8, S9, & S10 open		indicator 2 disabled

Touch switches no longer give the mechanical feedback of their predecessors, which is why it’s worth using illuminated indicators to confirm the action requested. For a single switch, D7 only will be fitted in the middle position, while with two separate channels D8 and D9 will be used. Capacitors C17 and C18 are recommended [1] in the event that the electrodes detect impedance changes (of the MOSFET transistors Q5 and Q7, as it happens) that might disrupt their operation. Bridges S5–S10 define the behavior of the LEDs with a choice of permanent pilot light, touch confirm, or copying the output status (see **Table**). To drop the 12 V voltage present on J4, I chose a step-down regulator (U1) specially designed for low powers. With its associated components, it supplies a maximum current of 10 mA @ 3 V — plenty to power this little world.

Soldering iron in hand...

There’s a downside to the miniaturization of surface-mount components: they’re jolly small between our big fingers. So I used 1206 format passive components, a little easier to solder. The three PCBs are supplied as one board (**Figure 2**)

100% soldering iron configurable

– a dodge to reduce manufacturing costs (at the expense of a few hours of extra work on routing). It'll be easier if you keep them together during the soldering stages. Start by soldering all the surface-mount components on the top side, then continue with the SMDs on the underside. If you choose to use only a single way of your switch, fit only LED D7. For two separate channels, fit D8 and D9, and not D7. On the assembly drawing, the rectangle in the corner of the LED symbols indicates the position of their cathodes. Then fit the through-hole components on the power circuit (130272-3). The male and female headers that form J3–J6 will be soldered later, during assembly. The capacitive detection circuit doesn't require any soldering for the moment, as the two copper electrodes are the sole components.

Checking

Temporarily link across J7-1 and J7-2 using a short length of flexible hook-up wire. Do the same with J8-1 and J8-2. Using a 9 V battery or a bench supply set to this voltage, power the logic section via connector J4-2, taking care to respect the polarity shown on the copper. If everything is OK, you ought to measure a voltage of 3 V across C3. Place your finger **on the insulating side** of one of the electrodes, the LED for the relevant channel should light at once; the capacitive detection here always takes place through an insulating surface – do not touch the copper electrodes directly, operation will be erratic.

On the "power" side, connect a voltmeter to the pins of J4-1 then power the circuit by applying the AC power supply line voltage to terminal block J1. Never forget that the whole of the circuit is now at a lethal voltage, and from now on you must not touch it. Check you have a voltage close to 12 V on J4-1.

Now separate the three circuits using cutters, using a small, flat file to smooth the cut edges. Insert J3 to J6 in the positions provided, but for the moment solder only one pin on each of the headers. Stack the two "driver" and "power" circuits together and check the connectors line up properly. Touch up your soldering if necessary, then finalize it all by soldering the remaining pins.

Final assembly

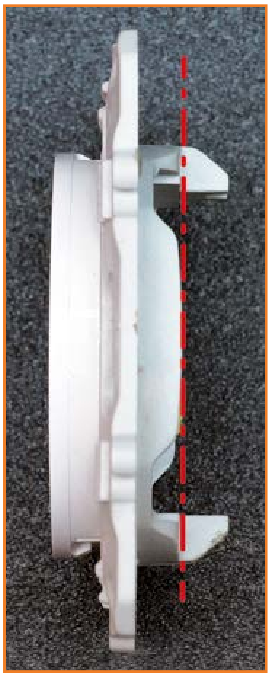
In order to give a professional finish and integrate perfectly into an existing electrical system, the electronics are preferably built in to wall box normally used to hide an electrical junction. In order to match my own installation at home in France, I chose the Odace range from Schneider Electrics. The fitting consists of three parts: the light grey mount that fixes to the wall-box, the white circular blanking plate, and the trim, which comes in different colors. To mount the electronics, the first step is to cut off the two lugs at the rear of the mount (**Figure 3**). A junior hacksaw or mini cutting disk will be perfect for this job.

The first PCB, the electrode one, is going to be glued into the circular blanking plate (**Figure 4**). Apply a thin, even layer of epoxy adhesive all over the copper side of this board. I must emphasize it's vital that **the entire surface** must be evenly covered to **avoid any air pockets** that might disrupt the capacitive detection. You can then insert the glued-up PCB into the blanking plate, taking care to align the two parts as accurately as possible. Depending on the number of indicators installed (D7, D8, D9), drill holes in the blanking plate using a 3 mm drill and fit one or two light-guides (**Figure 4**). To finish this part, finally solder two 15 mm long rigid wires (e.g. resistor lead offcuts) to the pads J7-2 and J8-2.

The detection board is assembled behind the grey mounting plate using four spots of epoxy adhesive in the corners (**Figure 5**), after having carefully inserted the two electrode connection leads into the corresponding pads. Before completing the gluing, check that the LEDs are in line with the blanking plate light-guides—it's all too easy to get it the wrong way round. Lastly, solder pads J7-1 and J8-1. All that remains to complete the assembly is to plug the power part (**Figure 6**) onto the connectors provided. The cross-section view (**Figure 7**) shows the details of the stacked boards.

The connections to be made for configuring as 2-way switches or momentary buttons are given in **Figure 8a**. Very often with most mechanical switches, you will find in your back box only a

Figure 3.
Modifying the mounting plate.



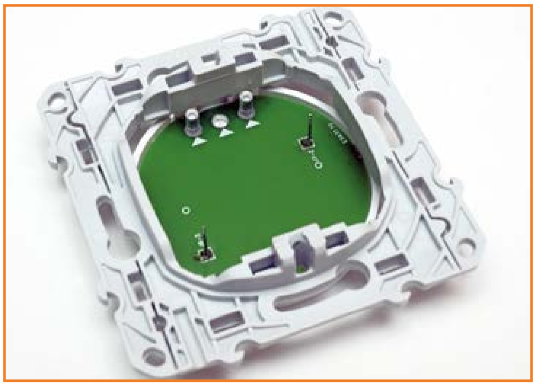


Figure 4.
Assembling the electrodes.

Live (hot) wire (check the color used in your country) so you'll also have to run a Neutral (cold) wire (check color in your country) which you'll be able to pick up from the nearest socket outlet, for example. If you should inadvertently reverse the Phase and Neutral connections on J1, the touch part, the LEDs, and the relays would all work normally, but the loads being controlled wouldn't light up. Check the wiring again carefully before closing up your installation.

The markings R and O refer to the French identification of the relay contacts translating to *Rest*

Component List

Resistors (SMD 1206, 5%)
R1,R2 = 47Ω 0.25W
R3,R9,R11,R12,R29,R30 = 470kΩ
R4,R19,R24 = 120kΩ
R5 = 330kΩ
R6,R7 = 2.2MΩ
R10,R13,R27,R28 = 10kΩ
R20,R22,R23,R25,R26,R31,R32,R33 = 1kΩ

Capacitors (ceramic, SMD1206, 20%)
C2,C3 = 4.7µF 16V
C4 = 22pF 50V
C7,C8,C10,C12,C16,C17,C18 = 100nF 50V
C9,C13 = 4.7nF 50V X7R
C11,C15 = 1nF 50V

Capacitors (miscellaneous)
C1 = 470µF 25V, Panasonic EEEFK1E471AP, (1244419)
C5 = 100nF 305V, X2 Class, 15mm pitch, Epcos B32922C3104M (1112840)
C6,C14 = 100µF 25V, Panasonic EEEFK1E101AP (1244416)

Inductors
L1 = 22µH 0.11A, Multicomp MCFT000190 (1711917)

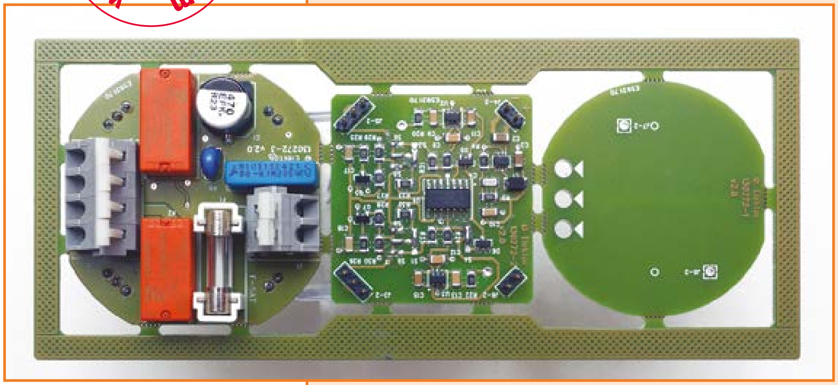
Diodes
D1,D5,D6 = BAT54 (9526480)
D2 = BZX84C12 (1902445)
D7,D8,D9 = LED, yellow, Kingbright KPT-3216SYCK (2099249)

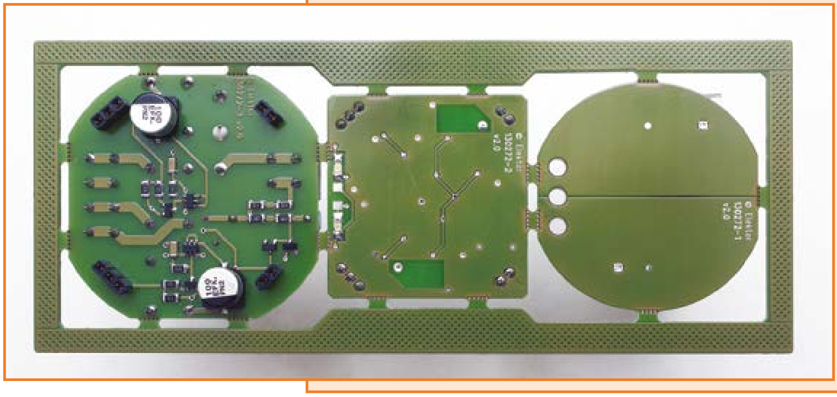
Semiconductors
Q1,Q2,Q5,Q7 = 2N7002ET1G (2317616)
U1 = TPS62120DCNT (1864820)
U2,U3 = AT42QT1010-TSHR (1841593)
U4 = SN74HC74D (9591680)
U5,U6 = ZXGD3005E6TA (1904033)

Miscellaneous
F1-1 = fuse holder, Littelfuse 64900001039 (1271673)
F1-2 = fuse, 5A slow, 5x20mm, Schurter 0034.3124 (1360818)
J1 = 2-way PCB spring terminal block, 5.0mm pitch, Wurth 691414720002 (1841365)
J2 = 4-way PCB spring terminal block, 5.0mm pitch, Wurth 691414720004 (1841367)
J3-1,J4-1,J5-1,J6-1 = 10-pin pinheader, low profile, 0.1" pitch (1668506)
J3-2,J4-2,J5-2,J6-2 = 10-way receptacle, low profile, 0.1" pitch (1668102)
K1,K2 = relay, bistable, 12V, TE PE014F12 (9913459)
R8 = varistor, 300V, Epcos B72205S0271K101 (1004358)
GL1,GL2,GL3 = LED light pipe, Bivar PLP2-375, (2293497)
PCBs 130272-1, 130272-2, 130272-3 (elektorPCBservice)

(numbers in round brackets are Farnell/Newark order codes)

www.elektorpcbservice.com





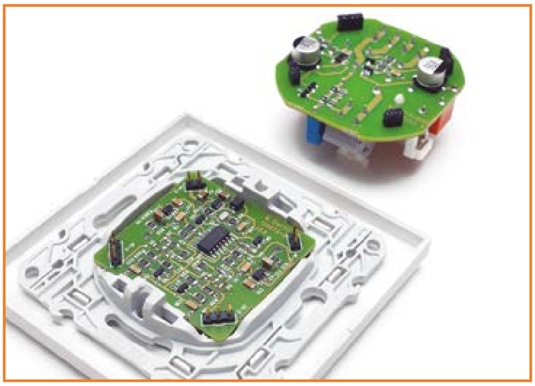


Figure 5. Assembling the “small signals” circuit.

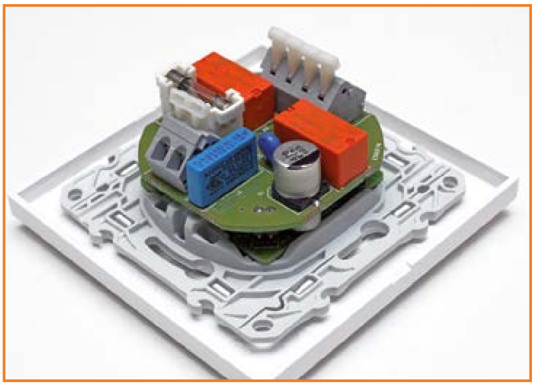


Figure 6. Fitting the “power” section.

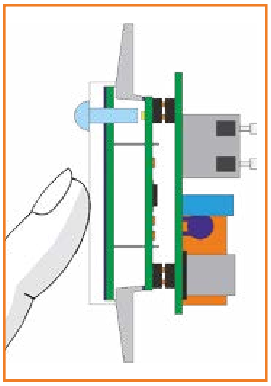


Figure 7. Cross-sectional view of the assembly.

and *Operate.* If the state of the LED indicator is reversed with respect to the load connected, all you have to do is swap the connection over between these R and O terminals. **Figure 8b** shows how to wire it up as a 2-way switch with other mechanical switches or IMPACT switches. As the configuration of each of the two channels is independent of the other, you can even mix the two types of wiring on the same switch. Lastly, in the case of a configuration as a single channel, the connection will be made only to the terminals O1 and R2. If you’re feeling adventurous, don’t hesitate to send me photos of your own projects [2]!

(130272)

Web Links

[1] Atmel - QTAN0079 “Sensor design guide”: www.atmel.com/Images/doc10752.pdf

[2] ardouin.david.projects@gmail.com

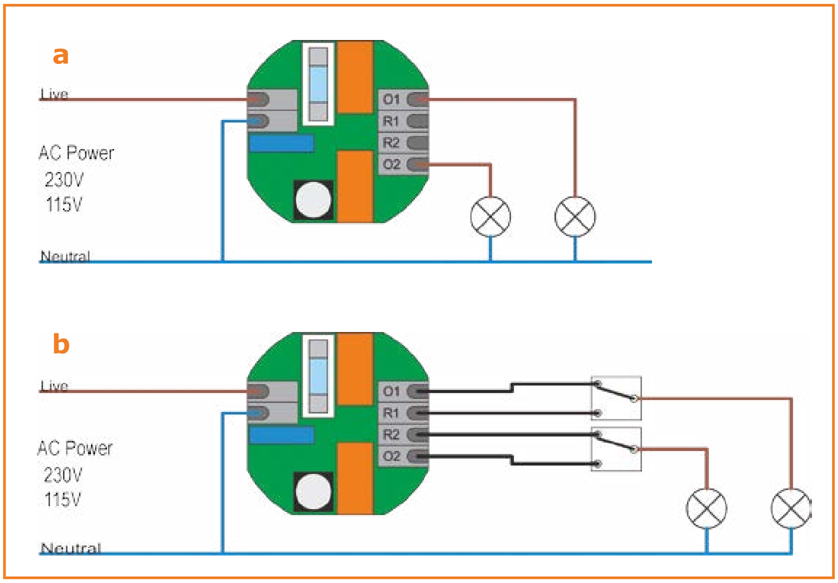
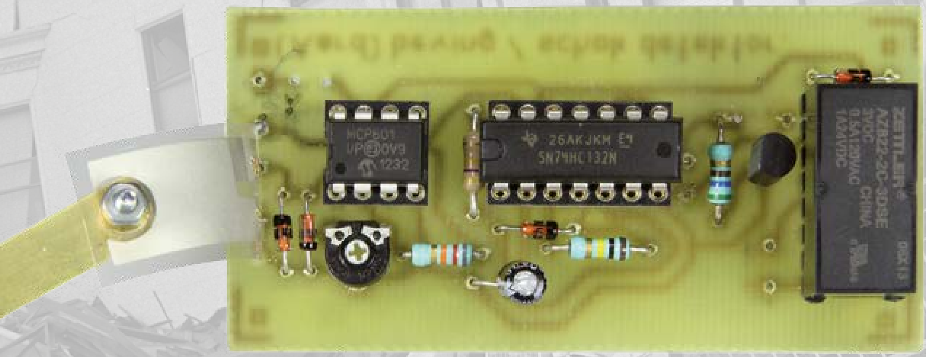


Figure 8. Wiring as switch or momentary button (a) or as a 2-way switch (b).

Seismic Detector

Using a piezoelectric sensor



This simple circuit generates acoustic and visual alarms when it detects a shock, vibration or earthquake. It also has a relay that can be used to energize other devices or external indicators.

By **Wouter Eisema**
(Netherlands)

The author developed this circuit in response to the many earthquakes that have occurred in the Groningen area in the Netherlands in recent years as a result of 50 years of gas extraction in this province. It can also be used to detect passing trucks or other sources of vibration. The sensitivity is adjustable to allow the detector to be used under various conditions.

Along with an LED and a buzzer for the visible and audible indications, there is a relay that can be used to energize other circuits or devices. A small 433-MHz (or 868-MHz) LPR (transmitter) could also be connected to the relay output for wireless transmission of the detector signal to a remote location. A simple transmitter/receiver combination suitable for this purpose is also described in the article 'Wireless Signaling' in this edition of Elektor. Among other things, this arrangement allows the detector and transmitter to be mounted in a location that is not easily accessible.

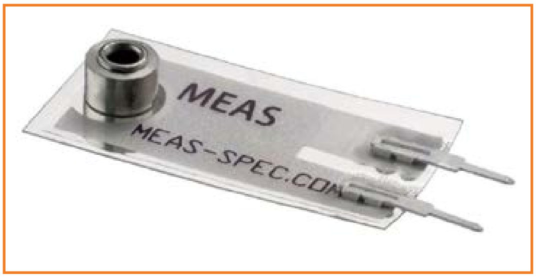


Figure 1.
This piezoelectric sensor from Measurement Specialties generates a voltage when it is moved back and forth.

Operation

The key component of this compact circuit is the vibration sensor (**Figure 1**). The LDTM-028K sensor from Measurement Specialties used here consists of a thin piezoelectric plastic film sealed in plastic, which has two solder pins at one end for fitting to a PCB and a threaded bush at the other end for attaching a pendulum or a weight. When the sensor is moved back and forth, for example by vibrations, the piezoelectric film generates a voltage that depends on the degree of bending and can be as high as 70 V or so.

With very small motions (e.g. light vibrations) the signal level from the sensor is only a few millivolts, so a lot of amplification is necessary if you want to use it to switch something. For this purpose, the sensor is connected to the input of IC1, a type MCP601 opamp from Microchip (see the schematic diagram in **Figure 2**). This single-supply opamp with rail-to-rail output can operate with a supply voltage as low as 2.7 V. The gain of this opamp stage can be adjusted over a

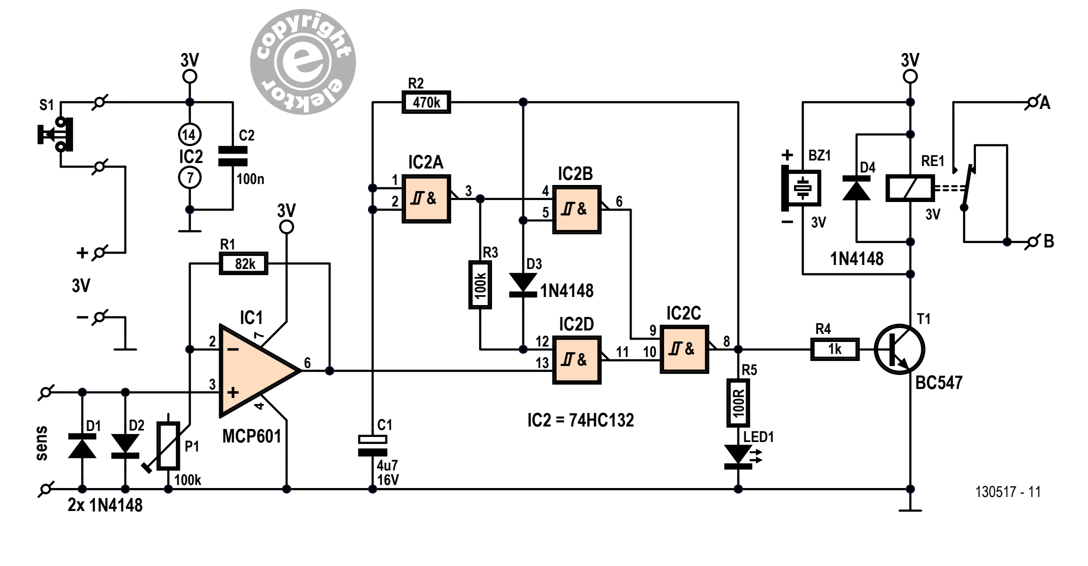


Figure 2.
The circuit design is very simple, consisting of an amplifier stage (IC1), a pulse stretcher (IC2) and an indicator stage with a relay.

wide range with trimpot P1. Diodes D1 and D2 on the non-inverting input of IC1 protect it against excessive voltage from the sensor.

The opamp output is low under quiescent conditions. The output is connected to a pulse stretcher built around IC2a–IC2d. The output of the pulse stretcher is low when the opamp output is low; C1 is discharged and the outputs of IC2a, IC2b and IC2d are high. When the vibration sensor generates a pulse, the output of IC2c goes high, and it is kept high by IC2b until C1 has charged enough to cause the output of IC2a to go low. When the voltage on C1 reaches the necessary level, pin 12 of IC2d is pulled low by R3 and the output of IC2d goes high. The output of IC2b also goes high, and the pulse stretcher returns to its initial state. The next pulse from the vibration sensor can be processed after C1 has discharged again.

Diode D3 and resistor R3 ensure that on pin 12 of IC2d, a high level at the output of IC2a overrides the signal level at the output of the pulse stretcher (pin 8 of IC2c). The pulse length of the pulse stretcher is approximately 20 seconds

Component List

Resistors

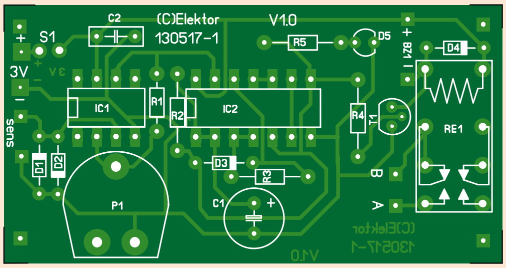
R1 = 82kΩ
R2 = 470kΩ
R3 = 100kΩ
R4 = 1kΩ
R5 = 100Ω
P1 = 100kΩ trimpot

Capacitors

C1 = 4.7µF 16V
C2 = 100nF

Semiconductors

D1,D2,D3,D4 = 1N4148
LED1 = LED, low-current, red, 3mm
T1 = BC547
IC1 = MCP601 (Microchip)
IC2 = 74HC132



Miscellaneous

BZ1 = active piezo buzzer, e.g. Multicomp MCKPT-G1210-3916
S1 = pushbutton with break contact
RE1 = PCB relay, 3V (e.g. Omron G5V2H13DC)
Sensor = LDTM-028K (Measurement Specialties)
PCB # 130517-1 [1]

Figure 3.
All of the components (including the sensor) can be mounted on this small PCB. Depending on the actual application, the sensor can also be mounted on the underside of the board.

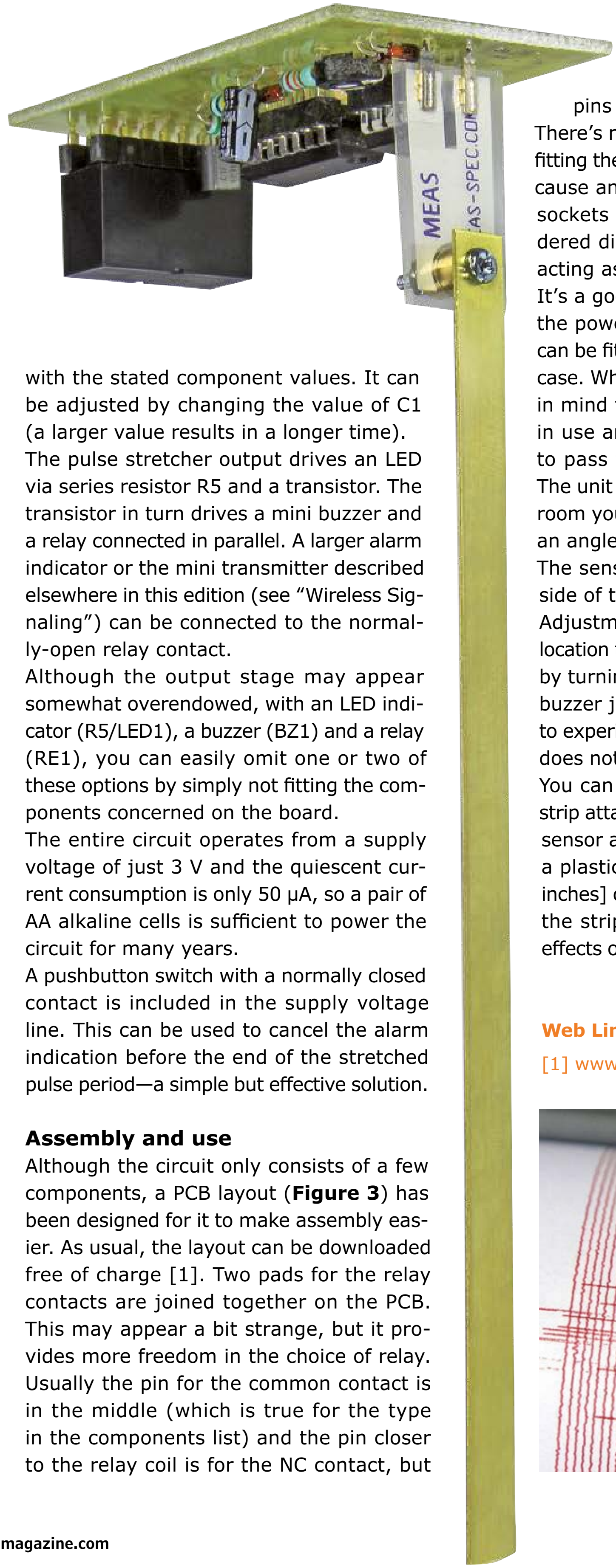


Figure 4.
The sensitivity can be increased by attaching a metal strip to the sensor to act as a pendulum. The length and weight of the metal strip can be varied as desired.

with the stated component values. It can be adjusted by changing the value of C1 (a larger value results in a longer time).

The pulse stretcher output drives an LED via series resistor R5 and a transistor. The transistor in turn drives a mini buzzer and a relay connected in parallel. A larger alarm indicator or the mini transmitter described elsewhere in this edition (see “Wireless Signaling”) can be connected to the normally-open relay contact.

Although the output stage may appear somewhat overendowed, with an LED indicator (R5/LED1), a buzzer (BZ1) and a relay (RE1), you can easily omit one or two of these options by simply not fitting the components concerned on the board.

The entire circuit operates from a supply voltage of just 3 V and the quiescent current consumption is only 50 µA, so a pair of AA alkaline cells is sufficient to power the circuit for many years.

A pushbutton switch with a normally closed contact is included in the supply voltage line. This can be used to cancel the alarm indication before the end of the stretched pulse period—a simple but effective solution.

Assembly and use

Although the circuit only consists of a few components, a PCB layout (**Figure 3**) has been designed for it to make assembly easier. As usual, the layout can be downloaded free of charge [1]. Two pads for the relay contacts are joined together on the PCB. This may appear a bit strange, but it provides more freedom in the choice of relay. Usually the pin for the common contact is in the middle (which is true for the type in the components list) and the pin closer to the relay coil is for the NC contact, but some relays (such as the AZ822 from American Zettler) have these pins reversed.

There’s not much that needs to be said about fitting the leaded components, which shouldn’t cause any problems. If desired, you can use sockets for IC1 and IC2. The sensor is soldered directly to the PCB, and a metal strip acting as a pendulum can be attached later. It’s a good idea to place the two AA cells for the power source in a battery holder, which can be fitted together with the PCB in a plastic case. When fitting the board in the case, bear in mind that it will be mounted upside down in use and the metal strip needs to be able to pass through the case and move freely. The unit can be mounted on the ceiling of the room you want to monitor, or on a wall using an angle bracket.

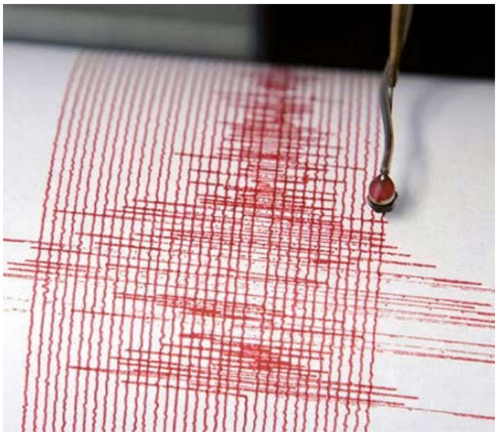
The sensor can also be fitted on the underside of the board if this is more convenient.

Adjustment: After mounting the unit at the location to be monitored, adjust the sensitivity by turning trimpot P1 to the point where the buzzer just stops sounding. It’s a good idea to experiment with this a bit so that the alarm does not go off every time a truck drives by. You can also adjust the length of the metal strip attached to the sensor as necessary. The sensor and metal strip can also be housed in a plastic pipe (with a diameter of 10 cm [4 inches] or so) for protection, mounted so that the strip is free to move. This reduces the effects of wind and air currents on the sensor.

(130517-I)

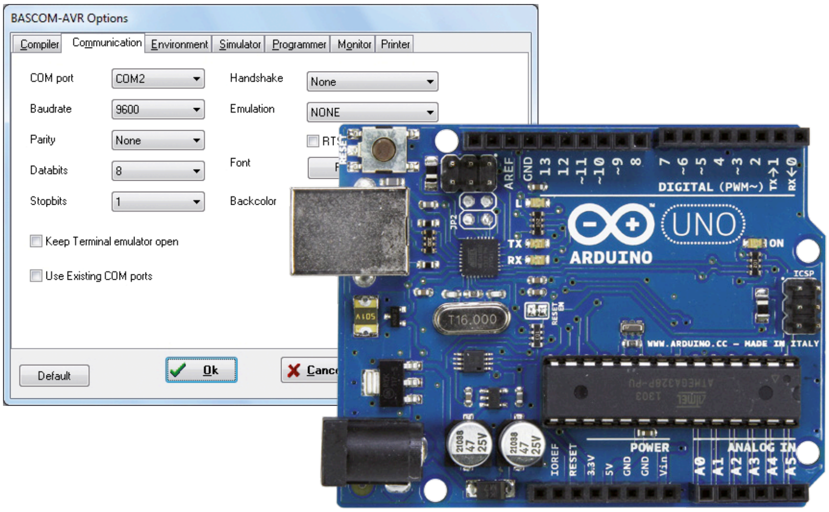
Web Link

[1] www.elektor-magazine.com/130517



Microcontroller BootCamp (3)

Serial interface and A/D converter



BASCOM-AVR Options

Compiler | Communication | Environment | Simulator | Programmer | Monitor | Printer

COM port: COM2
Baudrate: 9600
Parity: None
Databits: 8
Stopbits: 1
Handshake: None
Emulation: NONE
Font
Backcolor
□ RTS
□ Keep Terminal emulator open
□ Use Existing COM ports

This instalment focuses on the analog to digital converter, which is effectively a voltmeter built into the microcontroller. However, it does not have a pointer or a display, so you have to do a bit of work to be able to read the measurements. The A/D converter simply supplies data. In order to be displayed somewhere, this data has to be transmitted. That's where the serial interface comes into play.

By **Burkhard Kainka** (Germany)

Although most PCs nowadays have dispensed with the traditional serial interface, it is still widely used in the microcontroller world. This interface was originally developed to transfer serial data over a conductor. The individual bits obediently travel down the wire one after the other. The bit timing is precisely defined so that the receiver can make sense of the serial bit stream. A commonly used data rate is 9600 bits per second, which is also called 9600 baud. In addition to the eight data bits of each byte, there is a start bit and one or two stop bits. Each data bit is present on the wire for an interval of approximately 100 µs (at 9600 baud).

Print output

Every ATmega microcontroller has a serial interface (UART) with RXD (PD0) and TXD (PD1) lines. These signals are TTL compatible, which means that the signal level is 5 V in the quiescent state and 0 V in the active state. By contrast, a COM port on a PC operates with RS232 signal levels. They are -12 V in the quiescent state and +12 V in the active state. For this reason, a peripheral interface IC such as the MAX232 is often necessary to invert and adapt the signal levels. Instead of this, the Arduino board has a serial to USB converter that sends the data over USB. This means that you need a driver for a virtual serial port (such as COM2) on the PC. For programs running on the PC, that makes the data transported over USB look like it entered the PC through a conventional serial port. This data can therefore be displayed using a standard terminal emulator program.

We recommend that you use the terminal emulator program integrated into Bascom. You can open it under Tools > Terminal Emulator or with the key combination Ctrl-T, but you have to configure the right settings to make it work properly. In particular this means selecting the right COM port (the same one you configured for the boot loader) and setting the right baud rate (in this case 9600). For the rest you can use the default settings: 8 data bits, 1 stop bit and no parity (**Figure 1**).

Now you have to persuade the Arduino Uno to transmit something. That's easy in Bascom, thanks to the Print command. See **Listing 1** for an example of how to use the Print command (note that all code files can be downloaded at [1]). This command can be used to send output to a printer, which explains its name. However, to avoid wasting paper it's better to send text and data to the monitor. The result is shown in **Figure 2**.

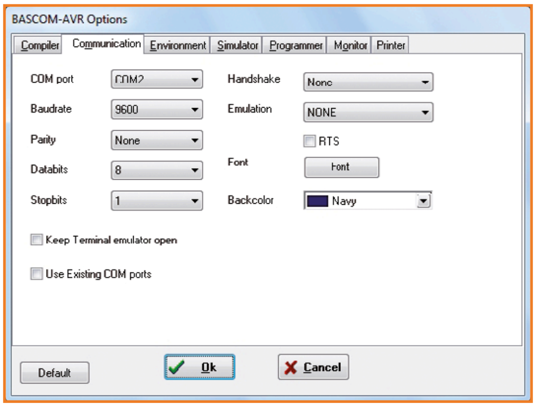
There are two Print commands in the program. The second one sends a message in quotation marks: "Uno". But first a number is sent – more particularly, the number N. If it's been a while since you had anything to do with math, you may still have a vague memory that unknown quantities in algebra are often designated as x. You could do the same in Bascom, but in situations where numbers are simply incremented (1, 2, 3 and so on), the symbols N, M, I and J are commonly used in source code. However, you are free to choose your own symbols for variables of this sort. The only thing that really matters is that you first tell Bascom what type of number each variable represents. This is because Bascom has to know how many bytes of memory the number needs and how computations should be performed with the number in the code. For this reason, the variables must be declared (dimensioned) before they are used. That's the purpose of the following instruction: Dim N as Byte. This means that N is a number of type Byte, which clearly indicates that this number consists of eight bits (recall the previous instalment) and has a number range from 0 to 255.

Assignments

Now you can perform calculations with the number variable N. The variable is assigned the value 0 at the start of program execution. Although you might think this is only logical, it is actually a particular feature of Basic. In other languages you have to write 'N = 0', but in Bascom this is done automatically. The value of N is subsequently incremented by 1 each time the loop is executed. My old math teacher would have boxed my ears if I wrote 'N = N + 1', because it is not valid mathematical equation. However, in many programming languages the equal sign is used as an assignment operator. The intention here is that the variable N is assigned a new value by adding 1 to the existing value.

You can see the results of this ongoing incrementing in the terminal window: the value of N increases by 1 after each output. You can also see something else: the value stops rising after it reaches 255, since we defined N as a single-byte number. This means that 255 + 1 is not 256, but instead 0. This is called number overflow. Here this is not a problem, but in other places it can be a problem – namely when you have inadvertently chosen a number type that is too small and the overflow is not detected.

There's another detail that should be noted here: why does the display always go to a new line after "Uno", but not after the number? The answer is

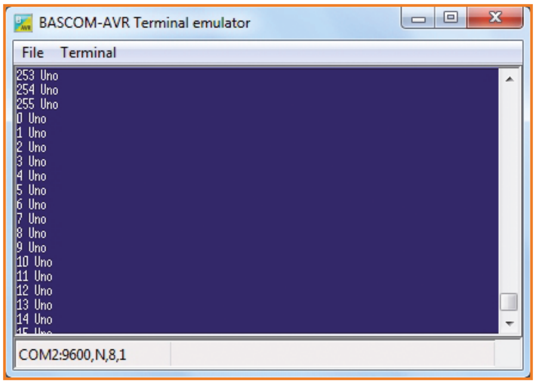

BASCOM-AVR Options

COM port: COM2
Baudrate: 9600
Parity: None
Databits: 8
Stopbits: 1
Handshake: None
Emulation: NONE
□ RTS
Font: Font
Backcolor: Navy
□ Keep Terminal emulator open
□ Use Existing COM ports

Figure 1.
Terminal emulator settings.

Listing 1. Print output

```
‘------------------------------------
‘UNO_Print.BAS
‘------------------------------------
$regfile = “m328pdef.dat”
$crystal =
$baud = 9600

Dim N As Byte

Do
  Print N;
  Print “ Uno”
  Waitms 200
  N = N + 1
Loop
```


BASCOM-AVR Terminal emulator

```
253 Uno
254 Uno
255 Uno
0 Uno
1 Uno
2 Uno
3 Uno
4 Uno
5 Uno
6 Uno
7 Uno
8 Uno
9 Uno
10 Uno
11 Uno
12 Uno
13 Uno
14 Uno
15 Uno
```

COM2:9600,N,8,1

Figure 2.
Print output transmitted over a serial line.

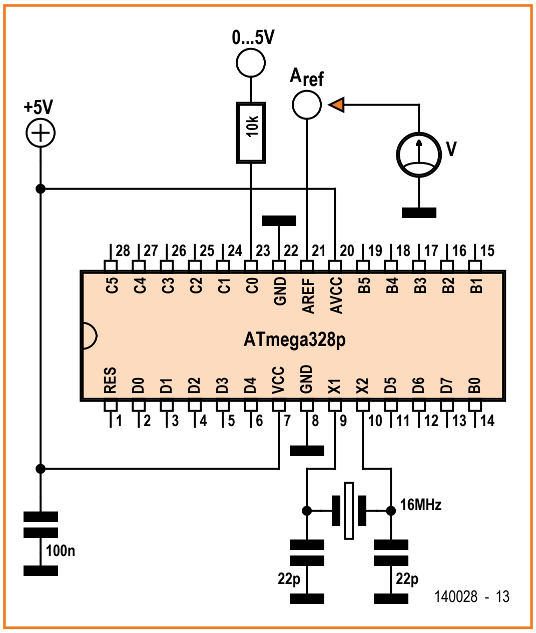


Figure 3.
Using the A/D converter.

simple: by default, Bascom sends the control character CR (which stands for 'carriage return', like an old-fashioned typewriter) and LF (line feed) at the end of each Print command. If this is not what you want, you have to put a semicolon at the end of the instruction (Print N;). That's why the text is on the same line as the number. A space is also inserted to separate the number from the text. As you can see, it's all very simple and straightforward; you could use the same approach to display '200 mV' on the monitor. After all, our original intention here was to display measurements from the A/D converter, and now we're ready to do so.

The serial bits output by the Atmega328, which are sent to the serial to USB converter on the Uno board, can easily be seen with an oscilloscope. Simply touch the scope probe to the TX pin of the microcontroller, which is routed to the socket header at the top right on the Arduino board. Then you can see the data stream. The RX pin is next to the TX pin, and if you type some characters on the terminal you can see them on the RX line. This shows that the PC can also send data to the microcontroller. At this point the received data does not do anything because the program ignores it.

Listing 2. Using the A/D converter

```
'----------------------------------------
'UNO_AD1.BAS  ADC
'----------------------------------------
$regfile = "m328pdef.dat"
$crystal = 16000000
$baud = 9600

Dim D As Word

Config Adc = Single , Prescaler = 64 , Reference = Avcc  '5 V

Do
  D = Getadc(0)
  Print D
  Waitms 200
Loop
```

The A/D converter

The analog to digital converter (ADC) in the microcontroller is a sort of measuring device. As we all know, measuring involves comparing. First you need some sort of unit to serve as a reference quantity. Before you can measure a distance in meters, you have to know how long a meter is. Likewise, you have to know how big a volt is before you can say how many volts are lurking in your wall outlet. The situation here is similar. The microcontroller needs a reference voltage so that it can compare the voltage on a selected analog input (A0 to A5 on the Uno board) to the reference voltage. The reference voltage is connected to the AREF pin. However, you can also use a register to select the reference voltage. For example, you could apply an external reference voltage of 1 V or connect a 5 V reference voltage from inside the microcontroller, but of course you shouldn't do both at the same time. Now try measuring the voltage between AREF and GND (see **Figure 3**). Since the A/D converter hasn't been configured yet, the voltage is zero. If you load the program in **Listing 2** into the microcontroller and make this measurement again, you will see a voltage of 5 V. This is due to the following configuration statement:

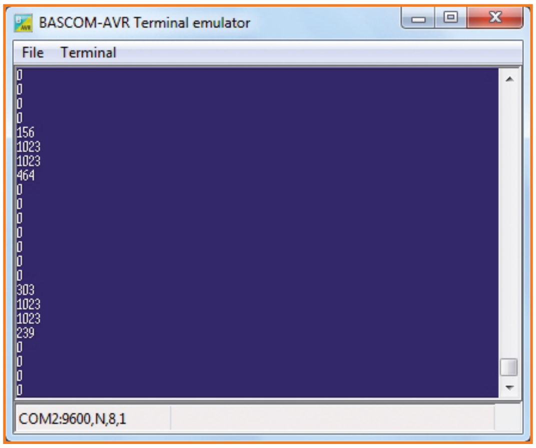
```
Config Adc = Single , Prescaler = 64 ,
Reference = Avcc
```

This initializes the ADC, which means it enables the ADC with specific attributes. Here Single mode means that only one measurement is made for each request. The other option is Free (short for free-running mode), in which measurements are made repeatedly without interruption. The prescaler generates a clock signal for the A/D converter by dividing the processor clock signal, which is 16 MHz on the Uno board. In this case the A/D converter runs at 250 kHz (16 MHz divided by 64). It can also run faster, but then it is not quite as accurate. The setting 'Reference = Avcc' connects the Aref pin to Avcc, which the supply voltage of approximately 5 V. Incidentally, it's worthwhile taking a look at the data sheet for the microcontroller – the section on the A/D converter is practically a data sheet in its own right. If after that you still don't have any idea of what settings you can or should use, the Bascom Help is a good source of information. Simply point the mouse to 'Config' and press the F1 key, and you will be rewarded with all sorts of useful information and a bit of sample source code.

The 'instruction D = Getadc(0)' initiates a measurement of the voltage on A0 and copies the result to the variable D. The A/D converter provides readings with a resolution of 10 bits, which corresponds to a number range of 0 to 1023. The variable D must therefore never be dimensioned as a byte variable. You should use either the type Word (range 0 to 65535) or the type Integer (range -32768 to +32767) to ensure that the readings will fit.

The measurements are made using a successive approximation algorithm with ten steps. First the converter compares the input voltage to half the reference voltage. If it is higher than the reference voltage, the next comparison is to three-quarters of the reference voltage. If it is still higher, the next comparison is seven-eighths, and so on. The resolution doubles with each step. At the end you have number that indicates which step on a ladder with 1024 steps between zero and the reference voltage corresponds to the measured voltage. Each step is approximately 5 mV (5 V divided by 1023) if you use a reference voltage of 5 V. For comparison, the resolution of a digital voltmeter with a 3-½ digit display is roughly twice as good (2000 steps). This makes the microcontroller a fairly good measuring device, although you shouldn't confuse resolution with accuracy – the accuracy can be seriously compromised by an inaccurate reference voltage.

The analog inputs are subject to the same considerations as the digital inputs: an input voltage well below zero or well above the supply voltage can lead to undesirable side effects, extending as far as latchup (as described in the previous part of this series). However, here again a 10-kΩ resistor in series with the analog input can prevent serious problems. With that precaution in place, it's even okay to touch the input with your finger. If you do so, you will see varying readings in the terminal window (**Figure 4**), including many limit values (0 and 1023) because the hum voltage exceeds the measuring range. The overall effect is similar to the waveform from a half-wave rectifier as seen on a oscilloscope. If you compare the measurement cycle time, consisting of the programmed wait interval of 200 ms plus the actual measurement time, with the AC line voltage period of 20 ms (at 50 Hz), you can see that here again there is a stroboscope effect. This is called undersampling, and it produces a low-frequency alias signal because the measurement samples do not all lie within the same period of the measured signal. In fact, there are several periods of the input signal between each pair of samples.



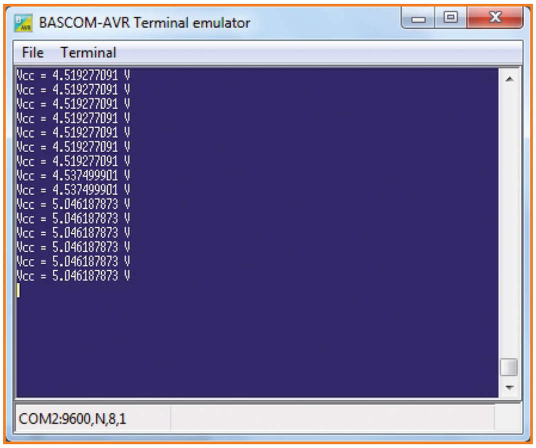
```
0
0
0
0
156
1023
1023
464
0
0
0
0
0
0
0
303
1023
1023
239
0
0
0
0
```

COM2:9600,N,8,1

Figure 4.
Measurement data from a 50 Hz signal.

A bit of math

Our first simple measurement program only generates raw data, so you have to calculate the signal voltage yourself. Consider the following example: You connect analog input A0 to the 3.3 V output of the Arduino board. Now you see a reading of 676, or something close to that. You grab your pocket calculator and calculate: 676 ÷ 1023 × 5 V = 3.305 V (okay). Another option is to modify the program and have the microcontroller do the math (**Listing 3**). For this you need a variable that can hold more than just integer values. You can use a variable U of type Single (which means a single-precision floating point / real number variable), which is fully suf-



```
Vcc = 4.519277091 V
Vcc = 4.519277091 V
Vcc = 4.519277091 V
Vcc = 4.519277091 V
Vcc = 4.519277091 V
Vcc = 4.519277091 V
Vcc = 4.519277091 V
Vcc = 4.537499901 V
Vcc = 4.537499901 V
Vcc = 5.046187873 V
Vcc = 5.046187873 V
Vcc = 5.046187873 V
Vcc = 5.046187873 V
Vcc = 5.046187873 V
Vcc = 5.046187873 V
```

COM2:9600,N,8,1

Figure 5.
Measuring the microcontroller's own supply voltage.

ficient. Now you can convert the raw data in two steps. You can only perform one calculation in each instruction (that's a Bascom rule). The long chained equations you see in C or Pascal are not possible here.

```
U = D * 5.0
U = U / 1023
```

Now you can see the result in the terminal window. Of course, you should treat the large number of decimal places with caution, since they give a false impression of the actual resolution. Later we will show you how to properly round off readings of this sort, but for the time being it's nothing to worry about.

Listing 3. Conversion to volts

```
'-----------------------------------------
'UNO_AD2.BAS    0...5 V
'-----------------------------------------
$regfile = "m328pdef.dat"
$crystal = 16000000
$baud = 9600

Dim D As Word
Dim U As Single

Config Adc = Single , Prescaler = 64 , Reference = Avcc  '5 V

Do
  D = Getadc(0)
  U = D * 5.0
  U = U / 1023
  Print U ; " V"
  Waitms 200
Loop
```

At this point you can see that it makes a difference whether you power the Uno board over USB or from an external power supply. The supply voltage on the USB port can easily differ from 5 V by 10% or more (see **Figure 5**), and the accuracy of the measurement results will vary accordingly. By contrast, the 5 V regulator on the Uno board has a relatively narrow tolerance, typically around 1%. Try both options for yourself. Also measure the actual voltage on the 3.3 V terminal and the voltage on the AREF pin in each case. Armed with that information, you can significantly improve the accuracy. Suppose you measure a reference voltage of 5.03 V with an external power supply (using a high-precision DVM). Enter this value in the program in place of the nominal value of 5.0 V, and your readings will be nearly spot on.

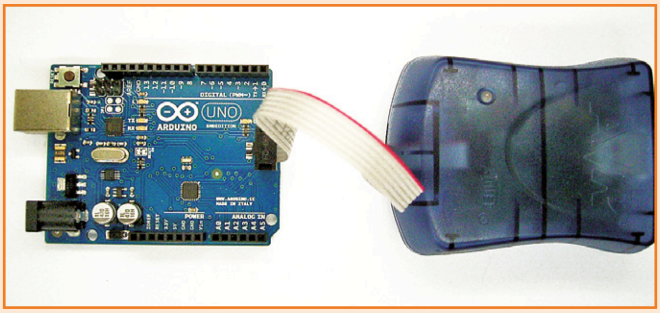
You should also try other reference settings. If you configure 'Reference = Aref', at first you do not have any reference voltage at all. You have to provide your own reference voltage, with a free choice anywhere in the range of 0 to 5 V. For example, you can connect the Aref pin to the 3.3 V terminal of the Uno board. In this case the measuring range extends to 3.3 V. Another option is 'Reference = Internal'. In that case the A/D converter uses an internal 1.1 V reference voltage, and you can measure this voltage on the Aref pin. The data sheet very modestly states a tolerance of approximately 10%, which means 1.0 V to 1.2 V. In our case we measured 1.08 V, which is only 2% away from the nominal value. However, you should measure the actual value yourself. There are two things worth noting about this relatively low reference voltage. The first is that the accuracy is independent of the supply voltage; and the other is that it gives you a relatively high resolution of approximately 1 mV.

Measuring the microcontroller's own supply voltage

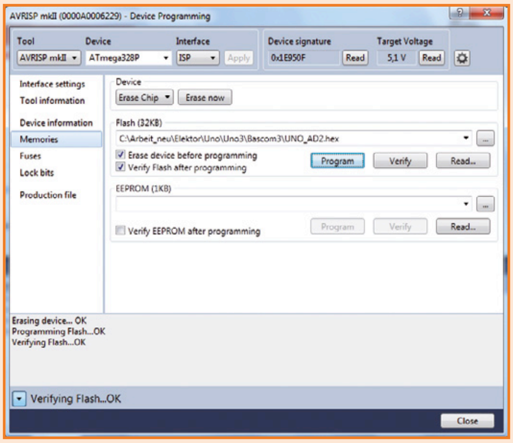
You might wonder whether the microcontroller can measure its own supply voltage At first the answer appears to be no, since you would need a sufficiently large reference voltage that is independent of the supply voltage. However, it turns out that this is indeed possible because the data sheet reveals several interesting details about the A/D converter. The input multiplexer (an analog switch similar to the well-known 4051) has

External programmer

When you want to use a microcontroller, you usually need some sort of programming device. This is not necessary with the Arduino because it has a built-in boot loader, as described in the first part of this series. However, you do not have a boot loader when you buy a new AVR microcontroller and fit it on your own PCB, so you have to use a programmer. One low-cost option is the Atmel ISP mkII. It can be used with the free AVR Studio 6 development environment. However, there are lots of other programmers that can do the same job.



A six-pin ISP connector is normally used for in-system programming (ISP) of AVR microcontrollers. Many microcontroller boards, including the Arduino, have a suitable 6-pin header for this. The SPI interface, which consists of serial data streams (MOSI to the microcontroller and MISO back to the programmer) and a clock signal (SCK), is often used to transmit the programming data. This interface will be described in more detail in a later instalment. The pinout of the ATmega328 is:



AVRISP mkII (0000A0006229) - Device Programming

Tool: AVRISP mkII | Device: ATmega328P | Interface: ISP | Device signature: 0x1E950F | Target Voltage: 5,1 V

Device: Erase Chip

Flash (32KB): C:\Arbeit_neu\Elektor\Uno\Uno3\Bascom3\UNO_AD2.hex

☑ Erase device before programming
☑ Verify Flash after programming

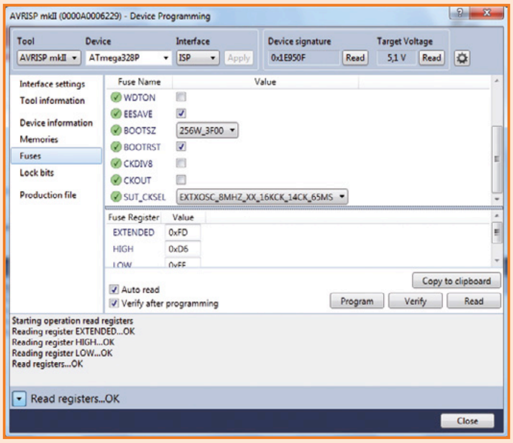
EEPROM (1KB)

☐ Verify EEPROM after programming

```
Erasing device... OK
Programming Flash...OK
Verifying Flash...OK
```

Verifying Flash...OK

1	MISO, PB4
2	Vcc
3	SCK, PB5
4	MOSI, PB3
5	Reset
6	GND



AVRISP mkII (0000A0006229) - Device Programming

Tool: AVRISP mkII | Device: ATmega328P | Interface: ISP | Device signature: 0x1E950F | Target Voltage: 5,1 V

Fuse Name	Value
WDTON	☐
EESAVE	☑
BOOTSZ	256W_3F00
BOOTRST	☑
CKDIV8	☐
CKOUT	☐
SUT_CKSEL	EXTXOSC_8MHZ_XX_16KCK_14CK_65MS

Fuse Register	Value
EXTENDED	0xFD
HIGH	0xD6
LOW	0xFF

☑ Auto read
☑ Verify after programming

```
Starting operation read registers
Reading register EXTENDED...OK
Reading register HIGH...OK
Reading register LOW...OK
Read registers...OK
```

Read registers...OK

The Arduino Uno board has two ISP ports for external programmers. The one close to the USB connector is best ignored, since it is used to program the USB to serial converter described in the body of this article. The ISP port for the ATmega328 is located at the edge of the board. It's nice to know that it's possible to connect an external programmer, because it means you can always restore everything to the original state if you do something really wrong, such as accidentally deleting the boot loader.

You can also use the programmer to read out the content of the flash memory, for example in order to make a backup copy (including the boot loader) that you can use to restore the Arduino if necessary. A backup copy (UnoBoot.hex) [1] is also available in the Elektor archive in case you need it.

In order to load your own program into the microcontroller, you first have to load the hex file. In this case you must tick the option 'Erase chip before programming' to ensure that the boot loader is deleted. This means you have to decide whether or not you want to use the boot loader. You can also opt to use another boot loader, such as the MCS boot loader. We'll describe how that works in one of the upcoming instalments.

You can also view the microcontroller fuse settings with Bascom or in Atmel Studio 6. By the way, the term 'fuse' comes from the early days of microcontroller technology when there was program memory in which links were literally burnt through to program the memory once and for all. The modern fuses in ATmega microcontrollers are actually flash memory cells that must be configured to define specific basic settings. Among other things, they allow you to switch back and forth between the internal clock and an external clock source. The screenshot shows the factory default fuse settings of the Arduino Uno board. You can see that the boot loader is enabled (BOOTRST) and how much memory is reserved for it.

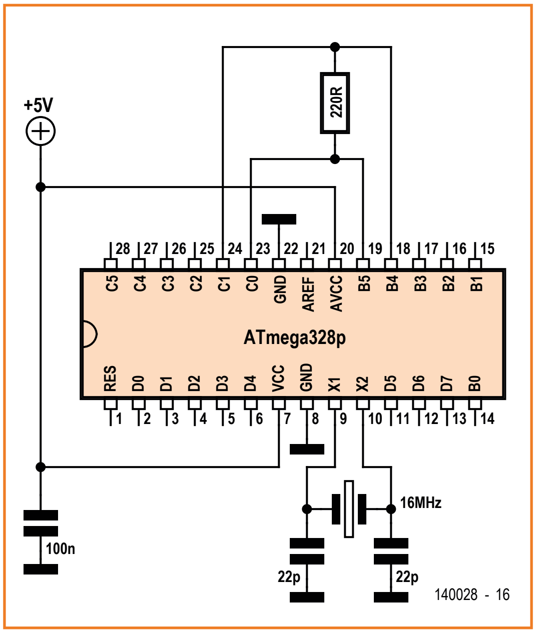


Figure 6.
Temperature measurement under load.

a total of eight channels, of which six are connected to pins A0 to A5. The other two are only fed out in the SMD version of the ATmega328. However, there are also several ‘hidden’ internal channels, and one of these (channel 14) allows the microcontroller to measure its internal 1.1 V reference voltage. The trick here is to use the imprecise supply voltage as the reference voltage and measure the precise internal reference voltage. In this case the program must calculate in the opposite direction to determine the actual supply voltage (see **Listing 4**). The first measurement (Figure 5) shows the supply voltage with USB power, which in this case is about 4.5 V. Then an external power supply is connected while the program is running, so the supply voltage is provided by the distinctly more precise 5 V voltage regulator. The corresponding measurement is accordingly close to 5.0 V.

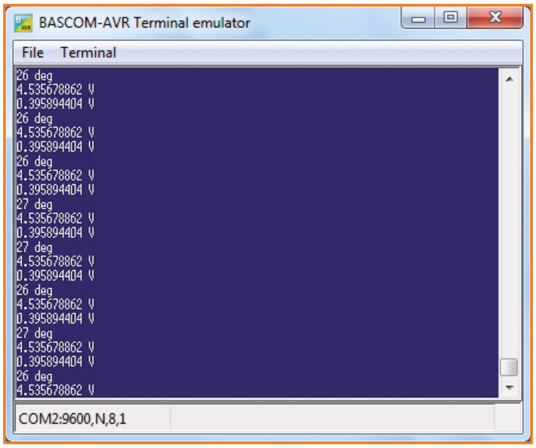
Listing 4. Measuring V_{CC}.

```
‘----------------------------------------
‘UNO_AD3.BAS  Vcc / 1.1 V
‘----------------------------------------
$regfile = “m328pdef.dat”
$crystal = 16000000
$baud = 9600

Dim D As Word
Dim U As Single

Config Adc = Single , Prescaler = 64 , Reference = Avcc

Do
  D = Getadc(14)                    ‘Ref 1.1 V
  U = 1023 / D
  U = U * 1.1
  Print “Vcc = “;
  Print U ; “ V”
  Waitms 1000
Loop
```

Measuring the temperature

In addition to measuring its own supply voltage, the ATmega328 can measure its own temperature thanks to an internal temperature sensor connected to channel 8 of the A/D converter. The output voltage of this sensor is proportional to the temperature, with a factor of approximately 1 mV per degree. The accuracy is not especially high – the specified tolerance is ten degrees. However, you can always calibrate it yourself. According to the data sheet, the sensor output is 242 mV at –45 °C, 314 mV at 25 °C and 380 mV at 85 °C. To obtain meaningful readings with voltages in this range, you have to use the relatively low internal reference voltage (1.1 V). However, the same program is supposed to measure higher voltages as well, so it automatically switches to the higher reference voltage (Avcc) as necessary. For internal temperature measurement the A/D converter operates with the internal 1.1 V reference voltage and a resolution of about 1 mV, which roughly corresponds to 1 degree at the temperature sensor output. At 25 degrees C the sensor output is approximately 314 mV. We decided to take a quick-and-dirty empirical approach, and we determined that the temperature in degrees C could be found by subtracting 338 from the measured value (see **Listing 5**). However, even better results could be obtained with a bit more computation effort. In any case, you should adjust the results according to your actual situation to obtain the best possible match with the temperature shown by an ordinary thermometer. Next we held a finger on the microcontroller to see whether the temperature rose. Then we wanted to see whether the temperature of the microcontroller increases when it is driving a load. **Figure 6** shows a 220 Ω resistor connected between two port pins. If one output

is set high and the other is set low, the voltage on the load resistor is close to 5 V. This results in a load current of roughly 20 mA. We wanted to see whether this causes the microcontroller to warm up. The program also measures the voltage drops on the port pins. For this purpose, the reference voltage must be briefly switched to 5 V. Although it is somewhat unusual for a program to work with two different reference voltages, switching voltages while the program was running does not cause any problems.
The results: with an output current of 20 mA, the voltage drops are just 0.4 V at the lower output and 0.5 V at the upper output. This leaves 4.1 V



```
26 deg
4.535678862 V
0.395894404 V
26 deg
4.535678862 V
0.395894404 V
26 deg
4.535678862 V
0.395894404 V
27 deg
4.535678862 V
0.395894404 V
27 deg
4.535678862 V
0.395894404 V
26 deg
4.535678862 V
0.395894404 V
27 deg
4.535678862 V
0.395894404 V
26 deg
4.535678862 V
```

Figure 7.
Temperatures and voltage drop

Listing 5. Temperature and voltage drops

```
‘-------------------------------------------
‘UNO_AD4.BAS   Temp
‘-------------------------------------------
$regfile = “m328pdef.dat”
$crystal = 16000000
$baud = 9600

Dim D As Word
Dim N As Word
Dim U As Single

Config Portb = Output
Portb.5 = 1
Portb.4 = 0

Do
  Config Adc = Single , Prescaler = Auto , Reference = Internal  ‘1,1 V
  Waitms 200
  D = Getadc(8)                                                ‘Temperature
  D = D - 338
  Print D ; “ deg”
  Waitms 500
  Config Adc = Single , Prescaler = Auto , Reference = Avcc ‘5 V
  Waitms 200
  D = Getadc(0)
  U = D * 5.0
  U = U / 1023
  Print U ; “ V”
  D = Getadc(1)
  U = D * 5.0
  U = U / 1023
  Print U ; “ V”
Loop
```

across the load resistor, yielding a current of 19 mA. The additional power dissipation in the microcontroller is 17 mW (0.9 V x 19 mA). Significant warming cannot be expected from this amount of power, and that's exactly what we saw from the temperature measurement (**Figure 7**). According to the data sheet, the maximum current at any port pin should not exceed 40 mA and the total current should not exceed 200 mA. In our experiments we found that the ports could handle currents up to 100 mA without damage, which means that even small DC motors could be operated directly from the ports without driver ICs. However, if you want to be on the safe side the rule is to never exceed 40 mA.

Listing 6. Measuring the input hysteresis

```
‘---------------------------------------------------
‘UNO_AD5.BAS   Hi/Lo Input Threshold
‘---------------------------------------------------
$regfile = “m328pdef.dat”
$crystal = 16000000
$baud = 9600

Dim D As Word
Dim Dmin As Word
Dim Dmax As Word
Dim N As Word
Dim U As Single
Config Portb = Output
Config Adc = Single , Prescaler = 64 , Reference = Avcc ‘5 V

For N = 1 To 10000
     Portb.5 = Not Pinc.5
Next N

Dmin = 1023
Dmax = 0

Do
  For N = 1 To 10000
     Portb.5 = Not Pinc.5                ‘13 100k A5
     D = Getadc(5)                       ‘A5 100µF GND
     If D < Dmin Then Dmin = D
     If D > Dmax Then Dmax = D
  Next N
  U = Dmin * 5.0
  U = U / 1023
  Print “Min = “;
  Print U , “ V”
  U = Dmax * 5.0
  U = U / 1023
  Print “Max = “;
  Print U , “ V”
Loop
```

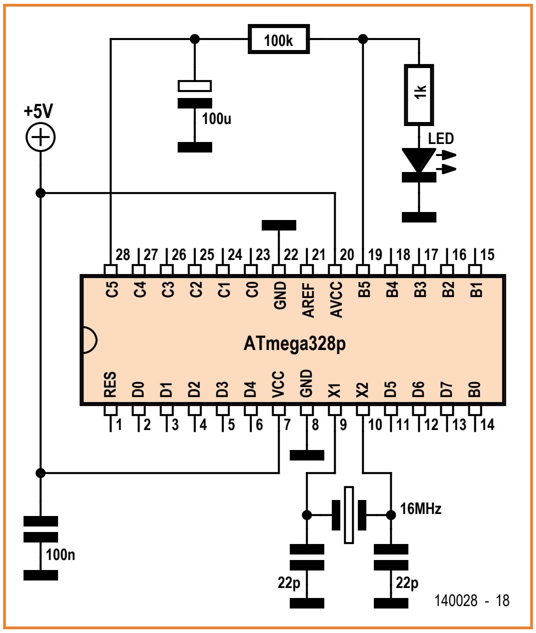
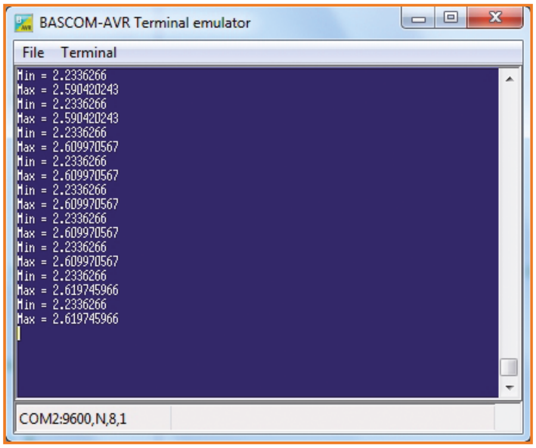


Figure 8. Measuring the input hysteresis.



```
Min = 2.2336266
Max = 2.590420243
Min = 2.2336266
Max = 2.590420243
Min = 2.2336266
Max = 2.609970567
Min = 2.2336266
Max = 2.609970567
Min = 2.2336266
Max = 2.609970567
Min = 2.2336266
Max = 2.609970567
Min = 2.2336266
Max = 2.609970567
Min = 2.2336266
Max = 2.619745966
Min = 2.2336266
Max = 2.619745966
```

COM2:9600,N,8,1

Figure 9. The upper and lower switching thresholds of an input.

Measuring the input hysteresis

In the previous instalment of this series we used external test equipment to determine the switching thresholds of a digital input. Now we want to the same thing entirely automatically with the built-in A/D converter (see **Figure 8**). For this we use two new variables (Dmin and Dmax) to hold the values of the lower and upper switching thresholds (see **Listing 6**). The measurement loop is preceded by a control loop which ensures that the input voltage is already within the desired range before the actual measurement starts. At first the maximum possible value is stored in the Dmin variable and zero is stored in the Dmax variable. The program then looks for the actual limit values. This is done using a random-sample approach. The longer the measurement session lasts, the more accurate the determined limit values are.

This program shows how to use loop counters. The For-Next loop counts down from N = 1000 to 0 and executes the instructions inside the loop exactly 1000 times. Although one thousand iterations may sound like a lot, the entire process takes only a fraction of a second. The large number of measurements increases the probability that the measurement results include the true limit values. This means that you have a good chance of finding the correct values after just one round. This can be seen from the fact that the subsequent rounds do not yield any significant changes.

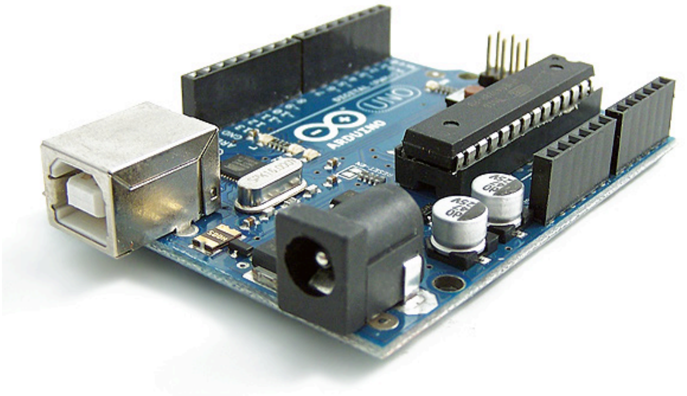
```
For N = 1 To 1000
     … instructions …
Next N
```

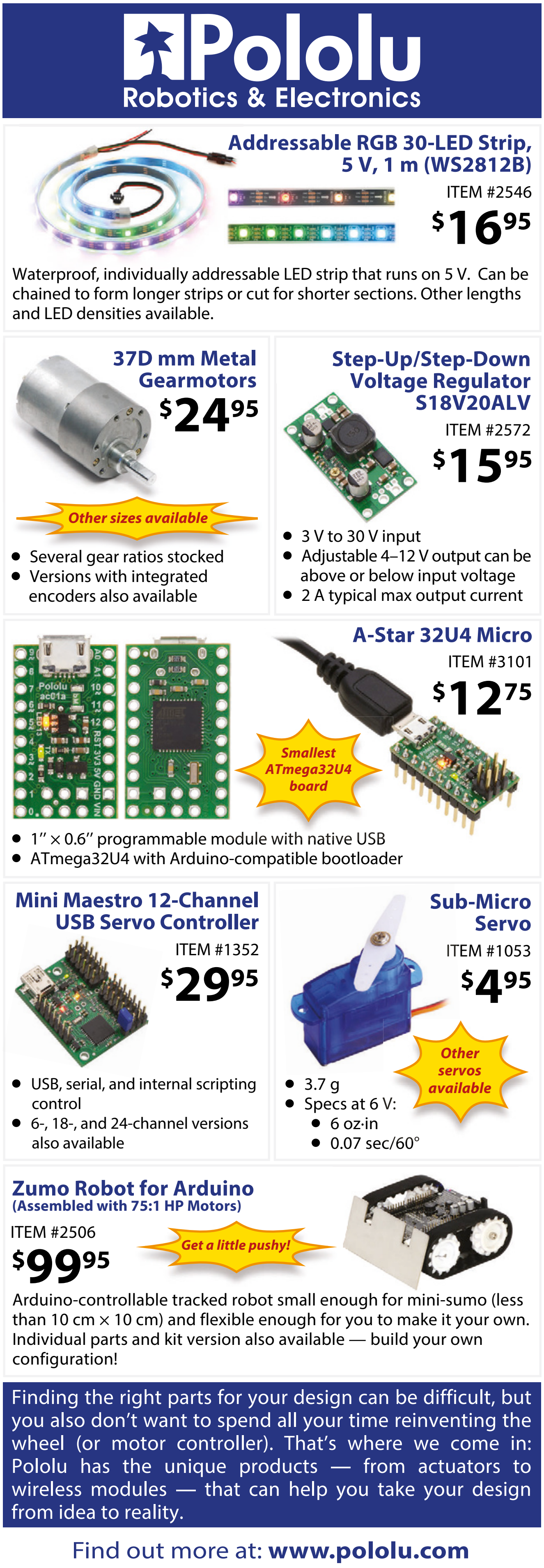
Figure 9 shows the result of this experiment. The switching thresholds are 2.23 V and 2.62 V. These are approximately the same as the values determined using the external test equipment.

(130568-I)

Web Link

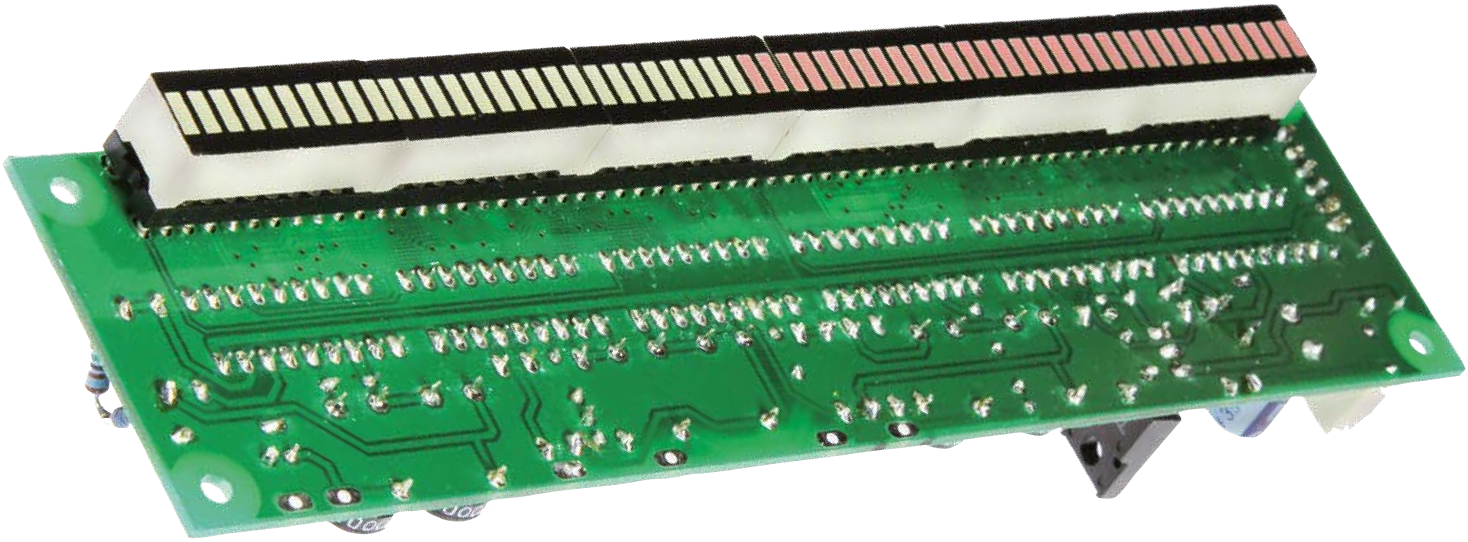
[1] www.elektor-magazine.com/130568





XXL LED VU Meter

With a wide range and high resolution



By **Emile van de Logt**
(Netherlands)

An LED VU meter is an excellent tool for keeping a close eye on the magnitude of audio voltages and so help prevent an input from being overloaded, for example when used with a mixing desk or a guitar amp. The circuit described here has an exceptionally wide input range of 60 dB and a step size of 1 dB thanks to the use of 6 LM3915 driver ICs, which control a total of 60 LEDs.

The author was looking for an LED VU meter for his DIY guitar tube amplifier. After some research an old veteran soon presented itself: the LM3915 dot/bar display driver. This IC spans 30 dB with a step size of 3 dB. It can be used to drive a total of 10 LEDs. Various LED VU kits using this IC are available and are usually satisfactory.
Further research resulted (of course) in an Elektor article by Rikard Lalic. This article from the 2002 Summer Circuits edition [1] describes an LED VU meter, again using the LM3915, but now with a range of 60 dB, which is achieved by using 2 LM3915 ICs, where the second IC receives a voltage that is 30 dB smaller.

Rising to the challenge to make an LED VU meter that has this wide range, as well as a step size of 1 dB, this article describes the design, construction and test of such an XXL LED VU meter, with a range of 60 dB and a resolution of 1 dB, meaning there's a grand total of 60 LEDs to be controlled!

An interesting aspect of this design is that it is entirely analog (there is no microcontroller to be found) and that is has a didactic purpose. The author uses it to explain to his students that mathematics and the design of electronics go hand in hand. This article also contains a few sidebars where readers can refresh their own theoretical knowledge somewhat!

Design and calculations

Lalic, in his original design, assumed a fixed setpoint of 5 V for the first LM3915. To allow this design to measure higher powers as well, he

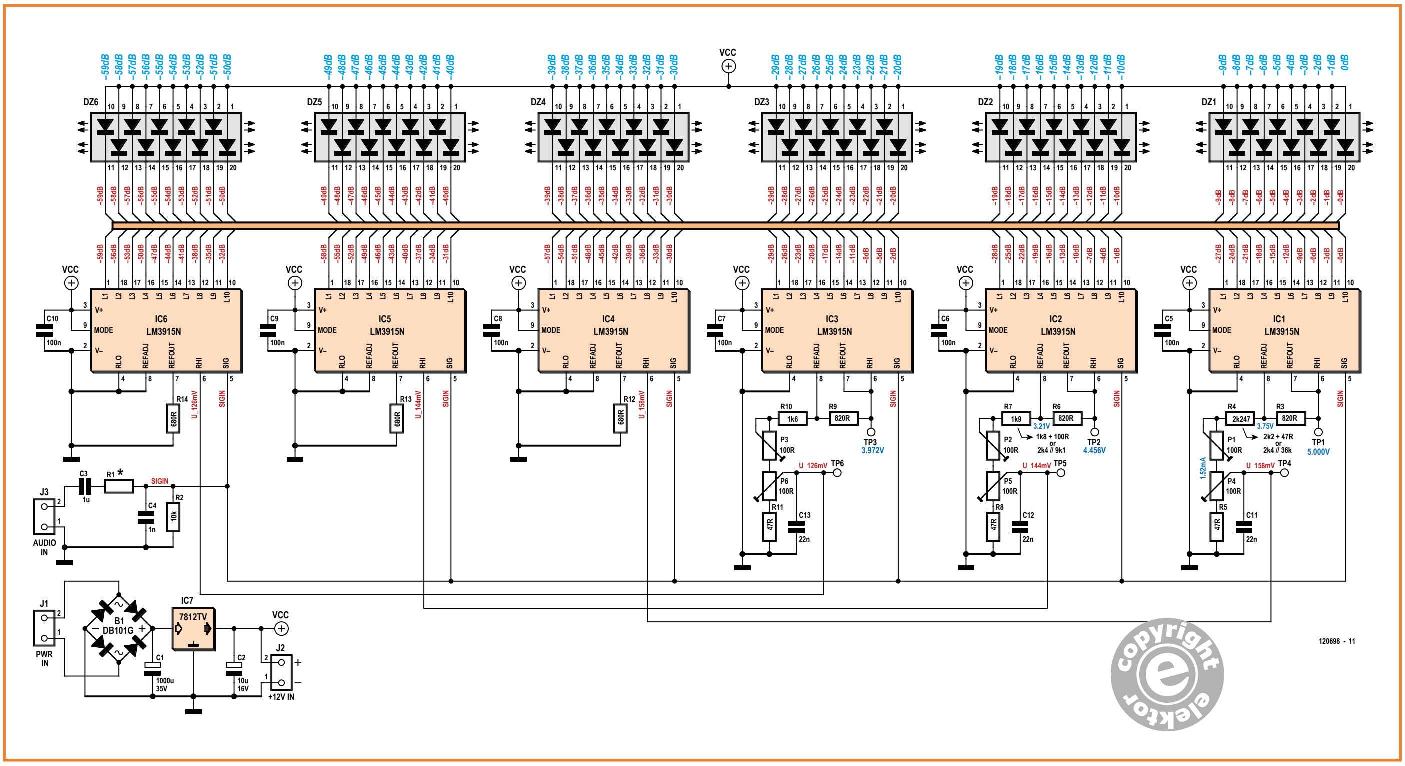


Figure 1.
Because six ICs type LM3915 have been used, a total of 60 LEDs can be controlled, which results in a range of 60 dB and a step size of 1 dB.

supplied a table where the input signal to the LM3915 could be adjusted using a voltage divider. Because the LM3915 has a default step size of 3 dB, having a step size of 1 dB has to be solved by using multiple LM3915 ICs. In the original design the second LM3915 was adjusted 30 dB lower than the first LM3915. This can be further refined by adding two more ICs, which are adjusted to be 1 dB and 2 dB lower respectively, relative to both of the existing ICs. All this together will now create a total range of 60 dB in steps of 1 dB. Therefore we have a total of six LM3915 ICs which are adjusted according to **Table 1**.

As an example we will assume that full power drive is reached at an RMS power of 100 watts into 8 Ω. This corresponds to an 28.28 V_{rms} and 40 V_{peak} (see sidebar 'Power and voltage: RMS and peak?'). Since the LM3915 responds to the peak value (because it is, in fact, a comparator), the voltage divider has to be scaled such that this 40 V corresponds to the reference voltage of 5 V at the input of the LM3915. Supposing that R2 has a fixed value (10 kΩ), then the correct voltage divider ratio can be set with the aid of R1 for various (RMS) powers and loudspeaker impedances R_L.

In the sidebar we already observed that

$$P_{rms} = \frac{\hat{U}^2}{2R_L}$$

Rearranging this becomes

$$\hat{U} = \sqrt{2P_{rms}R_L}$$

This peak voltage Û is reduced by the voltage divider R1/R2 to 5 V, so that we obtain the following:

$$\hat{U} = \frac{10k}{R1+10k} = 5 \quad \Leftrightarrow$$

$$\hat{U} \times 10k = 5 \times (R1 + 10k) \quad \Leftrightarrow$$

$$\hat{U} \times 10k - 50k = 5 \times R1$$

Table 1: Reference voltage for each IC

IC-n0.	Ratio [dB]	Ratio	U_{REF} [V]
IC1	0 dB	1.000	5.000
IC2	–1 dB	0.8913	4.456
IC3	–2 dB	0.7943	3.972
IC4	–30 dB	0.0316	0.158
IC5	–31 dB	0.0282	0.141
IC6	–32 dB	0.0251	0.126

Component List

Resistors

Default: 0.25 W 1%
R1 = see text and Table 2
R2 = 10kΩ
R3,R6,R9 = 820Ω
R4a = 36kΩ
R4b,R7b = 2.4kΩ
R5,R8,R11 = 47Ω
R7a = 9.1kΩ
R10 = 1.6kΩ
R12,R13,R14 = 680Ω
P1–P6 = 100Ω trimpot, horizontal

Capacitors

C1 = 1000µF 35V, low ESR, 5mm pitch, 13mm diam.
C2 = 10µF 16V, low ESR, 2mm pitch, 5mm diam.
C3 = 1µF 100V, MKT, 5mm pitch
C4 = 1nF, 5mm pitch
C5–C10 = 100nF, 2.5mm pitch
C11,C12,C13 = 22nF, 2.5mm pitch

Semiconductors

B1 = DB101
D1–D50 = 10-element LED bargraph display, green, 10.16 x 25.40 mm
D51–D60 = 10-element LED bargraph display, red, 10.16 x 25.40 mm
IC1–IC6 = LM3915N
IC7 = LM7812 (TO220)

Miscellaneous

J1,J2,J3 = 2-pin pinheader, 0.1’’ pitch
6 pcs. DIP-20 IC socket for LED bargraph displays
6 pcs DIP-18 IC sockets for LM3915 ICs
PCB # 120698-1, see [2]

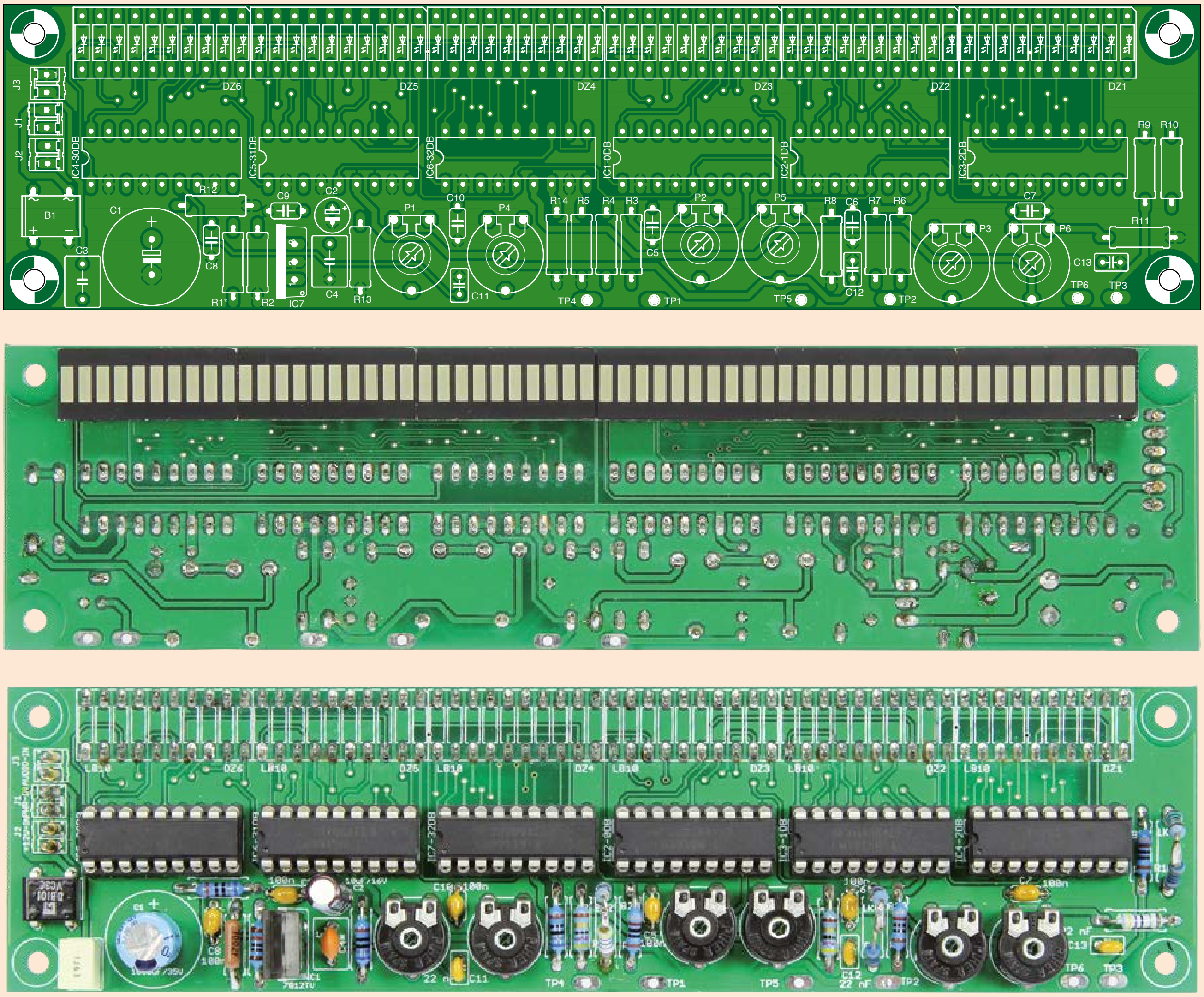


Figure 2. The printed circuit board layout designed by the author. The LEDs can be fitted at either the component side or the solder side, whichever is preferred (but note the correct polarity).

Table 2: Value of R1 for different powers

Loudspeaker-Impedance R_L	4 Ω	4 Ω	4 Ω	8 Ω	8 Ω	8 Ω	16 Ω	16 Ω	16 Ω
RMS Power P_{RMS}	10 W	50 W	100 W	10 W	50 W	100 W	10 W	50 W	100 W
Peak Voltage Û	8.9 V	20.0 V	28.3 V	12.6 V	28.3 V	40.0 V	17.9 V	40.0 V	56.6 V
R1 (Ω)	7889	30000	46569	15298	46569	70000	25777	70000	103137
R1 – implementation	22k//12k (-1.58%)	47k//82k (-0.41%)	47k (+0.9%)	15k (-2.0%)	47k (+0.9%)	220k//100k (-1.8%)	47k//56k (-0.87%)	220k//100k (-1.8%)	330k//150k (0.0%)

And finally we can solve this for R_1:

$$R1 = \hat{U} \times 2k - 10k$$

Using the formulas for $\hat{U}$ and R1, **Table 2** can be populated with various values of P_{RMS} and R_L. The purpose of capacitor C4 at the input is to prevent undesirable RF interference and together with R1 forms a low-pass filter. A 12-V voltage regulator provides a stable power supply voltage.

Design of the reference voltages

The generation of the reference voltages requires a little extra attention. For one thing, since the range of 60 dB is reasonably large this has the consequence that the reference voltages can become quite small. A voltage ratio of 60 dB does, after all, mean a ratio of 1000 to 1. The bottom-most LED will therefore already turn on at only 5 mV! A good printed circuit board design with ground and power planes is essential for a successful implementation!

The LM3915 generates a constant voltage of 1.25 V between pin 7 (Ref Out) and pin 8 (Ref Adj). The current that is required to generate this voltage also determines the current that will flow through each LED. Using a resistance value of 820 Ω there will be a current of about 15 mA running through each LED. This is sufficient to turn the LEDs on with plenty of brightness.

As the first step, the reference voltage at IC1 can be set to 5 V using potentiometer P1. This voltage is measured at test point TP1. Once this is done, the voltage at IC4 can be set to 158 mV (see **Table 1**) using potentiometer P4. This voltage is measured at test point TP4.
After this proceed to adjust the center sections. Using potentiometer P2 adjust the reference voltage for IC2 to 4.456 V. This voltage is measured at test point TP2. This is then followed by setting the voltage for IC5 to 141 mV using potentiometer P5. This voltage can be measured at test point TP5.
Next use potentiometer P3 to set the reference voltage for IC3 to 3.972 V. This voltage is measured at test point TP3. Finally use potentiometer P6 to set the voltage for IC6 to 126 mV. This voltage is measured at test point TP6.

Circuit board assembly

Assembling the circuit board should present few difficulties. For his prototype the author chose to mount the LEDs on the solder side of the circuit board. These, however, could also be fitted without any problems on the component side, if preferred. Just make sure that the LEDs are mounted with their polarity the correct way around. One of the four corners of the LED has a bevel. This side must face the long edge of the board.

With some resistance values (for example R1, see **Table 2**) it may be necessary to solder two resistors is parallel in order to obtain the correct value. You can, of course, also use 1%-resistors, but these are not always all available in the assortment of resistors in the (hobby) lab.
After all the parts have been mounted (but do **not yet** fit the LM3915 ICs in their sockets) you can begin with testing the power supply section. There are two options here:

- Connect a transformer with an output of 12 V_{AC} to connector J1 and mount B1, C1 and IC7.
- Use an external 12 V_{DC} power supply and connect this to connector J2. In this case IC7 must **not** be fitted.

Measure that there is a stable 12-V signal everywhere (pin 3 and pin 9 of each IC socket). If

Table 3: Adjustment of the reference voltages

P1	P2	P3	P4	P5	P6
TP1	TP2	TP3	TP4	TP5	TP6
5.000 V	4.456 V	3.972 V	158 mV	141 mV	126 mV

The Author

Emile van de Logt works at Hogeschool Rotterdam, Netherlands, as Head of Department for the Electric Engineering and Health Care Technology departments. He studied Electric Engineering at Eindhoven Technical University, and Management Studies at Open University. An enthusiastic electronics hobbyist, Emile looked after Elektor's *Embedded C Programming* and *FPGA-VHDL* workshops. He builds tube amplifiers, guitar effects equipment and is an amateur beer brewer with an entirely automated brewing system, the hardware and software of which he designed himself.

not, switch off the power supply and track down the fault. Once all is well, you can fit (with the power supply off) all the LM3915 ICs carefully in their sockets. Turn the power supply back on and adjust all the reference voltages to their correct values according to **Table 3**.

After this the board is ready for use. The loudspeaker signal is connected to connector J3.

(120698-I)

Web Links

[1] www.elektor-magazine.com/000083

[2] www.elektor-magazine.com/120698

The Logarithm

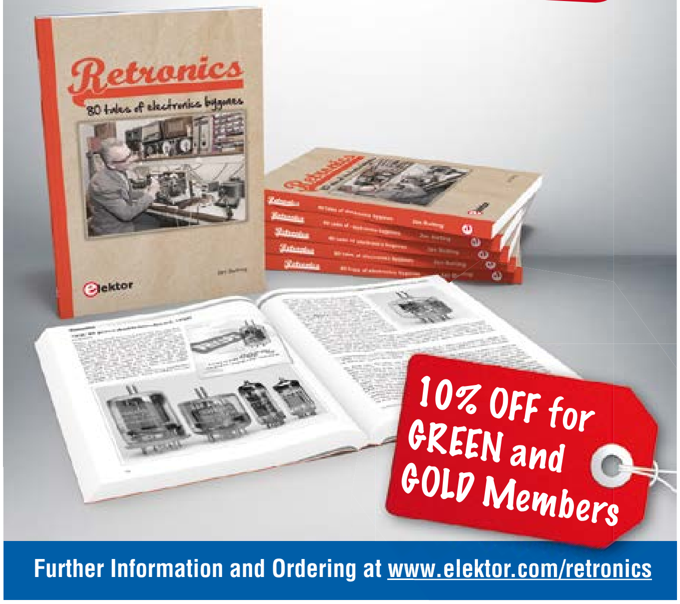
The logarithm is often used in order to allow large ratios between numbers to be expressed clearly. Normally the logarithm with base 10 is used. There are a few rules that are important when calculating with logarithms:
$\log_a(b) = x$ can also be written as a power: $a^x = b$.
The knack of working with logarithms is to transform one of these forms into the other.
For example: how big is $\log_{10}(1000)$? If we call the answer x, then we can also write: $\log_{10}(1000) = x$, that is $10^x = 1000$, that is $10^x = 10^3$, therefore x (the answer) is 3. Consequently $\log_{10}(1000)$ equals 3. Similarly, $\log_2(8) = 3$.

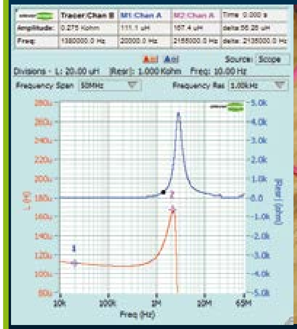
The Decibel

is named after Alexander Graham Bell. The Bel (B) was originally used to indicate the power loss in cables. An unwieldy unit it was soon redefined to deci-bel (0.1 bel).
When working with decibels it is important to make a distinction between power and voltage ratios. The definitions of these are as follows: number of dB's = $10 \log_{10} (P_1/P_0)$. When P_1, for example, is 100 times bigger than P_0, then this ratio corresponds to 20 dB.
With voltage ratios the definition is as follows: number of dB's = $20 \log_{10} (U_1/U_0)$. When U_1, for example, is 100 times bigger than U_0, then this ratio corresponds to 40 dB!
Assuming we want the difference between two voltages U_1 and U_0 to be 30 dB we can write: $20 \log_{10}(U_1/U_0) = 30$ that is, $\log_{10} (U_1/U_0) = 1.5$. According to the notations defined for the logarithm this can also be written as: $10^{1.5} = (U_1/U_0)$, that is, $U_1/U_0 = 31.62$. Consequently U_1 has to be 31.62 times bigger than U_0.

Power and voltage: RMS and peak?

For a pure sine wave signal it holds that the peak value (indicated with $\hat{U}$) is bigger by a factor of √2 compared to the RMS (root-mean-square) value (indicated with U_{rms}).
We know that P (power) = U (voltage) x I (current). Ohm's Law tells us that $U = I \times R$, therefore
$P = U \times I = U \times U/R = U^2/R$.
It is important to indicate which power is used: RMS power (P_{rms}) or peak power? You only get RMS power if you use the RMS value of the voltage: $P_{rms} = U_{rms}^2/R = (\hat{U}/\sqrt{2})^2/R = \hat{U}^2/2R$.
The RMS power is therefore half of the peak power!
An RMS power of 100 watts into a loudspeaker of 8 ohms is thus realized by a sine wave signal with an RMS voltage U_{rms} = 28.28 V. This signal has a peak voltage $\hat{U}$ of 40 V.



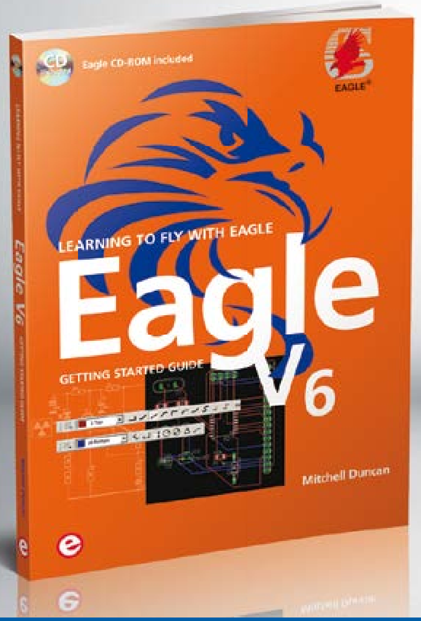


	Tracer Chan B	M1 Chan A	M2 Chan A	Time 0.000 s
Amplitude:	0.275 Kohm	111.1 uH	187.4 uH	delta 56.28 uH
Freq:	1380000.0 Hz	20000.0 Hz	2155000.0 Hz	delta: 2135000.0 Hz

Source: Scope

Divisions - L: 20.00 uH |Rser|: 1.000 Kohm Freq: 10.00 Hz

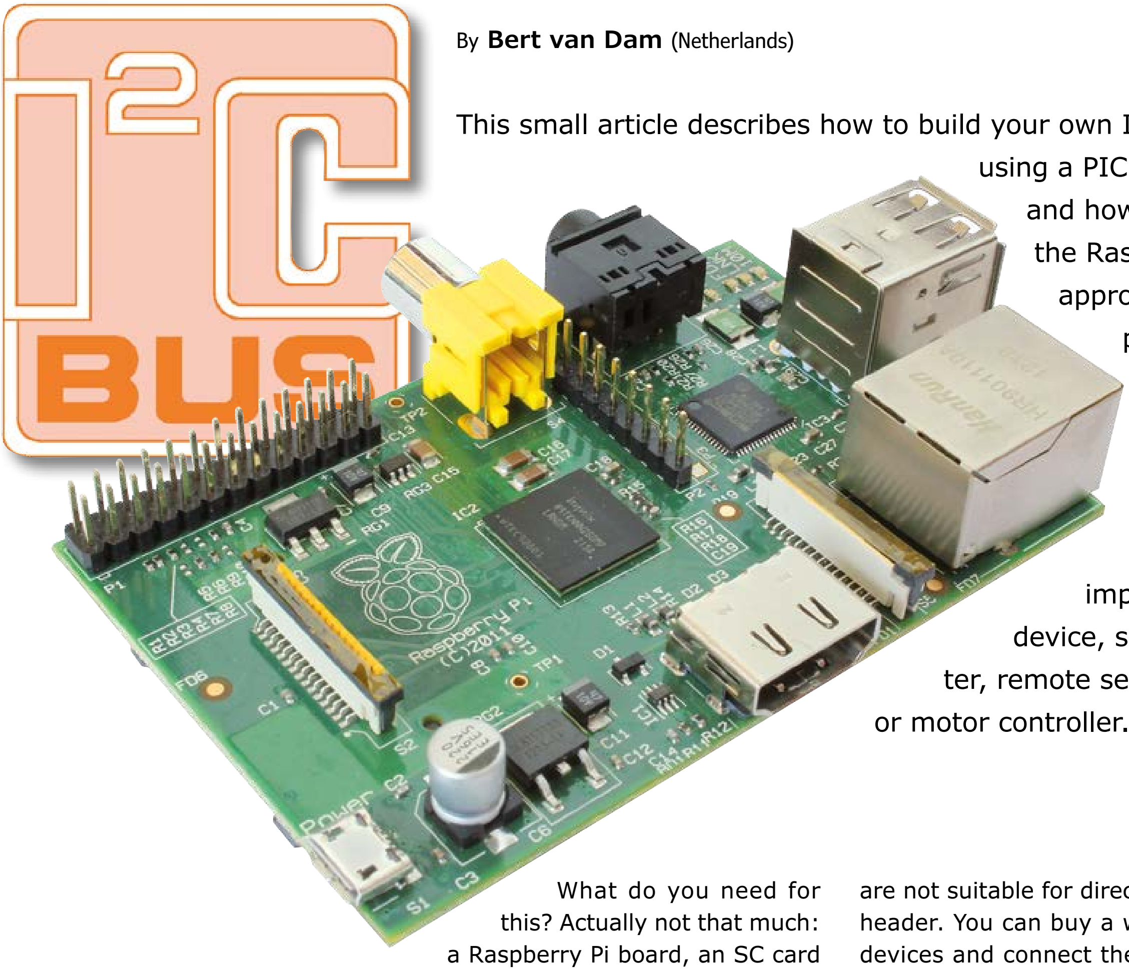
Frequency Span 50MHz Frequency Res 1.00kHz



DIY I²C for Raspberry Pi

Using a PIC16F88 microcontroller

By **Bert van Dam** (Netherlands)



This small article describes how to build your own I²C slave device using a PIC microcontroller, and how to control it with the Raspberry Pi. This approach combines the power of the microcontroller with the flexibility of the Raspberry Pi. There are many things that you can implement with an I²C device, such as a light meter, remote sensor, relay control or motor controller.

What do you need for this? Actually not that much: a Raspberry Pi board, an SC card with the Raspberry Pi operating system and I²C drivers (which you can obtain from the author's Raspberry Pi book, among other sources), a PIC 16F88 microcontroller, a PIC programmer, and a breadboard with an LED, an LDR and a few bits of wire.

What can you do with an I²C slave device?

The Raspberry Pi has a GPIO header for connecting external circuitry, such as I²C slave devices. The advantage of these I²C slave devices is that you can use them to connect components that are not suitable for direct connection to the I/O header. You can buy a wide range of I²C slave devices and connect them to the Raspberry Pi without further ado, including temperature sensors and I/O extenders. However, you can't buy devices for every possible application, and sometimes the available devices don't do what you want. If you build your own I²C slave using a microcontroller, the potential uses are virtually unlimited. For example, the 16F88 used in this article has several analog inputs, digital I/O, high-resolution PWM, a TTL RS-232 port, frequency counters, SPI and I²C ports and EEPROM all integrated into the device. The possibilities are only limited by your imagination.

Basic I²C bus structure

An I²C data bus consists of one master and one or more slaves. They are connected to each other by data and clock lines as shown in **Figure 1**. These two lines are held High by a pair of pull-up resistors. Consequently the voltage on the I²C bus depends on the voltage rail to which the pull-up resistors are connected. It also means that it's entirely possible for the master and slave devices to operate from different supply voltages. In the case of the Raspberry Pi, the pull-up resistors are built in and connected to 3.3 V, so the slaves must be able to handle 3.3 V and see this voltage as a logic high level. The PIC sees any voltage above 2 V as a logic high level, so it has no problem communicating with a Raspberry Pi operating at 3.3 V.

The bus master places a clock signal on the clock line by pulling it low at a specific frequency. The line automatically returns to the high level due to the pull-up resistor. The bus master also puts data pulses on the data line in the same manner, coordinated with the clock pulses. This means that the master controls the communication process and the slaves have to follow.

When a request is sent to a slave, it must respond. However, the slave may not be able to respond before the next clock pulse—for example, if it first has to compute something. In this case the slave can pull the clock line low. Now the master cannot issue another clock pulse because the slave has already pulled the clock line low, and releasing the line has no effect as long as the slave holds it low. This gives the slave the time it needs to generate the required response. When it is ready, the slave releases the clock line so the master can again supply the clock signal. Of course, the clock signal timing is skewed at this point because the pulse was too long. This procedure is called clock stretching. We also use this procedure in our project.

Setting up the I²C bus between RPi and PIC

In the schematic in **Figure 2** you can see the Raspberry Pi header on the right and the 16F88 on the left. The microcontroller pins that are not connected to anything in the schematic are left open. The two pull-up resistors required on the I²C data bus are built into the Raspberry Pi and are therefore not shown on the schematic.

The LDR and the LED with the associated resistors are included to show how the circuit works. You probably won't need them for your own projects. We use the LED in our first demo project and the LDR in the second one.

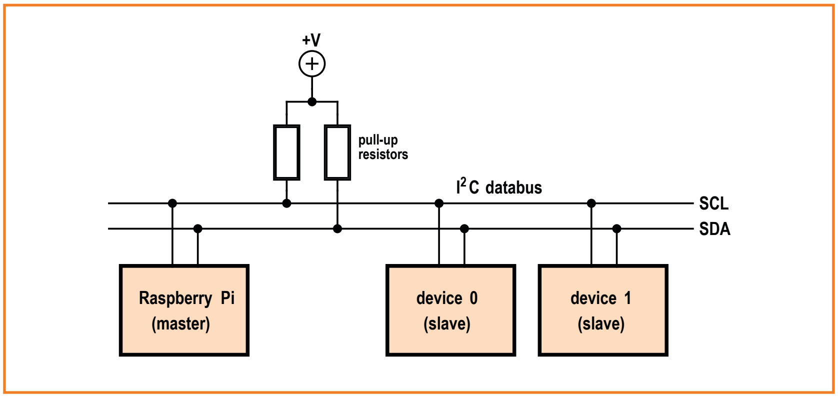
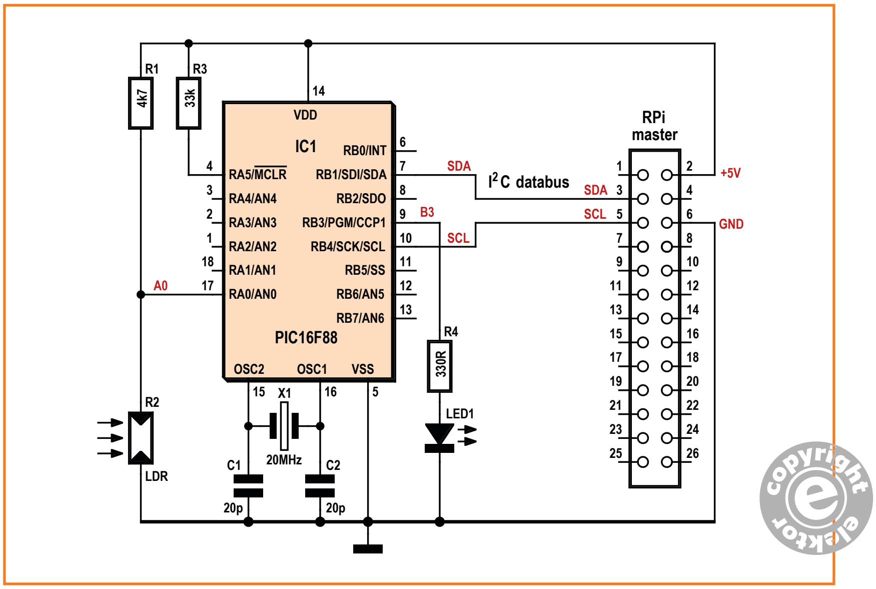


Figure 1.
Basic I²C bus structure.

If you build this circuit on a breadboard as shown in **Figure 3**, you must fit a 100 nF capacitor in each corner to suppress noise on the supply lines. These capacitors are not shown on the schematic. Note that if you previously used the microcontroller in other projects, pin 7 and/or pin 10 may already be configured as outputs. In that case they will have an output voltage of 5 V, which can damage the Raspberry Pi. To avoid this, load the I²C program into the microcontroller before you connect it to the Raspberry Pi. After this you can reprogram the microcontroller without any risk. One option for programming the microcontroller is to use the Wisp648 in-circuit programmer. In that case you can simply leave the microcon-

Figure 2.
The PIC microcontroller is connected to the Raspberry Pi over the I²C bus.



troller plugged into the breadboard during programming. This is particularly handy when you are experimenting with the circuit and constantly making changes to the software.

However, when you use an in-circuit programmer it is a good idea to use an external power source for the 5-V portion instead of the Raspberry Pi, to ensure that you always have enough power available. In that case the 5 V pin of the Raspberry Pi must be left open, since you can't power the circuit from two sources at the same time. However, the rest of the pins (including ground) should remain connected.

Software structure

For the sake of simplicity, we omit any description of the settings (you can read about them at your convenience in the source code) and limit ourselves to a number of basic instructions. Here we use Python, the standard free programming language for the Raspberry Pi.
We use the following Raspberry Pi instructions:

bus.write_byte(address, command)
This sends the content of the variable 'command' to the I²C slave device with the given address. This means that the slave receives an address and a command.

`data =`
`bus.read_byte_data(address, command)`
This sends the content of the variable 'command' to the I²C slave device with the given address. After this the master waits for a response from the slave, which is copied to the variable 'data'. In this case the slave receives an address, a command, and then another address.

`data = bus.read_byte(address)`
Sometimes the slave does not need any command. For example, it may only be able to measure one thing, so that is the only thing the master can request. In that the case we can omit the command and simply send the address with the Read bit set. Of course, the software in the slave device must know in advance what it has to send back.

`sudo i2cdetect -y 1`
You can issue this instruction when you want to know which I²C slaves are present on the bus. This is not a Python instruction, so you must enter it in a command line or use LXterminal if you are working with Xwindows (LXDE). In return you will receive the following reply:

```
pi@raspberrypi $ sudo i2cdetect -y 1
     0  1  2  3  4  5  6  7  8  9  a  b  c  d  e  f
00:          -- -- -- -- -- -- -- -- -- -- -- -- --
10: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
20: 20 -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
30: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
40: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
50: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
60: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
70: -- -- -- -- -- -- -- --
```

Here you can see that a single I²C slave has replied and its address is 0x20 in hexadecimal notation.

On the microcontroller side we also skip all the settings. Here we use JAL, a widely used free programming language for microcontrollers.
We use the following PIC instructions:

`i2c_slave_enable (address)`
You can use this instruction to configure the communication unit of the 16F88 for I²C and set the slave address. The maximum address value is 127 (7 bits).

`data =`
`i2c_slave_read_byte_timeout(error)`
This function reads a bytes and uses a timeout counter. The bytes normally arrive one after the other, but if it takes too long a timeout occurs. When this happens, the function stops waiting and sets the variable 'error' to true.

`data = i2c_slave_read_byte`
This function also reads a byte, but without a timeout. You can use this to wait for the first address. There is no timeout here because it does not matter how long you have to wait, since it is entirely possible that the master never tries to contact the slave.

`i2c_slave_write_byte(data, error)`
This function writes a byte of data. The clock line is held low until this function is ready, which means that the master must wait for the slave. If the write operation fails, the variable 'error' is set to true.

Demo project 1: LED switching

The first project involves controlling a LED over the I^{2}C bus. This requires the Raspberry Pi to send a command to the microcontroller, with no response expected. We use the following instruction at the Raspberry Pi end:

```
bus.write_byte(address, command)
```

This means that the microcontroller receives the address and a command.

```
-- wait for address (and ignore)
dummy = i2c_slave_read_byte

-- wait for command
command = i2c_slave_read_byte_timeout(error)
```

The LED must be switched on or off, depending on the content of the command. A ‘1’ causes the LED to light up, while a ‘0’ makes it go dark. A timeout during reading or a hung bus during writing is a serious error. Normally these errors do not happen, but users may send incorrect commands or there can be a technical problem with the bus. I^{2}C slaves usually do not have users, so there is nobody who can do anything to clear these errors. The best solution in such cases is to perform a soft reset on the microcontroller. This takes practically no time to execute, and it automatically restores all registers and flags to good states without requiring the user (that means you) to know exactly what was wrong.

```
if error then
   -- unexcepted I2C event, soft reset
   asm CLRF PCLATH
   asm GOTO 0x00
end if
```

Demo project 2: Light Meter

The second project is a light meter using an LDR. The microcontroller is blessed with five unused analog channels. Here we use just one of them to connect the LDR. In this case it is not necessary to send a command to the microcontroller, since there’s only one thing it can measure. We simply send the address with the Read bit set:

```
data = bus.read_byte(address)
```

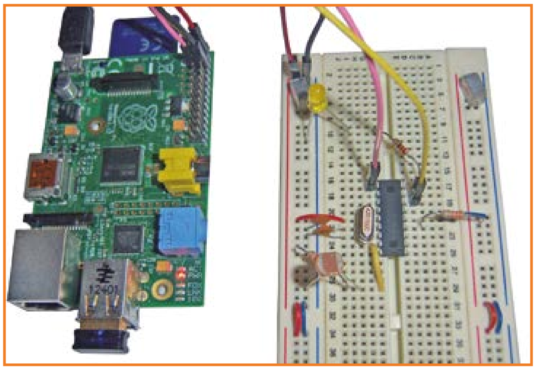


Figure 3. Circuit layout on a breadboard.

The microcontroller receives this address with the Read bit set and knows that it has to return a response. It prepares the response and sends it back:

```
-- wait for address (and ignore)
dummy = i2c_slave_read_byte

-- prepare reply and send it
mydata = ADC_read_low_res(0)
i2c_slave_write_byte(mydata, error)
```

This is followed in the code by the usual error handling routine, which you can read at your leisure in the downloadable source code for this article. With a few minor changes, you can also use the code to read a temperature sensor or operate an ultrasonic distance sensor, such as the SRF05.

The software necessary for this article is available for download at [1]. For more projects of a similar nature, see the books *Raspberry Pi – Explore the RPi in 45 Projects*, *50 PIC Microcontroller Projects for Beginners and Experts,* and *PIC Microcontrollers – 50 Projects for Beginners and Experts*, all available in the Elektor Store.

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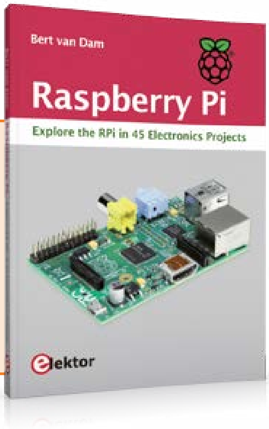
Web links

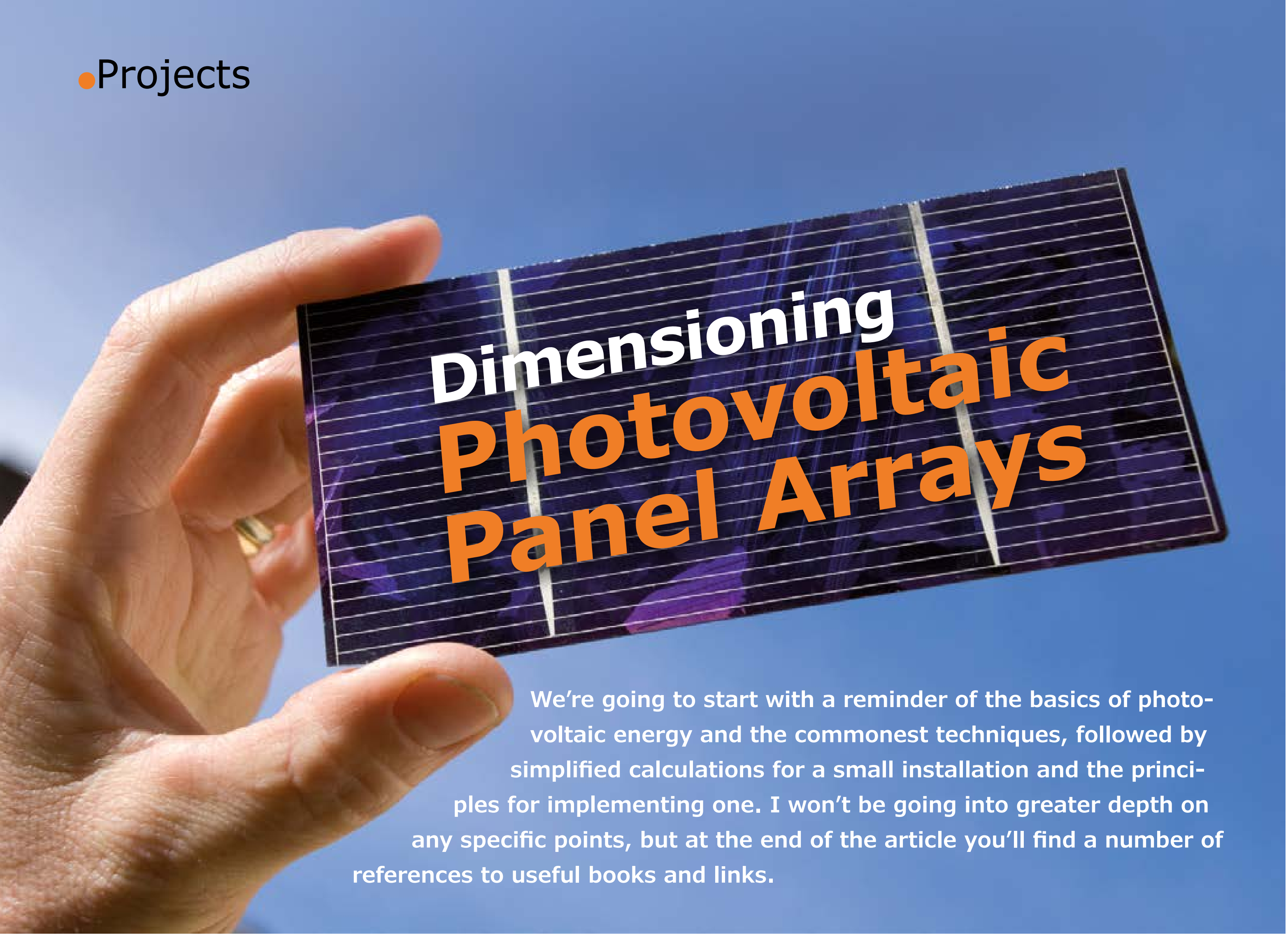
[1] www.elektor-magazine.com/130583

About the author

Bert van Dam is a freelance author of books, course material and articles about PIC and ARM microcontrollers, Arduino, Raspberry Pi, Artificial Intelligence, and the programming languages JAL, C, assembler, Python and Flowcode.



Dimensioning Photovoltaic Panel Arrays



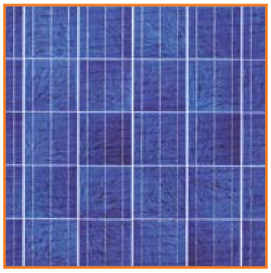
We're going to start with a reminder of the basics of photovoltaic energy and the commonest techniques, followed by simplified calculations for a small installation and the principles for implementing one. I won't be going into greater depth on any specific points, but at the end of the article you'll find a number of references to useful books and links.

By **Pascal Rondane** (France)
pascal.toursrondane@gmail.com

Many techniques are still at the research lab stage. Others, like those using gallium arsenide (GaAs), which currently offer the greatest efficiency (20–25%), are used for powering satellites. Their cost puts them out of reach for private individuals. Here are the commonest techniques.

Monocrystalline silicon

Monocrystalline silicon cells, very widespread, offer good efficiency: 15% (under standard test conditions). These bluish colored cells consist of a single crystal and have a uniform appearance. The manufacturing process involves melting bars of silicon then cooling them slowly to achieve a homogeneous crystal.



Polycrystalline silicon

As their name indicates, polycrystalline silicon cells are made up of multiple crystals, with an appearance rather like a mosaic; their efficiency is 12–14% below that of monocrystalline cells; they are also less expensive.

Amorphous silicon

Amorphous silicon cells have only low efficiency (5–7%), but they work just as well indoors as out, which means they are used primarily in consumer applications (watches, calculators, etc.)

CIS cells

CIS (copper/indium/selenium) cells represent the new generation of thin-film solar cells. The materials used in making are not toxic and are easy to obtain. This type of cell can be made on flexible modules, but the manufacturing process for them is quite complex.

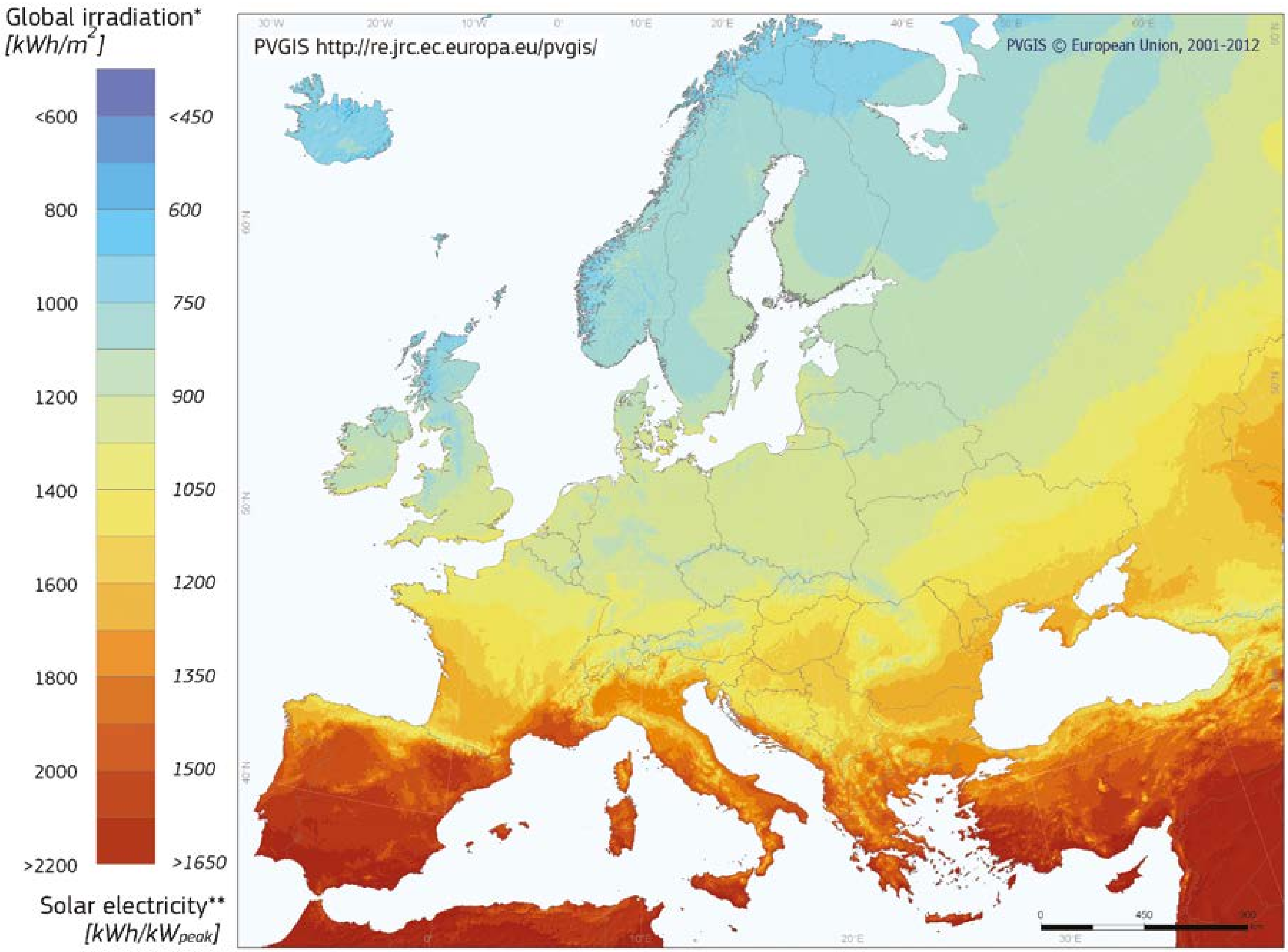
They offer good efficiency (10–14 % or even higher) and are starting to be produced, in particular by Saint-Gobain in the author’s home country, for industrial installations.

Definition of solar energy

It’s important to make it clear that the function of photovoltaic solar panels is to convert *light radiation* into electric current; if their operation was associated with direct *solar* radiation, the slightest cloud would compromise their reliability in use. The efficiency of a photovoltaic panel depends first and foremost on the *exposure*: in strong sunshine out of a cloudless sky, this can reach 1000 W/m². In cloudy weather, it is still around 500 W/m², while in overcast, rainy weather, it remains at best between 100 and 50 W/m²! If it doesn’t drop to 0 W/m²…

The watt-per-square-meter is the unit used to quantify solar irradiation. Solar panels are characterized by the electrical power they produce under solar radiation of 1000 W/m² at a temperature of 25 °C.

In concrete terms, a so-called 20-watt solar panel produces these 20 watts under light radiation of 1000 W/m² (strong sunshine in cloudless sky); in overcast weather, only around half of this power


Global irradiation* [kWh/m²]
<600
800
1000
1200
1400
1600
1800
2000
>2200
<450
600
750
900
1050
1200
1350
1500
>1650
Solar electricity** [kWh/kWpeak]
PVGIS http://re.jrc.ec.europa.eu/pvgis/
PVGIS © European Union, 2001-2012
30°W
20°W
10°W
0°
10°E
20°E
30°E
40°E
50°E
60°E
60°N
50°N
40°N
0
450
900

* Yearly sum of global irradiation incident on optimally-inclined south-oriented photovoltaic modules

**Yearly sum of solar electricity generated by optimally-inclined 1kWp system with a performance ratio of 0.75

will remain. Not forgetting the junction temperature of the photovoltaic cells, which also influences the panel's efficiency: the modules lose 0.4 % per degree. Solar panel operating temperature depends on the incident radiation, the ambient temperature, the color of the materials, and also the wind speed (5–14% cumulative loss). The second determining factor is the exposure duration, as even on a fine Summer's day, the lighting varies throughout the day in a not-insignificant way. The time window during which the solar panel receives its maximum energy is only a few hours. In Winter, the light radiation diminishes, and can even disappear for several days in the event of snow or fog.

Calculations and implementation

In order to size and then implement a photovoltaic system, we have to proceed in stages.

Evaluating requirements

Before starting to calculate, let's remember the difference between energy and power.
Power is an instantaneous dimension (rate of flow).
Example: a lamp consumes 20 W; a solar panel produces 40 W at instant *t*.
Energy is an element that is integrated over a period of time.
Electrical power is measured in watts (W), kilowatts (kW), or megawatts (MW). Power is the transfer of energy per unit time.

$$energy = power \times time$$

Energy is expressed in watt-hours (Wh). If the battery voltage is known, the unit of consumption normally used in calculations is the ampère-hour (Ah).

Evaluating consumption

Photovoltaic panels only supply energy during the day, but the unit of time used is the whole 24 hr period, which means we'll be working in Ah per day.

Sizing the battery

As the photovoltaic panel supplies energy only when it is receiving light radiation, a battery is needed to store the energy. The battery life expectancy is the time for which the battery can keep the load operating without being recharged by the photovoltaic panel. We generally allow for a battery life of five days, to cover severe winter weather conditions with extremely low light radiation.

In order to calculate the battery (accumulator) capacity, we multiply the electrical consumption (Ah) by the battery life required, and then apply a safety factor (0.7) corresponding to the battery's loss of charge at the lowest operating temperature considered and to the additional losses (battery charging efficiency, regulator conversion efficiency, battery self-discharge). The calculation indicates the capacity actually available at any moment. In the example below, this is equal to 70 % of the nominal capacity.

Table 1

device(s)	number of devices	current drawn (A)	duration of use in 24 hrs	energy = current x duration
photovoltaic regulator	1	0.020	24 h	0.020 x 24 = 480 mAh
LED lamps	3	0.150	4 h	0.150 x 3 x 4 = 1.8 Ah
total energy consumed over 24 hrs:			2.28 Ah	
power consumed per day:			2.28 x 12 V = 27.36 Wh/day	

useful capacity =
nominal capacity × usable percentage

$$C(Ah) = \frac{\text{consumption of the system in 24hr} \cdot \text{battery life in days}}{0,7}$$

$$C(Ah) = \frac{2.736 / d \times 3\, d}{0,7} = 12 Ah$$

The battery capacity has been rounded off.

It is preferable to choose a maintenance-free lead-acid gel battery (e.g. Yuasa 12 V 15 Ah) rather than a motorbike-type battery, where you have to check the level of the liquid electrolyte periodically.

Calculating recoverable solar energy

The solar irradiation (in W/m^2) falling on the photovoltaic panel varies during the day, depending on the time and weather conditions. Various websites give the amount of sunshine in Wh/m^2 according to the time of day and geographical location. The average values are spread over the year. For sizing the installation, we'll take the least favorable value (December).

A few average solar irradiation values:

• Paris region:	1.12 kWh/m^2/d
• South of France:	3 kWh/m^2/d
• North Africa:	5 kWh/m^2/d

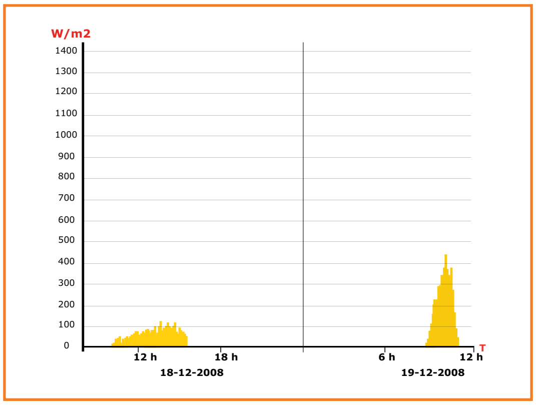
$$\text{panel power} =$$

$$\frac{\text{consumption of system over 24 hr (Wh/d)}}{\text{daily exposure } (kWh / m^2 / d) \times \text{loss factor}}$$

$$= \frac{32.8}{1.120 \times 0.7}$$

The panel power again has been rounded.
Which gives requirement for a solar panel with a power of 50 W.

Note: Settling for a 20-watt panel to power a load of the same power is a (frequent) error to be avoided!



Example of measuring exposure

These readings taken in December show that the exposure level was low (50 W/m^2 on 12/18 and 200 W/m^2 on 12/19) in the French city of Tours. The measurements were taken using a solarimeter, which gives an instantaneous reading of the solar irradiation in W/m^2.

Using photovoltaic panels

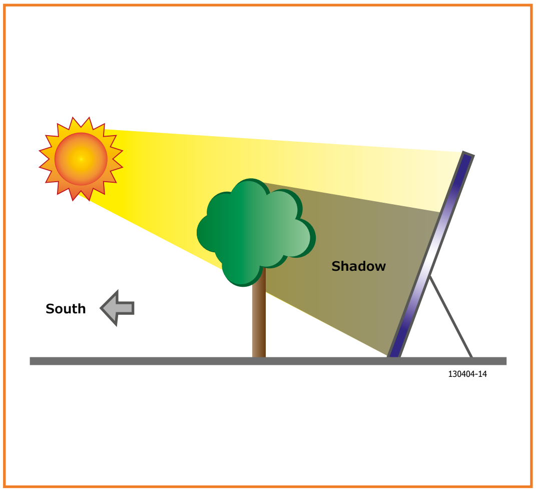
The position and orientation of the photovoltaic panels are determining factors for the efficiency of the installation.

Orientation: the cardinal point is located towards the sun's highest point; in the northern hemisphere, that's the south, and towards the north if you are in the southern hemisphere.

Inclination: the optimum inclination with respect to the horizon is usually taken as the latitude of the location plus 15°.

The "L+15°" inclination rule of thumb optimizes the production of energy in the least favorable months (Winter); for Summer use only, the optimum angle would be much smaller. You can refer to the website [2] which gives the optimum inclination for each month of the year (**Table 2**).

Shadows falling on the photovoltaic panels will affect their efficiency. These are mainly caused by chimneys, trees, or nearby buildings.
Or by dead leaves or any other object liable to cover part of the panel. Watch out! This is not harmless. You must take care to eliminate any obstacles of this type, as the cells in the panel that are no longer illuminated become current



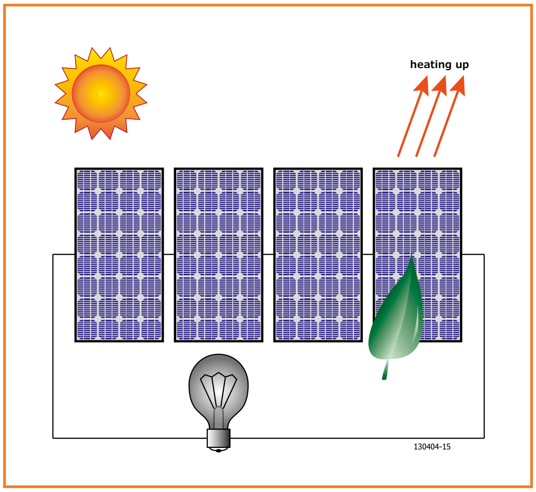


Table 2. Solar Irradiation for a site in central France,
drawn up by PVGIS (Photovoltaic Geographical Information System) [2]

Monthly Solar Irradiation | PVGIS Estimates of long-term monthly averages.
Location: 47°13’10” North, 2°11’50” East, Elevation: 113 m ASL.
Solar radiation database used: PVGIS-CMSAF.
Optimal inclination angle is: 36 degrees from vertical (= 54 degrees elevation).
Annual irradiation deficit due to shadowing (horizontal): 0.0 %.

Month	H_h	H_{opt}	$H(36)$	I_{opt}	T_{24h}	N_{DD}
Jan	1070	1710	1710	63	4.5	400
Feb	1780	2580	2580	57	5.4	341
Mar	3160	4120	4120	47	8.2	273
Apr	4590	5180	5180	33	10.4	173
Mei	5370	5390	5390	19	14.6	65
Jun	6050	5820	5820	13	18.3	16
Jul	5860	5780	5780	17	20.1	2
Aug	4960	5360	5360	28	20.2	15
Sep	3920	4920	4920	43	16.4	97
Okt	2290	3250	3250	54	13.3	214
Nov	1220	1910	1910	62	7.4	368
Dec	971	1530	1530	63	4.7	414
Year	3440	3970	3970	36	11.9	2378

H_h: Irradiation on horizontal plane (Wh/m^2/day)
H_{opt}: Irradiation on optimally inclined plane (Wh/m^2/day)
$H(36)$: Irradiation on plane at angle: 36deg. (Wh/m^2/day)
I_{opt}: Optimal inclination (deg.)
T_{24h}: 24 hour average of temperature (°C)
N_{DD}: Number of heating degree-days (–)
PVGIS © European Communities, 2001-2012

consumers and start heating up. It’s sometimes called the hot spot effect, and can have undesirable consequences.

Maintenance

With an inclination of L+15°, rain does a good job keeping photovoltaic panels clean.
You’ll need to periodically check the connections are in good condition (tightening, oxidation).

Charging regulator operating principle

The charging regulator [1] checks and protects the battery from over-charging and also deep discharge, which would damage it irreversibly. A photovoltaic installation is made up as follows.

Reverse blocking diode

Generally inserted in the circuit at the solar panel connecting box, this avoids the battery’s discharging through the solar panel at night or when the battery is fully charged and its voltage is higher than that of the panel under low illumination. Schottky diodes are preferred for their low forward voltage (0.4–0.6 V). On bottom-end panels, we find conventional diodes, which entail a voltage drop of 0.8 V. This higher threshold is not negligible in our calculations, as on a 12 V solar panel it entails a 7% loss.

Charging regulator

Its function is above all to preserve battery life. When the battery voltage reaches 14.4 V (nominal threshold), the regulator interrupts the charging of the battery, starting it again when the voltage drops below 12.6 V again.
Most modern chargers use a battery charge /

discharge calculation algorithm so as to make the best possible use of it.

Discharge limiter

Here, the aim is to protect the battery against deep discharge.

When the battery voltage drops below 11.6 V, the limiter disconnects the load being powered by the photovoltaic installation in order to relieve the battery; the load is connected again when the battery voltage reaches 12.6 V.

Batteries do exist that can withstand deep discharge, but they are markedly more expensive than a standard battery. A graph provided by the battery manufacturer makes it possible to calculate its life in accordance with the level of discharge accepted.

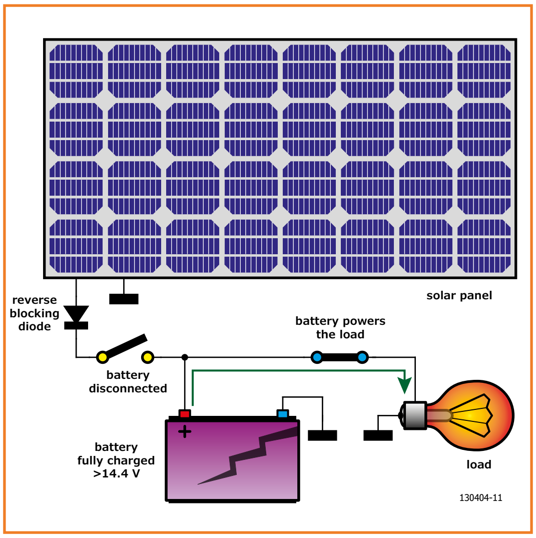
The heavier and more frequent the discharges, the shorter the overall battery life.

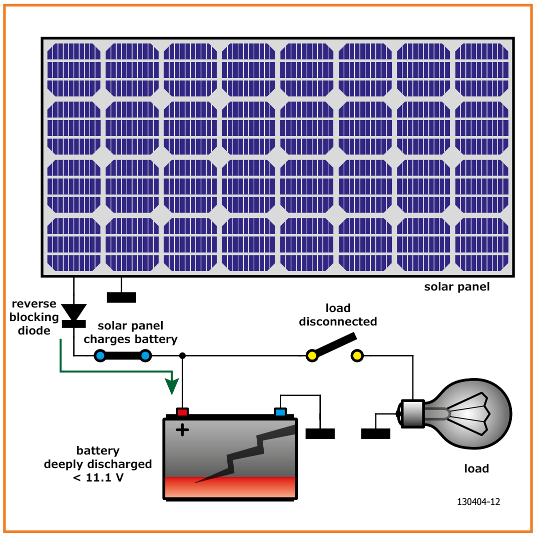
Modes

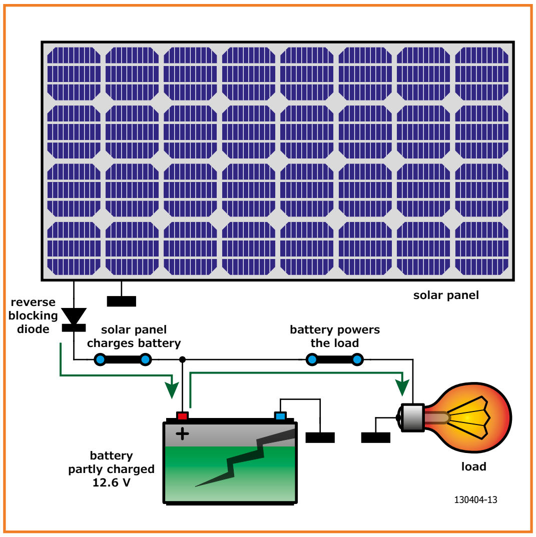
The drawings opposite show the system's three different modes of operation. At the top, the battery is fully charged and powering the installation. In the center, the battery is deeply discharged. Consequently the load is disconnected and the battery is being charged by the PV panel. The lower drawing shows the battery partly charged, and connected to the solar panel as well as the load.

To complement all these notions and put them into practice under the best conditions, I'll conclude by proposing a spreadsheet for calculating the battery life for your photovoltaic installation. Download it from the page for this article on our website [3]; it will enable you to find the optimal size for your panels, regulator, and battery.

(130404)







Web Links

[1] www.elektor-magazine.com/080305

[2] http://re.jrc.ec.europa.eu/pvgis/apps4/pvest.php#

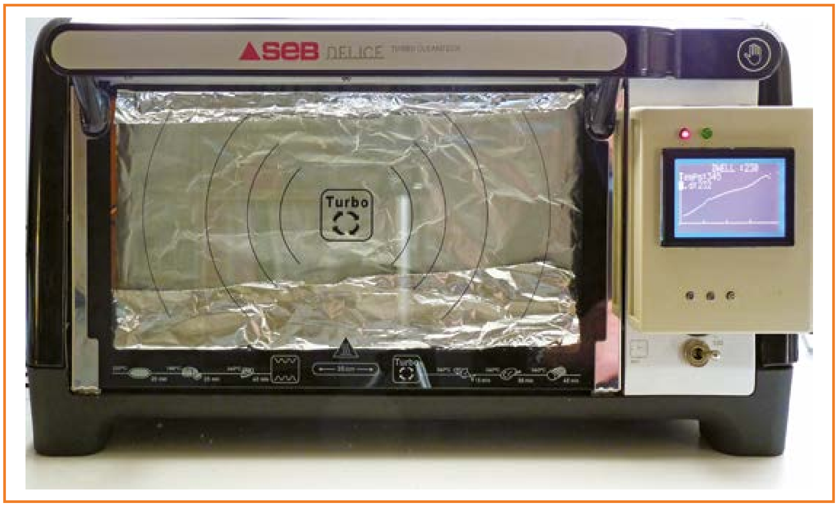
[3] www.elektor-magazien.com/130404

Sources

http://en.wikipedia.org/wiki/Photovoltaic_panel

Hack-Your-Own Reflow Oven

Fan-assisted oven for SMDs



Electronics is an activity where *not moving forward equals going backward*! From electronic tubes to microcontrollers, via 40xx CMOS and transistors, I've always tried to get to grips with and make use of the new techniques, while remaining cautious. The SMD step was a tricky one, but I managed it, and I'm very pleased with the outcome. I just hope you can benefit from my experience!

By **Jean-Pierre Duval**
(France)

Although the name doesn't actually say so, a reflow oven is used to solder surface-mounted devices or SMDs. Now certain integrated circuits exist only in an SMD version, it's more difficult for an electronics enthusiast to get by without these omnipresent SMDs. They are often cheaper than conventional through-hole components. Thanks to SMDs, printed circuits are getting smaller—and thus the cost of projects. The fact remains that for soldering these miniature components, you need little fairy fingers... or a reflow oven! You're hesitating? Well, I'm not hesitating any more.

Before getting into the reflow oven proper, it's worth taking a quick look at SMD technology (see **inset**) if this is new to you. This is also the moment to remind ourselves of the steps in producing a PCB using SMDs:
å

- If you use a program like ISIS/ARES, Eagle, etc. for designing the circuit, define right at the design stage the package to be used, allowing for the power to be dissipated.
- The layout itself isn't a problem, unless from the outset you are looking for a very high density.
- The solder paste can be applied either using a mask, or by syringe. The latter lets you reduce paste consumption. Using the mask, you spread a (larger) amount of paste, then remove the mask carefully to avoid overspill.

The Author

Passionate about his profession, electronics, through measurement and now particularly measuring time, Jean-Pierre Duval spent most of my career in electronics and robotics in the field of medical, biological, and agro-food laboratories. With the CECOS laboratory at the Cochin hospital in Paris, he perfected the first morphological sperm counters, which are still on the market today.

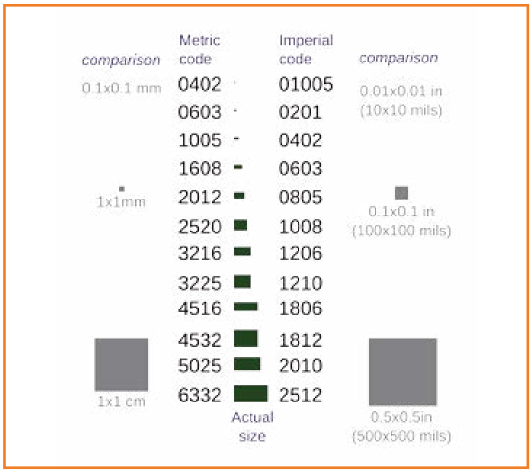
After use, the paste has to be kept in the ice-box and must be heated up at least 2 or 3 hours before you want to use it.

- Place the components on the paste pads (a delicate stage!)
- Baking or reflowing.
- Cleaning the circuit using a suitable chemical.
- Magnifier inspection to get rid of the little blobs of paste that are liable to create shorts.

Making the move to SMD involves a certain amount of investment, which you can minimize by making a sum of the tools yourself—including the reflow oven itself and the squeegee for applying the solder paste. But I will just point out that the project described here is not intended to be copied exactly. It should simply provide you with the initial inspiration, just as I myself drew inspiration from earlier projects [3].

Why fan-assisted?

Having worked for a long time inspecting ovens, incubators and autoclaves and measuring their characteristics, I know that an oven is only usable if its temperature is uniform at all points—whence the use of a fan-assisted oven. Imagine a cell culture to be carried out in an oven at 37 °C (98.60 °F). At 40 °C (104 °F) it will be cooked; at 35 °C (95 °F) it won't grow at all. So we need the same temperature everywhere. The same



comparison	Metric code	Imperial code	comparison
0.1x0.1 mm	0402	01005	0.01x0.01 in (10x10 mils)
	0603	0201	
	1005	0402	
	1608	0603	
1x1mm	2012	0805	0.1x0.1 in (100x100 mils)
	2520	1008	
	3216	1206	
	3225	1210	
	4516	1806	
	4532	1812	
	5025	2010	
1x1 cm	6332	2512	0.5x0.5in (500x500 mils)

Actual size

Figure 1a.
Identifying SMD resistors.

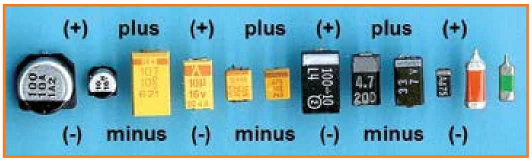

(+) plus (+) plus (+) plus (+)
(-) minus (-) minus (-) minus (-)

Figure 1b.
The polarized capacitors are marked. The + pole is indicated.

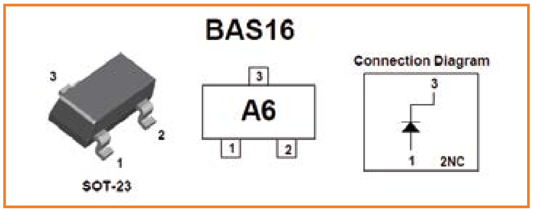


Figure 2.
The transistors and diodes in SOT packages (Small Outline Transistor) – Fairchild document.

SMD technology

For easier handling, it's best to choose components that are not too small. For resistors, just as for conventional components, the size of the device (**Figure 1a** and **1b**) varies according to the power to be dissipated. The .25-watt resistor size 1206, referring to its dimensions expressed in .01 inches, is the commonest. The metric designation is 3216 (3.2 mm by 1.6 mm).

Packages: there is a huge variety of packages, they are usually well described in the datasheets. To use certain devices like BGAs (Ball Grid Array ICs), which have ball-shaped soldering points hidden beneath the device, you need industrial fitting tools that amateurs and even smaller companies can't afford. Many SMDs exist in various packages, but some are only available in a single configuration.

Examples: SOT-23 (Small Outline Transistor) packages are often used for diodes or transistors, e.g. the BAS16 diode (**Figure 2**). For microcontrollers and other integrated circuits, some packages are easier to use than others; you can still just about handle a TQFP (Thin Quad Flat Package) with 64 pins on 0.8 mm pitch, but it becomes a real headache when you get down to a TQFP with 100 pins and only 0.5 mm pitch.

Certain components are not marked at all. The only solution: meticulous storage!

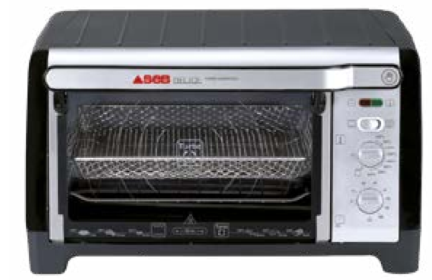


Figure 3a.
18-liter (.72 cft.) fan-assisted oven (SEB document).

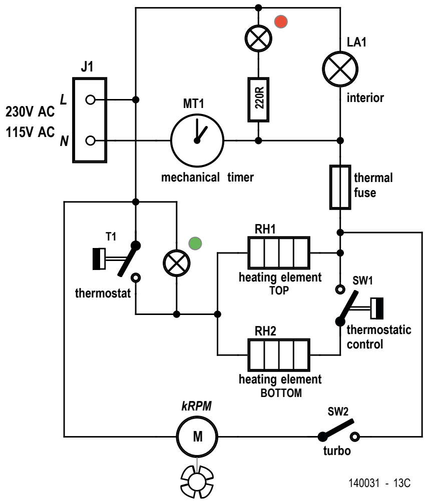


Figure 3b.
Oven circuit diagram.

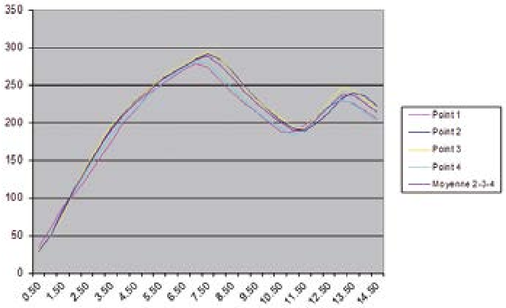


Figure 4.
Tests before modification. Curves 1–4 correspond to different points in the oven.

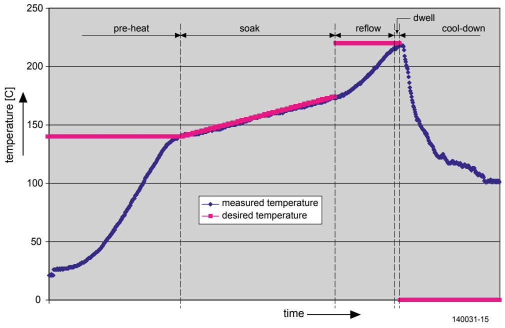


Figure 5.
The 2006 DIY Elektor Reflow Soldering Oven by Paul Goossens.

goes for an autoclave sterilizer: 121 °C (250 °F) means 121 °C (250 °F) everywhere. By stirring up the air in an enclosed space, the fan-assist avoids points of inertia and zones that are too cold or too hot.
I chose an SEB Délice 18-liter oven (**Figure 3**). To be quite truthful, I made a mistake when I bought my oven. Or rather, I was misled: the blurb said 1500 W heater element + 750 W grill. In fact, I have 750 W + 750 W. I should point out that the fault lies not with the manufacturer, SEB, but with the store.

Is 1500 W enough? Normally no—you need at least 2000 W; but with the fan assist *and* by adding heat reflectors, we can obtain a temperature and ramp-up times compatible with the specifications of the solder used. As a reminder, PCB-Pool offers a 1500 W convection oven. As for the high-quality oven offered by elektorPCBservice [1], that consumes 3000 W; its dimensions, in particular its height, allow the heat to be confined towards the PCB; its curves are remarkable.

Oven geometry

Before using or even modifying the oven, I wanted to check how even the heat was, taking four points in a plane within the space used for reflow: the center of the oven and three corners of a 10 × 12 cm rectangle.

Though the ripple on the curves, caused by the hysteresis of the bimetal thermostat, may seem surprising, they are all very close, irrespective of the measurement point, and confirm the assumption of the need to stir up the air. It will be noted that when set to 240 °C, the temperature measured at the center of the oven is over 270 °C—a difference doubtless explained by the off-center position of the bimetal strip, on the oven side wall. I recorded four cycles of 15 mins corresponding to the four measurement points, and took the average of the last three. Between each cycle, I let the oven cool down for around one hour (**Figure 4**). I discarded the first cycle as the thermocouple had moved.

The measurements were made using a K thermocouple, calibrated against a mercury thermometer that I used to use for my oven checking.

Thoughts on the reflow curves

Before starting this project, I read up on var-

In electronics, not moving forward equals going backward!

ious reflow ovens, particularly amateur ovens or ones converted by companies for sale to the public or small companies. Here, I'm only giving the curve for the Elektor Reflow Soldering Oven [3] (**Figure 5**).

The points in common with the other ovens I've examined are:

- The three fundamental phases:
- **Pre-heat:** phase where the temperature increases slowly; the duration doesn't seem to be critical, however the temperature must be less than 120 °C (100–120 °C)
- **Soak:** phase to prepare and activate the flux; increases slowly to 150 °C (150–170 °C)
- **Reflow:** rapid increase to around 30 °C above the melting-point of the solder paste used.
- **Dwell:** Hold for a short time (10–30 s) at the reflow temperature.
- Lastly cooling, end of heating, and (gently) opening the oven door.

We note that:

1. the temperature of each phase is first and foremost a function of the solder used. Check the recommended curve with your store or the manufacturer.
2. The **Pre-heat** time is important, it pre-conditions the **Soak** that comes next; the components are taken gently up to the soldering temperature. **Soak** and **Reflow** are a function of the oven power. They must not be too long, to avoid damaging the components.
3. Quality of the solder pastes used: those for SMDs are characterized by the eutectic point: the melting point of the alloy, which is lower than the melting point of each of the metals forming it. The quality of the flux is crucial, the wettability depends on it (**Figure 6**).

Constructing the reflow oven

Most of the questions you'll need to ask yourself revolve around the choice of the temperature sensor(s), the microcontroller, the regulation mode, and the display.

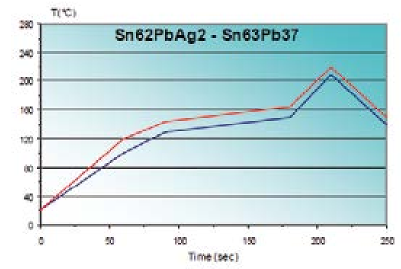


Figure 6. Examples of curves recommended by solder manufacturer MBO.

Measuring the temperature—a difficult one! Thermocouple, PT100, Anyone? I used a K-type thermocouple. As the oven is fan-assisted, it can be positioned under the board to be soldered. Everyone knows drafts cool down bodies. The thermocouple will indicate the temperature of the air and not the temperature of the bodies. As it's difficult to apply an inertia factor, I added an arbitrary 20 s of time for taking the temperature between pre-heat and reflow.

Microcontroller and programming language: I'm in the habit of using AVR microcontrollers from Atmel, programmed in Bascom BASIC; it's reliable and perennial. I only chose the Mega644 because I had one in stock and not the Mega32 to hand. They are pin compatible, but for this application the M32 would be more than adequate.

Choice of regulation mode: Pulsewidth modulation (PWM) or not? I asked myself that question at length. After a good many tests and experiments, I decided to go for a kind of slow PWM based on the slope of the measured temperature. I do not use the PWM timer. Instead, I measure the temperature as 0% at 0 seconds and 100% at 1000 ms. Every second, the temperature is checked and the system reacts accordingly. Everything is done in the `Phasefour()`routine of my program, which I am offering for you to download [2].

Choice of display: While I was perfecting the program, a graphics display (128 × 64) that I had was a great help for viewing the temperature/time curve; so I kept it in. It's a bit of a luxury—you could make do with an LCD.

Schematic: Only a few active components: the microcontroller, the graphics display, the Max6675 thermocouple converter, the solid-state relay, represented on the circuit by the terminal strip. Mine is a big relay that I had salvaged; this sort of solid-state relay, with no moving parts, has the advantage of switching at the zero-point of the phase voltage, meaning a total absence of interference.

I added a clock crystal so the durations could be controlled by a timed interrupt (**Figure 7**), two LEDs—one red (5 V supply indicator) and the other green (switching of the solid-state relay)—and filtering capacitors on the 5 V supply.

There is no 230 V AC line voltage in the electronic regulation part. I used a commercially available switch-mode power supply (5 V, 500 mA). The 230-V AC line voltage is applied via the original power cord; one wire though is connected to the large solid-state relay mounted on the oven carcass, the other goes via a fuse (8 A). For 120-V ovens a larger fuse is applicable.

Modifications

The modifications to the oven wiring involve removing the fan-assist/convection switch and the bimetal thermostat, and lastly, replacing the original timer with a switch (**Figure 8a**). I also

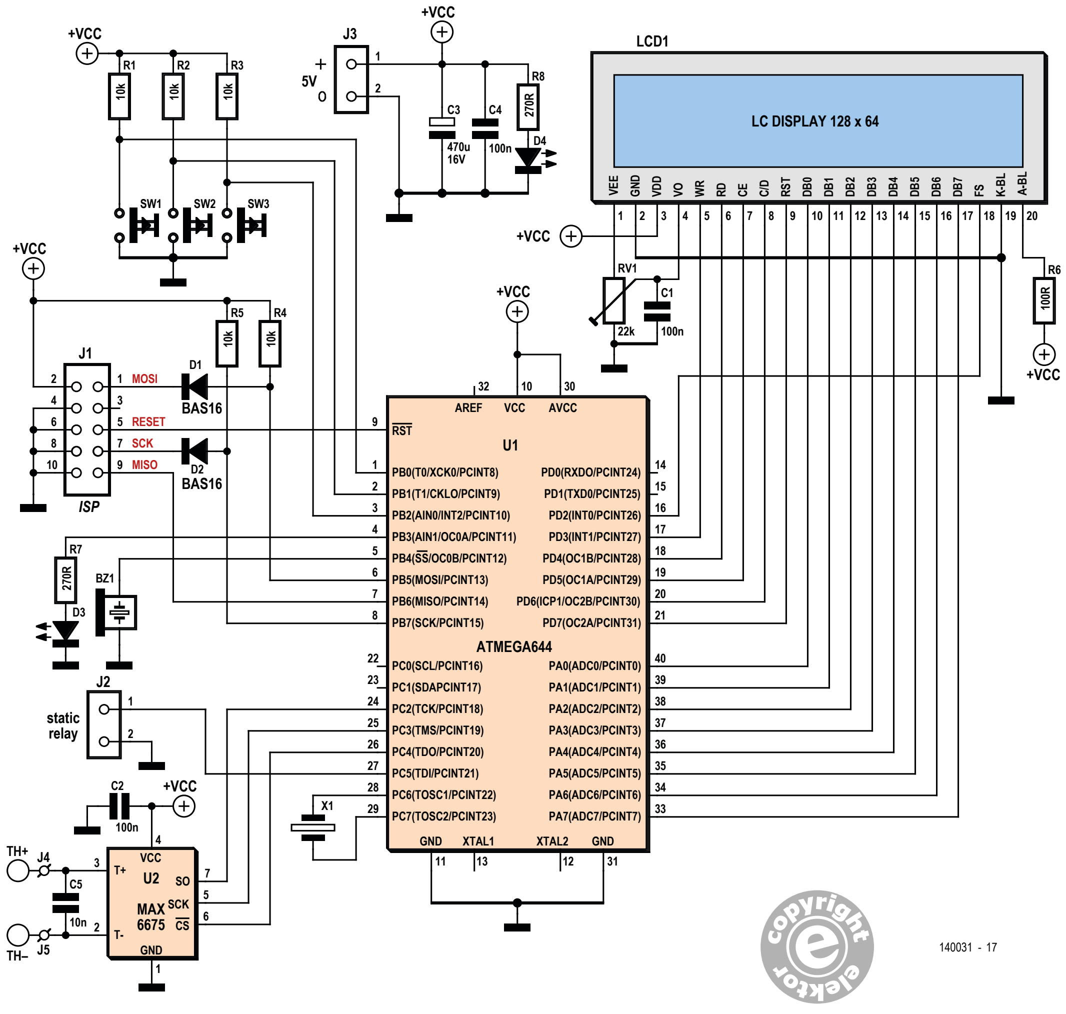


Figure 7.
Outline diagram of my control board.

fitted the solid-state relay (40 A, although 10 A would have been quite enough!) to the inside of the rear cover, a connector for the 5 V rail, along with a fuse holder and an 8-A fuse (**Figures 8b** and **8c**).

For improved efficiency, I modified the oven door. As manufactured, this consists of two glass panes spaced about 1 cm apart to avoid users burning themselves on the outside. To recover as much of the radiated energy as possible, I lined the *inner* wall with a reflector made from household aluminum foil, with the shiny side inwards. As the back of the oven includes a cavity to allow you to use round dishes, here too, in order to recover the maximum radiated heat, I inserted vertically a disposable aluminum freezer tray.

Operation

At start-up, the oven is in standby. Pressing the menu button takes us to the first choice: **Launch** corresponds to an immediate launch using the parameters in memory. **Parameters** gives you the choice to modify or view. Then depending on the choice, the user will be able to view or modify, for each phase, the temperature and the slope in % (**Figure 9a**) and (**Figure 9b**). By experiment, and paradoxically, the Pre-heat slope is 100 %—we need to overcome the oven's inertia.

Reflow sequence: For each phase, there are two parameters: the temperature and the slope, which can be changed depending on the solder paste, and which are saved in Flash memory, where they remain available even after a loss of power. The temperature settings copy the indications given with the paste used (see above). The slope corresponds to the speed at which the temperature rises.

A few screenshots of the reflow sequence (Figure 10): in these screens, Ts = time in seconds, t.d = temperature in degrees.
At the end of the cycle, the oven stops heats and an audible signal indicates it's time to open the door.

Results: The soldered SMDs are then examined under a magnifier: No micro-blobs? Are the solder joints shiny? Then everything's OK.

Figure 11a shows the board that drives my oven while it was being assembled.

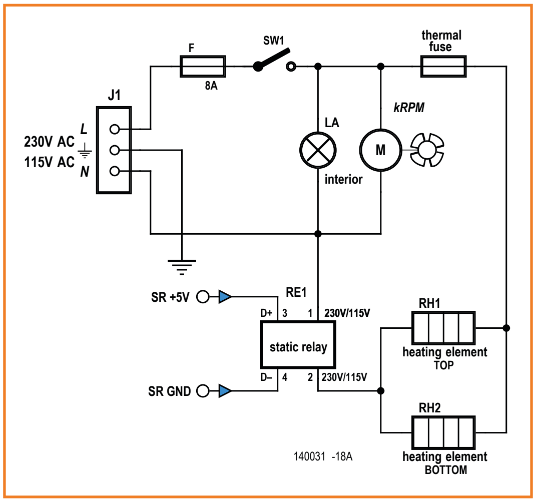


Figure 8a.
Circuit of the modified oven.

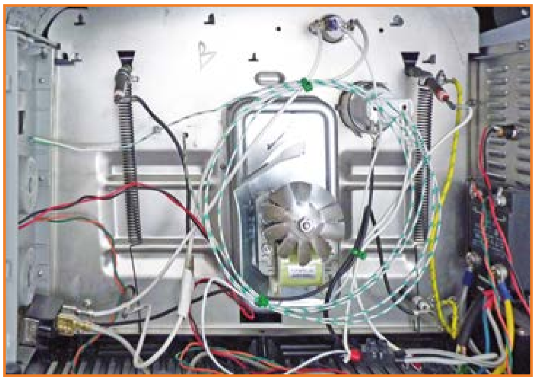


Figure 8b.
I kept the original Klixon safety thermostat.

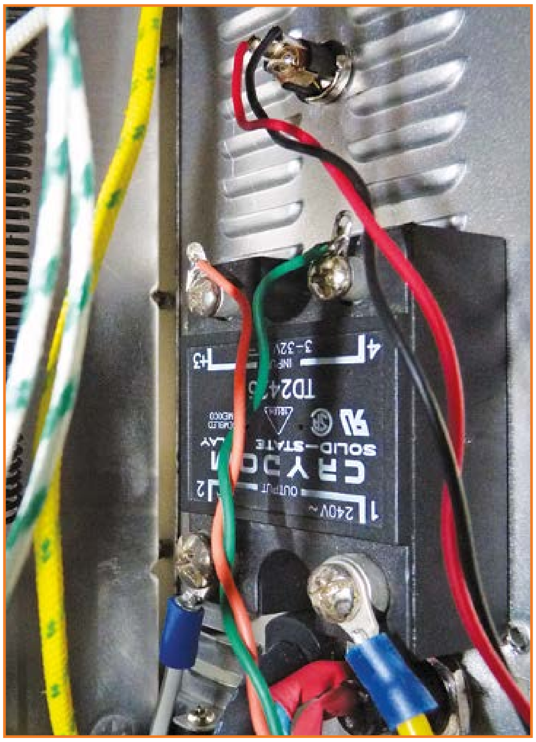
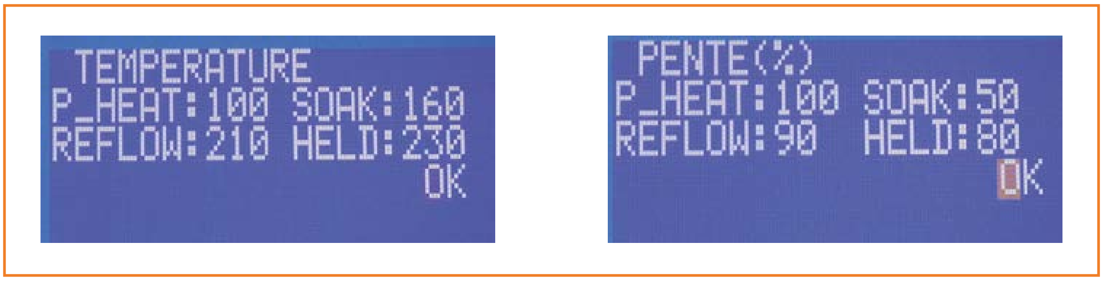


Figure 8c.
Detail of the salvaged solid-state relay and the 5 V socket.



```
 TEMPERATURE
P_HEAT:100 SOAK:160
REFLOW:210 HELD:230
                 OK
```

```
 PENTE(%)
P_HEAT:100 SOAK:50
REFLOW:90  HELD:80
                OK
```

Figure 9. Viewing the phase temperatures (a) and temperature rise coefficients (b).

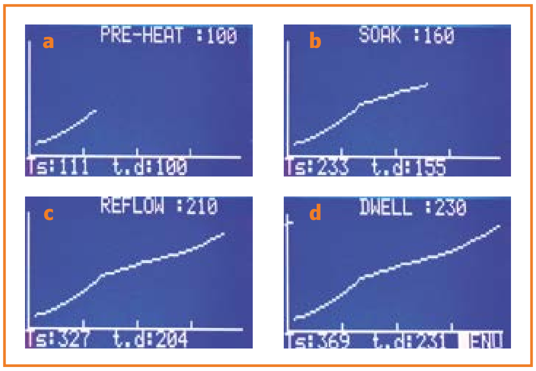


Figure 10. The phases: pre-heat (a), soak (b), reflow (c), dwell (d).

My first PCB soldered using the oven is a configurable resolution I²C thermometer from Maxim-IC (DS75) (**Figure 11b**).

The program

Apart from the ATMEGA 644, I've used the MAX6675, which compensates the reading of the thermocouple junction and converts it into a 16-bit digital value, of which 12 bits can be used for the temperature. One bit signals a thermocouple error: absence of thermocouple, for example. It uses the SPI protocol.

The program written in Bascom BASIC (thanks to EX4 on the Bascom forum who sent me the MAX6675 section) consists of a main module, `fourRefusion5.bas`, and two sub-programs, `SubandFunction.Bas` and `FonctionFour.bas`.

Interesting, isn't it? Are you still hesitating? Allow yourself to be tempted by the experiment, you won't regret it—once you start doing reflow, electronics takes on a whole new dimension.

(140031)

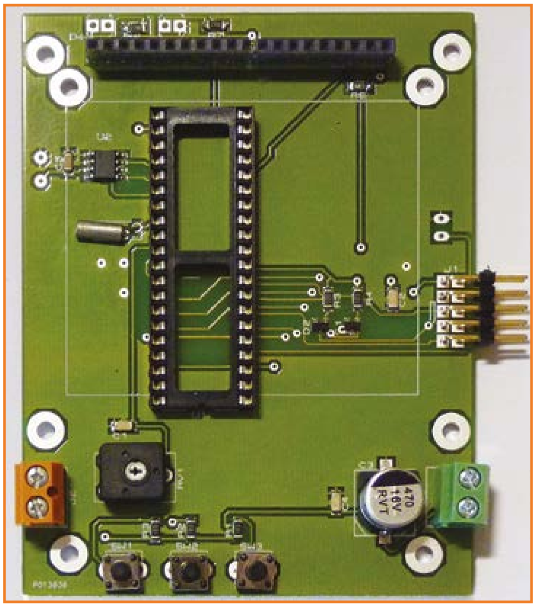


Figure 11. My oven control board being assembled.

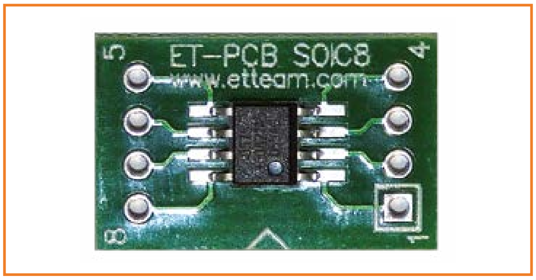


Figure 12. My first "cake": an I²C thermometer.

Web Links

[1] eC-mate reflow oven from elektorPCBservice: http://goo.gl/3gIZrn

[2] Project software (free download): www.elektor-magazine.com/140031

[3] Elektor Reflow Soldering Oven Elektor, January 2006: www.elektor-magazine.com/050319

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DesignSpark Tips & Tricks

Day #11: Working with Large Designs

By **Neil Gruending** (Canada)

Today let's try a larger, more complex design in DesignSpark PCB that uses multiple schematic sheets.

So far I've been using small design examples that fit on a single schematic sheet. Today let's try using multiple schematic sheets in DesignSpark PCB like you would for a larger design.

Creating multipage schematics

I usually like to partition larger designs into multiple schematic pages to help break it up into multiple logical blocks. Each page has its own unique net list and connections between sheets are done with "ports" or "sheet connectors" depending on the PCB package. DesignSpark PCB can do all of this with a little effort.

Once a schematic has been added to a project file, DesignSpark will make sure that it has unique reference designators across the entire design and will warn you if it finds any duplicates. Any added components will also get unique designators. Net connections on individual pages are also assigned unique names but you can create net connections between sheets by giving it a name which makes it global across the project. The name can be anything but I recommend that it doesn't start with "N" followed by numbers which is the default DesignSpark naming convention. DesignSpark already includes power and ground components which automatically create global power nets. Although you can use custom net names to join nets across pages I find it makes a schematic very difficult to follow and understand. So instead we'll create "port" symbols like in **Figure 1** which shows an example of an input port, bidirectional port and an output port. They are just a simple one-pin component with an arrow to indicate the signal direction.

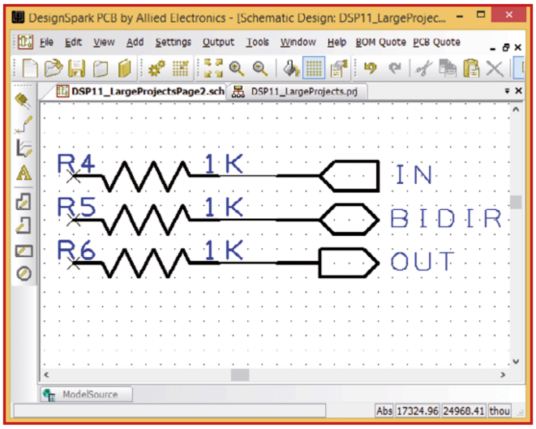
DesignSpark PCB by Allied Electronics - [Schematic Design: DSP11_LargeProjec...
File Edit View Add Settings Output Tools Window Help BOM Quote PCB Quote
DSP11_LargeProjectsPage2.sch
DSP11_LargeProjects.prj
R4
1K
IN
R5
1K
BIDIR
R6
1K
OUT
ModelSource
Abs 17324.96 24968.41 thou

Figure 1. Schematic port symbol example.

You use the ports by placing them on a schematic page and wiring them appropriately. DesignSpark doesn't allow library components to show net names automatically at a fixed position so you will need to do that manually. When you right click on a wire, you can select the "Display Net Name" to show the net name and then manually move it how you would like it. Don't forget to change the net name to a custom one by right clicking on the net name and selecting the "Change Net" option because

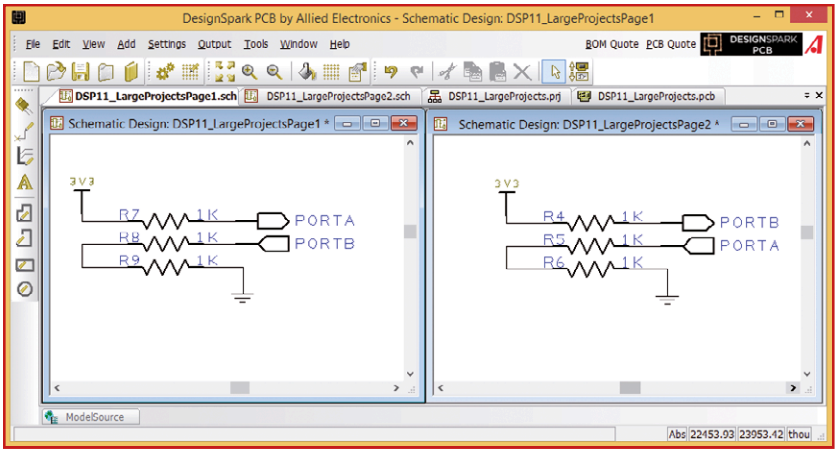
DesignSpark PCB by Allied Electronics - Schematic Design: DSP11_LargeProjectsPage1
File Edit View Add Settings Output Tools Window Help
BOM Quote PCB Quote
DESIGNSPARK PCB
DSP11_LargeProjectsPage1.sch
DSP11_LargeProjectsPage2.sch
DSP11_LargeProjects.prj
DSP11_LargeProjects.pcb
Schematic Design: DSP11_LargeProjectsPage1 *
3V3
R7
1K
PORTA
R8
1K
PORTB
R9
1K
Schematic Design: DSP11_LargeProjectsPage2 *
3V3
R4
1K
PORTB
R5
1K
PORTA
R6
1K
ModelSource
Abs 22453.93 23053.42 thou

Figure 2. Multipage schematic example.

DesignSpark will automatically hide all of the default net names in the "Change Net" window making them impossible to select.

Let's use the two-page schematic in **Figure 2** for the rest of our discussion. I've kept is simple so it's easy to see how net connectivity works in DesignSpark.

Creating the PCB

Now let's import our design into a PCB to make sure that the PORTA and PORTB nets are connected properly. First you create the PCB file using the File->New command and checking the "Add to Open Project" box which will give you a blank PCB. Now open one of the schematic pages and use the "Tools->Forward Design Changes" menu to add the components and nets to the PCB. After a little editing I got a PCB like in **Figure 3**. I labeled all of the net connections to show that the netlist was properly imported, including the PORTA and PORTB nets.

Cross probing nets

Our example multiple page schematic is pretty simple so it's easy to remember the entire schematic while working on it. But this becomes an issue for large complex designs when you are trying to understand a net connection and you want to do something like match a net connection in a PCB to a schematic. This is called cross probing the nets and it's one of the new features in DesignSpark PCB version 6.0.

So how do you cross probe a net in the new version? Use the "Edit->Cross Probe" menu to go into cross probe mode. Now every net connection you click on a net in the PCB will automatically be selected and shown in the schematic. If you click on a net in the schematic then it will be selected and shown in the PCB as well. Once you're done probing nets the "Edit->Cross Probe" menu will exit cross probe mode.

The PORTA and PORTB sheet to sheet connections in our example project are a special case for cross probing. When you select one of those nets in the PCB, DesignSpark will highlight all of the PORTA/B connections but it will only open one of the schematic pages for viewing. The easy way to see all of the PORTA/B connections is to go into cross probe mode in the schematic sheet and select the net. This makes DesignSpark open the reset of the schematic pages that contain that net and display them all simultaneously. For example, **Figure 4** shows how DesignSpark highlights the PORTB net when I clicked on it from the PCB with this procedure.

(140027)

Web Link

[1] www.rs-online.com/designspark/electronics/eng/knowledge-item/designspark-pcb-cross-probe-overview

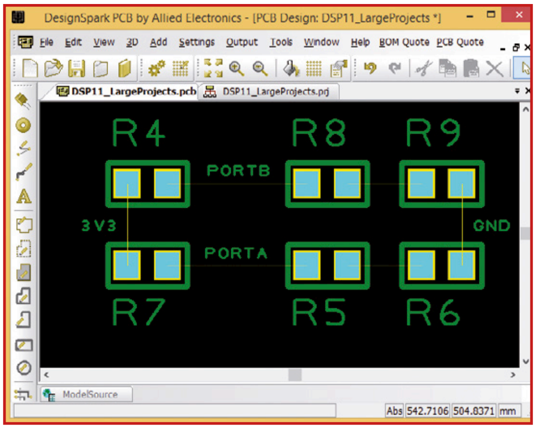
DesignSpark PCB by Allied Electronics - [PCB Design: DSP11_LargeProjects *]
File Edit View 3D Add Settings Output Tools Window Help BOM Quote PCB Quote
DSP11_LargeProjects.pcb
DSP11_LargeProjects.prj
R4
R8
R9
PORTB
3V3
GND
PORTA
R7
R5
R6
ModelSource
Abs 542.7106 504.8371 mm

Figure 3.
Imported PCB.

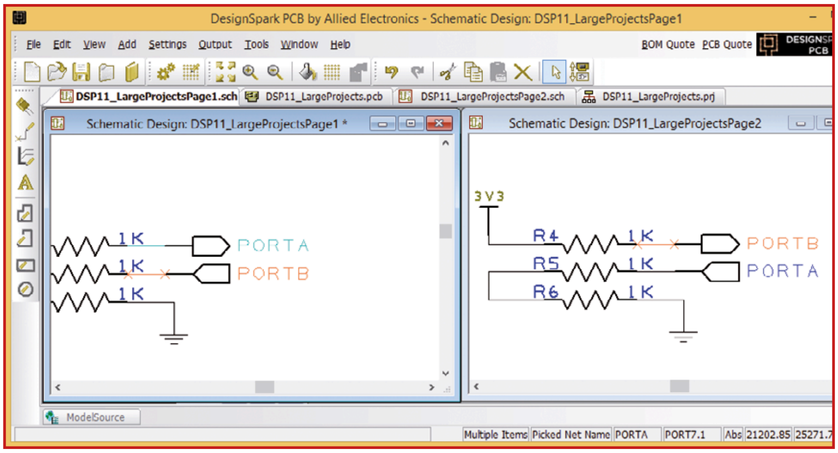
DesignSpark PCB by Allied Electronics - Schematic Design: DSP11_LargeProjectsPage1
File Edit View Add Settings Output Tools Window Help
BOM Quote PCB Quote
DESIGNSPARK PCB
DSP11_LargeProjectsPage1.sch
DSP11_LargeProjects.pcb
DSP11_LargeProjectsPage2.sch
DSP11_LargeProjects.prj
Schematic Design: DSP11_LargeProjectsPage1 *
Schematic Design: DSP11_LargeProjectsPage2
1K
1K
1K
PORTA
PORTB
3V3
R4
R5
R6
1K
1K
1K
PORTB
PORTA
ModelSource
Multiple Items Picked Net Name PORTA PORT7.1 Abs 21202.85 25271.7

Figure 4.
Cross probing nets.

Varactor Diodes

Weird Component #6

By **Neil Gruending**
(Canada)

If you've ever touched any RF circuitry there's a very good chance it contained at least one variable capacitor in its voltage controlled oscillators (VCOs) and filter circuits. They used to use mechanical variable capacitors but now varactor diodes, also known as varicaps, are preferred because of their small size, high performance and excellent tracking ability. **Figure 1** shows the schematic symbol for them.

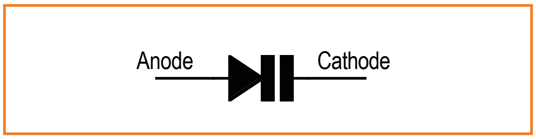

Figure 1.
Varactor (varicap) schematic symbol.

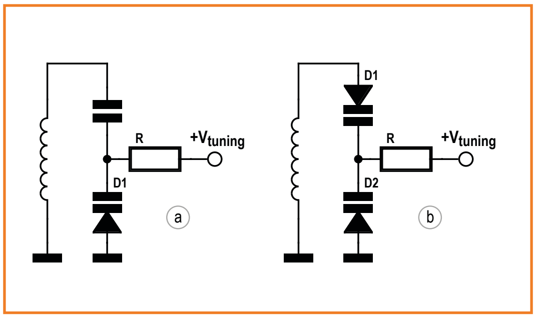

Figure 2.
Varactor circuit examples.

All semiconductor PN diode junctions have a small amount of variable capacitance when they're reversed biased. The reverse bias on the diode PN junction creates an insulator region at the junction that creates a small parallel plate capacitor. The insulator width will increase with the bias voltage which decreases the effective capacitance. This is what gives diodes their variable capacitance. Varactor diodes, however, are specifically optimized for their capacitance properties and have two distinct types based on their adjustable range. Abrupt varactor diodes change a small amount of capacitance for a change in bias voltage which gives them high *Q* (quality factor) and low distortion properties. Hyperabrupt diodes on the other hand have a much larger change in capacitance over the same bias voltage change which can increase distortion. Abrupt diodes can have a capacitance range of 2:1 whereas hyperabrupt diodes typically have a capacitance range of 10:1. In the past, power varactors of the hyperabrupt variety were used as frequency multipliers (mostly triplers), providing a cheap way for radio hams to produce a few watts of RF power on UHF like 70 cms (144 MHz × 3) or SHF like 23 cms (430 MHz × 3). The method is suitable for non-linear modes only, i.e. FM and CW.

Figure 2 shows two varactor diode circuit examples. Both circuits are using the varactor diode to adjust an LC tank circuit by changing the diode reverse bias voltage V_{tuning}. Figure 2a is a simpler design and works well with low amplitude signals. However, when the signal gets too large it will affect the diode bias voltage and cause distortion. Figure 2b uses two diodes to counteract the distortion at higher signal levels. This is because as the signal causes one diode to decrease its capacitance the other one will increase its capacitance by the same amount. The downside is that the two diodes in series will have half the capacitance which is significant when we're talking about capacitors in the picofarad range.

The varactor diodes don't need a lot of bias current so the value for R isn't critical as long as it provides enough isolation between the bias voltage and the tank circuit. Sometimes you will see an inductor used instead, but its function is the same. It's also important to keep the diodes reverse biased because they will create a lot of spurious noise if they start to forward conduct. If you want to experiment with varactor diodes but don't have any, try a regular diode from your parts box. Lots of people have had success using 1N400x diodes, power rectifier diodes, zener diodes and even LEDs. Just don't give up—it may take several tries to find a diode that works!

(140026)

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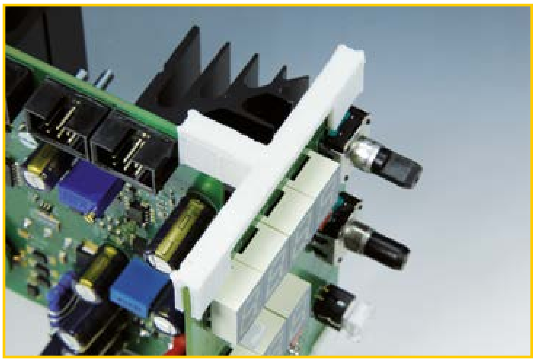
3D-Print Your Own Ink

By Clemens Valens (Elektor.Labs)

3D printing is all the craze. Even national TV networks covered the subject and today you can buy a 3D printer on almost every street corner. And yet, with all these printers around, with all those enthusiasts busy printing in 3D, I still have to see the first really useful 3D-printed output.



A useful (to us!) 3D-printed object to keep two PCBs together.

Officially, none of these objects were 3D-printed at Elektor Labs.

Many 3D printers are used to print parts to build another 3D printer. It is almost a self-replicating machine, and it is probably fair to say that 3D printers have brought mankind one step closer to this self-imposed goal. Printing such parts is nice, but why would you do that if you already have a 3D printer? “So that someone else can build one too!” is the habitual answer. I see.

Another popular job for 3D printers is to print “things” — all kinds of small objects, artful or not, that serve no other purpose than showing off the 3D printer’s capabilities.

Technology forecasters predict that in a few years’ time most households will own a 3D printer and they may very well be right. I do find this a bit worrying though, because what are all these people going to print? Exactly! Lots of objects and things that have no other purpose than to keep their 3D printer busy.

The “ink” used by most 3D printers is a kind of plastic wire—actually, a polymer filament, which implies that their output consists of polymer objects. According to Wikipedia, common polymers used in 3D printing are acrylonitrile butadiene styrene (ABS), polycarbonate (PC), polylactic acid (PLA), high density polyethylene (HDPE), PC/ABS, and polyphenylsulfone (PPSU)—available in brilliant colors, of course.

Probably, most of the polymer objects we are going to print in huge quantities will sooner or later end up as 3D printed waste, resulting in tons of high-tech waste besides our obsolete cellphones. Already, projects have been launched to find ways to create the polymer filament from waste products, so we will not run out of “ink” soon. But wait a minute—wouldn’t it be much simpler and cheaper to print the polymer filament with our 3D printer? Then we can use the printer to not only print itself, but also its own ink and we have a truly self-sustaining system. All we have to do is to put energy in it to keep it running. Lots of energy, I admit, but well spent, because the 3D printing circus has a high amusement factor.

After this rant I dare you to 3D print something useful and I don’t mean a coat hanger or some other trinket or gizmo you can buy of better quality and for less money than you can print it. Please post photographs of your useful 3D printed objects on Elektor.Labs (or send them to labs@elektor.com and we will put them on the web for you). The photograph of the most useful object (subjective, I know!) will win something nice, I promise. Meanwhile here is a photo of a useful object we printed for one of our upcoming projects. The other photo shows other products of a less useful variety.

(140025)

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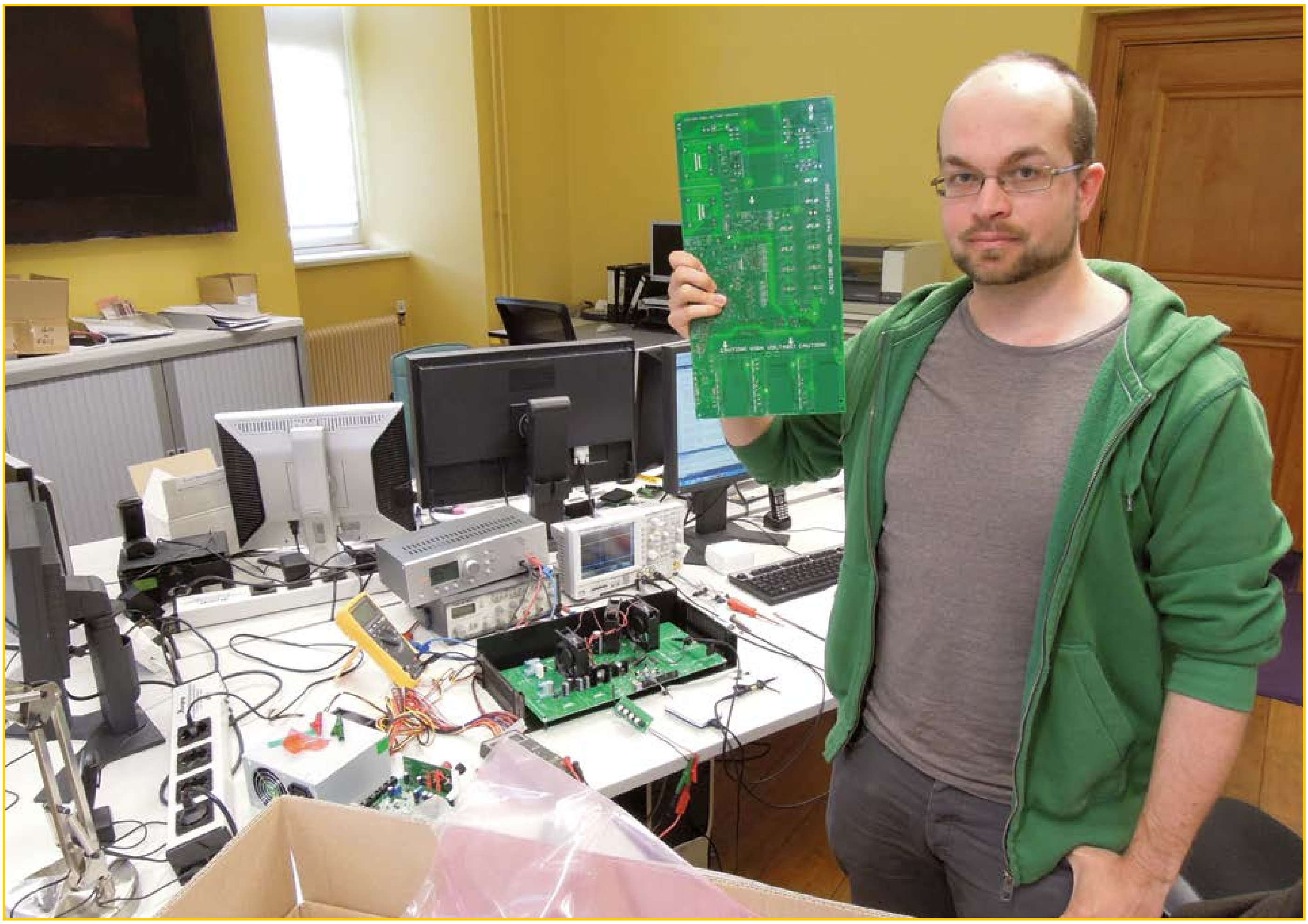
Jumbo PCB to escape from Labs



By **Thijs Beckers**
(Elektor Labs)

We suspect Labs trainee Arne Hinz, student of Electrical Engineering at RWTH Aachen, Germany (photo) has designed what is believed to be the largest PCB ever to originate from Elektor Labs. This first prototype of the board measures an amazing 37.5 × 19 cms (14.8 × 7.5 inches). After fitting it into a case, thoughts arose to make the board even bigger to facilitate easy mounting onto the available screw mounts.

What does it do, you ask? Well, it's a beefy single-phase to three-phase AC converter with adjustable frequency. Final specifications are subject to change, but the initial goals were:

- frequency adjustable from 0 to 400 Hz;
- output power 3 kW.

With this first prototype, the input voltage is limited to 230 VAC, but other line voltage options like 120 VAC are not ruled out and can be implemented at a later stage of the design cycle.

Though this project will not be ready tomorrow, we are planning on releasing the plans later this year rather than next year, so keep an eye on upcoming magazines if you are interested in this design!

(140024)

Chip Tips: The MAS6510

Capacitance-to-Digital-Converter

By
Viacheslav Gromov
(Germany)

Many modern sensors express their measurements in the form of a change of the sensors capacitance or inductance. Converting these changes into digital values usually requires a special interface and complex electronics. In-house solutions using a microcontroller require not just programming skills but also analog know-how and usually, a bit of tinkering. It's good that there are also some tailor made ICs available to do the job. The chip used here is a Capacitance to Digital Converter (CDC); it needs nothing more than connection to the sensor. There are a few features to consider for reliable and stable operation.

Figure 1.
A miniature capacitive pressure sensor from VTI technologies.

The IC MAS6510 is supplied by the 'fabless' semiconductor manufacturing company **M**icro **A**nalog **S**ystems Oy based in Finland. This particular chip is only supplied in a QFN16 package outline measuring 4 x 4 x 0.75 mm. It features a Delta-Sigma-converter with 24-bit resolution suitable for interfacing with capacitive pressure and humidity sensors in MEMS technology (see **Figure 1**). Sensors using the change of capacitance of a single capacitor connect to pins CS and CC (see **Figure 2**) of the MAS6510. The chip also has a CR input for dual capacitance sensors. More details of this configuration can be found on the data sheet [1]. MAS also produce a simplified variant of this chip with 'only' 16-bit resolution and a version specifically for piezoresistive sensors. All variants use the familiar SPI and I²C bus interfaces.

The MAS6510 block diagram in **Figure 2** shows two internal trimmer capacitors at the sensor inputs CS and CR. These capacitor matrices are used for sensor-offset calibration and their values are software programmable. These parameters along with parameters defining the clock division ratio and operating mode are stored in an internal 32 Byte EEPROM. The chip's I²C address is also stored here, leaving 27 bytes available for storage of any other application specific data such as sensor trim and calibration values. The data sheet gives detailed information about memory usage and register description. The principle mode of operation is governed by the type of sensor in use whether it has one or two capacitors at its output: it can measure the capacitance of a single capacitor or the ratio of two capacitors (CS - CR)/CS or the difference between the two capacitor values CS – CR. The measurement range extends to 20 pF (see **Table 1;** view original specs at [2]). Use of the internal clock divider allows this base capacitance range to be increased. A capacitance difference of 20 pF is allowed in differential mode which can also be extended by using a lower clock frequency. Some sensors that use the ratio of two capacitors employ linearization to correct the otherwise non-linear 1/C characteristic. The internal divider can divide the clock by a maximum of 1/8. The clock can optionally be derived from an external source.
Supply voltage to the chip is in the range from 1.8 to 3.6 V. The operating current is dependant on supply voltage and the sample rate ranging from a minimum of 3.3 to 48 µA at one sam-

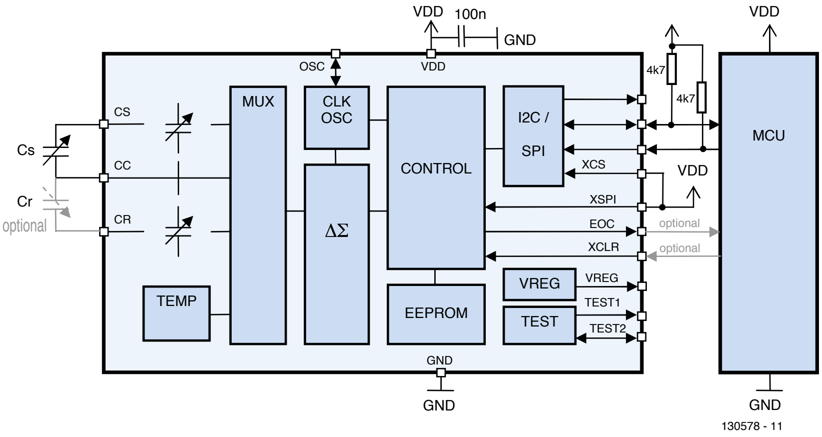


Figure 2.
The MAS6510 block diagram.

ple per second. Between measurements most of the power-hungry chip functions are switched to sleep mode. The maximum conversion rate is dependant on the clock rate between 12 and 173 Hz. The actual useable resolution will always be 17.5 bit. The MAS6510 can also measure chip temperature and V_{DD} supply voltage for use as measurement compensation to improve accuracy.

(130578)

Web Links

[1] www.mas-oy.com/en/products/sensor-signal-interface-ssi/mas6510/

[2] MAS6510 datasheet: http://www.mas-oy.com/uploads/Data%20sheets/DA6510.pdf

Table 1. The MAS6510 characteristics (author's summary).

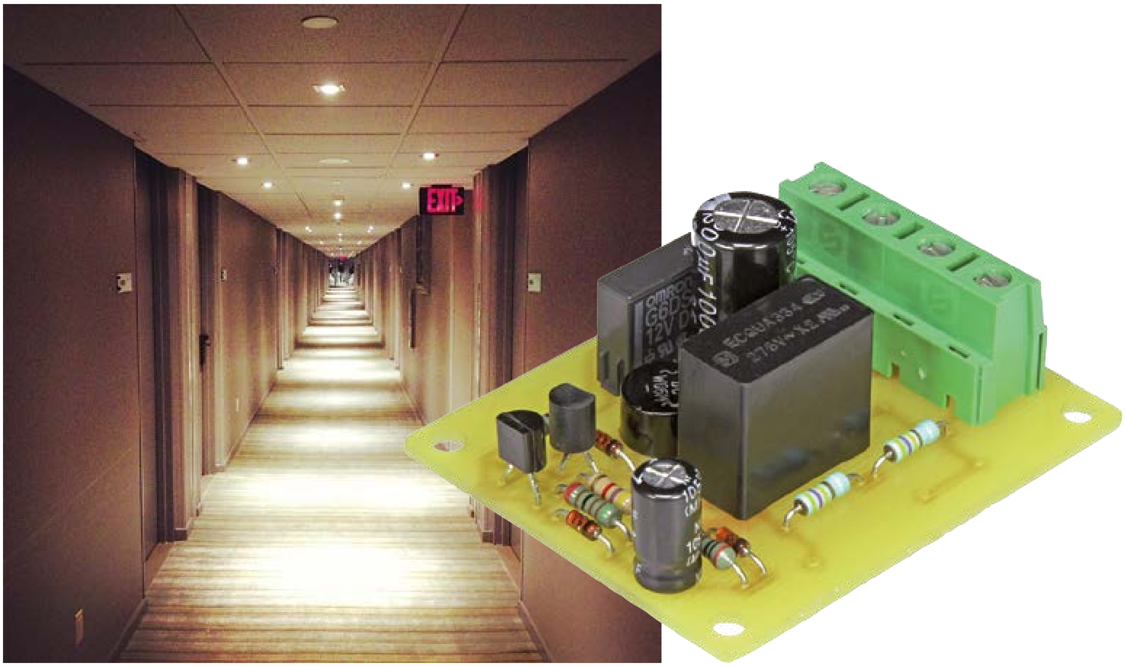
Parameter	Conditions	Min.	Typ.	Max.
Supply Voltage V_{DD}		1.7 V	2.7 V	3.6 V
Average current Consumption I_{DD_AVG} (resolution dependent)	1 conversion/s; Cap. Dif. Reg OFF		3.3 µA	

Conversion time t_{CONV}	Normal clock (SOSC=00);
	OSR=256
			5.8 ms	

Internal system clock oscillator frequency f_{SYS_CLK}	Normal clock (SOSC=00)		200 kHz	
Sensor excitation frequency M_{CLK}	Normal clock (SOSC=00)		50 kHz	
Serial Bus Clock Frequency f_{SCL}	I²C bus SPI bus			400 kHz 2 MHz
Changing capacitance range in capacitance difference mode ΔC_{DIFF}	Division by 2 (SOSC=01)	2 pF		30 pF
Maximum sensor capacitance in capacitance difference mode C_{S_MAX}	Division by 2 (SOSC=01); int. oscillator			40 pF
Changing capacitance range in capacitance ratio mode ΔC_{RATIO}	depending on sensor characteristics	2 pF		20 pF (>20 pF)
Operating Temperature T_A		–40 °C	+25 °C	+85 °C

Multi-switch Lights Control

For corridors and hallways



By
Michael A. Shustov
(Russia)

Complex electrical wiring is required if a single load like hallway or corridor lighting is to be switched on and off by any one of a large number of switches. Here we propose a workaround using a DIY thyristor.

Looking at the schematic in **Figure 1**, imagine the AC grid voltage to the circuit arriving on K1 via a chain of pushbutton switches of the normally-closed type. The switches can be any number from two in a small hallway to tens distributed along endless hotel corridor walls like we saw in *The Shining*. Electrically the switches are in in series in the Neutral or Live line. LA is the load, it is powered through relay contact RE1B and connector LA1.

Initially the circuit's AC supply voltage arrives on rectifier B1 through series capacitor C3 (or C3||C4 for 115 VAC grids) shunted by R6/R7, and R5. Zener diode D3 at the rectifier output limits the voltage on the control circuit to about 15 V. Resistor R4 and capacitor C2 (which has a relatively low capacitance) shunt the zener diode. Capacitor C1 (with a high capacitance—1000 µF) is connected via diode D2. The quasi thyristor formed by transistors T1, T2 and relay coil RE1A is effectively in parallel with C1. The 'control electrode' of the thyristor-analogy is connected to the cathode of D2.

When any of the pushbuttons (not drawn) in the AC supply voltage chain is pressed, capacitor C2 discharges rapidly and the control electrode of T1-T2 is effectively connected to C1. The DIY thyristor 'fires' thanks to capacitor C3 discharging. Consequently the relay contact is energized, switching on (lamp) load LA.

When the pushbutton in the chain is released, the AC grid voltage is applied again to the circuit, causing a charge voltage to C1 to be upheld and the *ersatz* thyristor to keep conducting. To turn off the lights, users press any of the pushbuttons in the corridor and hold it down for about a second. This causes capacitor C1 to discharge completely, T1-T2 to be reset, and the relay and consequently the load to be switched off.

Construction

The PCB deigned for the project appears in **Figure 2**. It is compact at a size of 54.4×45.5 mm. It might just fit inside a flush-mount wall electrical box but certainly inside a junction box. If necessary the PCB corners can be filed off. The relay is a type with low power consumption and a small footprint (approximately 5×20 mm). The high sensitivity coil type of the 12-V version device from Omron's G6DS series from only requires 10 mA nominal coil current to activate—it has one normally-open (NO) contact. In practice, this relay should actuate at about 70% of the nominal value. The single, normally-open, relay contact can handle up to 5 A with a resistive load, or 2 A with an inductive load.

The lead spacing of the capacitors in the AC grid voltage divider (C3 and C4) is either 15 mm or 22.5 mm. Their values are not the most common for X2 class capacitors. C4 should only be mounted if the AC grid voltage is 115 VAC.

(130179)

Caution. Parts, connections, wires and copper tracks in this circuit are at live potential. The circuit must be enclosed in an approved case observing all relevant precautions in terms of electrical safety. Never work on the circuit with AC power connected to K1.

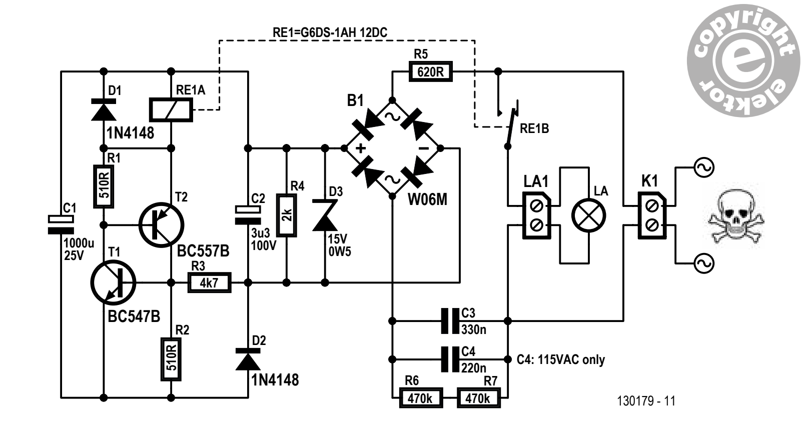


Figure 1.
Schematic of the Multi-switch Corridor Lights Control.
T1-T2-RE1 do a good job at mimicking a thyristor.

Component List

Resistors

R1,R2 = 510Ω 1%, 0.25W
R3 = 4.7kΩ 5%, 0.25W
R4 = 2.0kΩ 1%, 0.25W
R5 = 620Ω 1%, 0.5W
R6,R7 = 470kΩ 5% 0.25W

Capacitors

C1 = 1000µF 20% 25V, 0.2'' pitch, diam. 10mm max.
C2 = 3.3µF 20% 100V, 0.1'' pitch, diam. 6.3mm max.
C3 = 330nF 20% 275VAC, Class X2, 15 or 22.5mm pitch, width 11mm max.
C4 = 220nF 20% 275VAC, Class X2, 15 or 22.5mm pitch, width 8mm max.*

Semiconductor

B1 = W06MG, bridge rectifier, 600Vpiv, 1.5A (WOBM)
D1,D2 = 1N4148
D3 = BZX55C15, 15V zener diode, 0.5W, DO-35
T1 = BC547B
T2 = BC557B

Miscellaneous

K1,LA1 = 2-way PCB mount screw terminal block, 7.5mm pitch
RE1 = relay, G6DS-1AH 12DC, PCB mount, SPNO, coil 12VDC / 10mA, contact 250VAC / 5A
PCB # 130179-1 v1.1

* use with 115VAC only

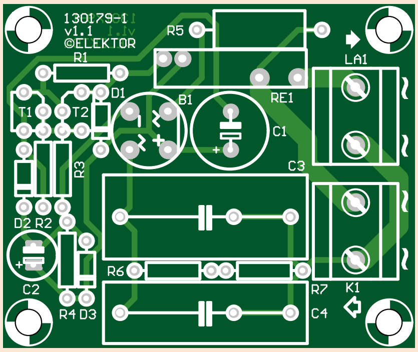
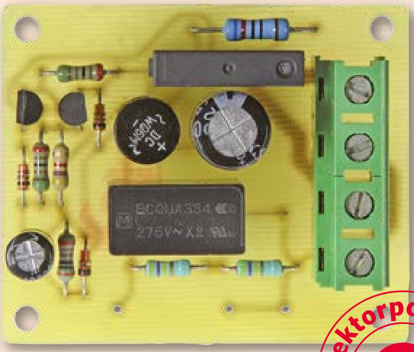
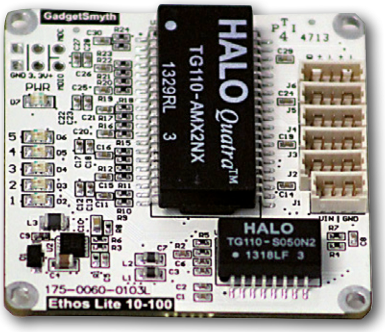


Figure 2.
Circuit board designed for the control.





Ethos lite Tiny Ethernet Switch

The **Ethos lite** is a tiny unmanaged Ethernet switch that has 5 ports, supports 10/100 Mb data rates on a board measuring just 1.75" x 1.75" and weighing only 15 grams. One primary area where the Ethos lite stands out is in situations where weight and power are high priorities such as Unmanned Aerial Vehicles or robotics. All 5 ports are fully shielded with magnetic couplers for common mode rejection meeting Ethernet wiring specifications. This allows designers the ability to skip the large RJ45 connectors and wire directly onto connected peripherals or place the connectors in a more flexible location.

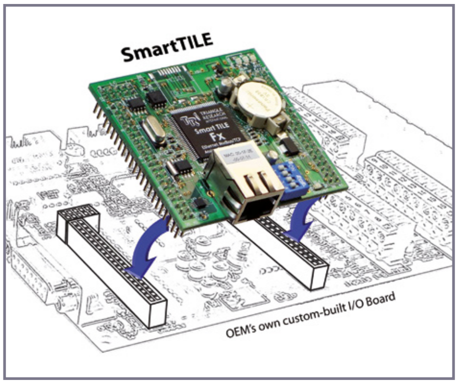
The Ethos board can accept a wide range of voltage input from 5-15V making it an ideal fit for Unmanned Systems that provide battery power. The Ethos board can also double as a 3.3 V regulator providing up to 1 amp of current. Under full load (all 5 ports actively sending data) the Ethos consumes less than 2 watts. Connections to the Ethos lite are provided by Molex PicoBlade headers with one for each port and an additional connector for power. As an added feature the MDIO lines to the Ethernet switch IC have been exported allowing developers access to management data registers. Included with the Ethos lite is the main board along with 6 Molex PicoBlade cables (5 with RJ45 connectors, 1 with bare wires for power). The Ethos lite costs $250 with the ability to purchase extra Molex cables in a variety of configurations.

www.gadgetsmyth.com (130521-V)

Tastier Than Four Raspberry Pis

HABEY USA, a leading manufacturer of embedded computer and a Freescale Connect Partner, announces The HIO Project, an open hardware project to enable developers and users to have access to an affordable Freescale i.MX6 ARM Cortex A9 Processor based open architecture platform. The core component of the HIO Project is the HIO Mainboard, model HIO-EMB-1200. It is a Post-it sized, Lego-like ARM based open modular platform for rapid prototyping, quick application module development and fast time to market. Unlike the traditional Computer-on-Module (COM) or PC/104 standard, the HIO Mainboard is a fully functional ARM computer board with on-board Freescale i.MX6 ARM processor, RAM, iNAND flash, HDMI, USB and power input from mainboard or add-on boards. Measuring just 72mm x 80mm, the HIO-EMB-1200 is based on HIoTX, a newly developed form factor by HABEY USA for the HIO Project. It is 80% smaller than the mini-ITX form factor and 20% smaller than the tiny PICO-ITX standard. The HIoTX form factor leverages the Freescale i.MX application processor's rich I/O feature and flexibility. The HIO Mainboard's unique low-profile modular design allows it to fit into space-restrictive applications while still allowing 3-dimensional expansion utilizing its 200-pin female header on the top and bottom of the board. It provides an fresh platform for the latest generation of small, smart, interactive and connected devices in the new Internet of Things.

www.hioproject.org (140116-I)



The SmartTILE (Smart TRi Integrated Logic Engine)

Triangle Research International Inc. (Tri) now gives OEMs an easy and affordable way to custom-build an in-house PLC for their own line of equipment products. The SmartTILE is a PLC CPU-board that plugs onto a carrier I/O board which an OEM is free to design, the combination being a fully integrated PLC optimized for the OEM's current and future needs. Compared to building a controller from scratch each time, this significantly shortens the OEM's time-to-market for all new product line releases, saves money from reduced assembly manhours and unnecessary components that come with off-the-shelf PLCs, and allows for a consistent standard for post-sales equipment troubleshooting, maintenance and related-training. Programmed in the powerful iTRILOGI Ladder+BASIC language, the SmartTILE includes an integrated Ethernet port and carries all the capabilities of TRi's established F-series PLCs, including floating-point math.

www.triplc.com/smarttile.htm (140116-II)

Sensirion's Liquid Flow Sensor Flies into Space

On May 6, a rocket will lift off bound for the International Space Station (ISS). On board will be a liquid flow sensor from Sensirion AG, Stäfa, Switzerland. The sensor is part of a research project by Minnehaha Academy in Minnesota that is investigating the impact of microgravity on the effectiveness of liquid flow. Among other potential findings, the project aims to shed light on the effects of weightlessness on the circulatory system.

The LS16 liquid flow sensor from Sensirion on board the ISS will measure the flow of demineralized water generated by a piezoelectric pump in zero gravity, and compare the results with those of a control experiment on earth. Numerous applications in fluid dynamics, physics, biology and hemodynamics (the forces involved in the circulation of blood) will benefit from these findings. The research team is extremely satisfied with the sensor. "Our experience with the Sensirion LS16 sensor has been outstanding – the LS16 has been accurate, precise and durable," says Max Thompson, Student Project Manager at Minnehaha Academy. But Sensirion did not just supply the sensor for the experiment, its developers also helped out in an advisory function. For instance, the LS16 liquid flow sensor had to be modified for the launch: to ensure that the sensor could withstand the enormous forces during lift-off, Sensirion's development team replaced the capillary glass tubes with robust capillary steel tubes. "Our project would not have been possible without the generosity, time and amazing commitment from Sensirion to make the flow sensor flight-ready," says Max Thompson.

Sensirion stands for innovation. Existing and new products from Sensirion continue to set standards and show that in the measurement of temperature, humidity, gas and liquid flows using sensors, Sensirion's expertise and innovative drive have made it number one worldwide. The research team at Minnehaha Academy was delighted to have Sensirion's support: "Sensirion has been a champion of companies to have as a partner to make this student-designed project a reality."

www.sensirion.com (140116-III)

Exar: Wide Frequency Universal Clocks with Ultra-Low Jitter

Exar Corporation (NYSE: EXAR), a leading supplier of high performance analog mixed-signal components and video and data management solutions, today announced an addition to its range of telecommunications timing products with a new family of Universal Clocks. The XR811xx series offers a wide range of output frequencies from 10 MHz to 1.5 GHz, with ultra-low phase noise jitter of less than 200 fs. Designed for communications, audio/video and industrial applications, the QFN-10 and TSSOP-8 packaged devices are footprint compatible with industry standard synthesizers, providing a superior performance second source option. The design of Exar's XR811xx synthesizers utilizes a highly flexible delta-sigma modulator and a very wide-ranging VCO in a PLL block that has been optimized to be extremely power efficient. With a core current consumption of just 20 mA, these parts dissipate 60% less power than equivalent competitive devices, providing a very compelling power efficiency benefit to system designers. The PLL can operate from either an input system clock or a crystal and incorporates both an integer divider and a high-resolution (<1 Hz) fractional divider for increased flexibility to generate any clock frequency. Additionally up to four different frequency multiplier settings can be stored allowing for different application configurations providing BOM savings compared to multiple synthesizers. The XR811xx family also offers a choice of LVCMOS, LVDS or LVPECL output drivers.

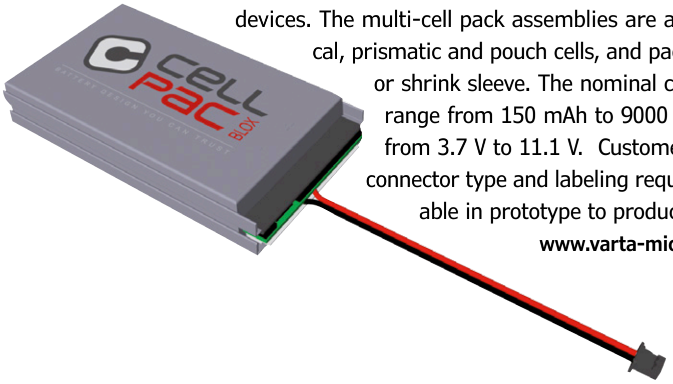
Exar's Universal Clock devices deliver extremely low, sub-200 fs, output phase noise jitter as integrated over a PLL loop bandwidth of 1.875 MHz to 20 MHz. This spans the requirements of most WAN and LAN systems and supports communications standards including: 10 GHz Ethernet, 2.5 GHz and 10 GHz SONET/SDH/OTN, xDSL and PCIe, as well as many other synchronized clock system applications.

www.exar.com (140116-IV)

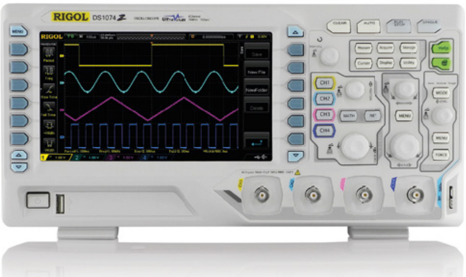
Semi-Custom Li-Ion or Li-Polymer Soft Pack Battery Solutions

Announced recently by VARTA Microbattery is the CellPac BLOX system. The CellPac BLOX system is a design program implemented to offer OEMs a semi-custom power solution when off-the-shelf lithium ion (li-ion) or lithium polymer (LiPO) soft pack battery assemblies do not meet the design criteria. A dedicated CellPac BLOX engineering staff is specifically trained to help accelerate time-to-market and minimize non-recurring engineering (NRE) by consulting with customers throughout every phase of the design cycle. Battery packs provided include those optimized to satisfy the most basic as well as the most complex requirements, in addition to those with high or low capacity specifications.

Comprised of standard cells and PCM (Protection Circuit Module) components, VARTA Microbattery's semi-custom soft pack battery assemblies are ideal for a broad range of portable industrial, medical and data communications instruments utilizing embedded rechargeable batteries. They are frequently employed in assorted medical equipment, ultrasound, health monitoring and diagnostic devices. The batteries are equally suitable in industrial applications such as bar code scanners, measurement, control products, telecom and data communication devices. The multi-cell pack assemblies are available with li-ion cylindrical, prismatic and pouch cells, and packaged in a soft pack design or shrink sleeve. The nominal capacity of the battery packs range from 150 mAh to 9000 mAh, with voltages ranging from 3.7 V to 11.1 V. Customers may specify wire length, connector type and labeling requirements. Devices are available in prototype to production quantities.



www.varta-microbattery.com (140116-VI)



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Circuit Cellar is such a great magazine, file system article is so helpful!
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Just received my @Circuit Cellar prize for the CC Weekly Code Challenge #11. Thanks:-)
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2 Nov

Elektor ComputerScope (1986)

Goodbye green-only ‘scope CRT

By **Jan Buiting**
(Editor in Chief)

Back in 1986 at the crowded Elektor Electronics laboratory, somebody approved the idea proposed by a young Dutch BSc. graduate of Electronics to make an oscilloscope add-on for personal computers. I had been appointed as an assistant editor just months before, and being able to wield an electric typewriter and an English Dictionary I was asked to write a deft letter to ITT Semiconductors of Freiburg, Germany, asking for a few samples of their latest UVC3101 device.

I was told it was a “high-speed” ADC and DAC in one chip and “difficult to get”. I got a favorable reply by telephone from Reinhard W. Preuss, the most officious and gentlemanly PR and Press Officer I have come across in the electronics scene these past 25 years. A few days later the ICs arrived, complete with engineering notes. The lot allowed Rene van Linden to start designing his ComputerScope project and hopefully complete his BSc. thesis.

October 1986
Elektor Electronics
UK £1·30
IR £1·94
(incl. VAT)
COMPUTERSCOPE
Gallium-arsenide vs silicon: the future
Converter for satellite TV reception
Video interface for Atari-ST
Europe’s own space race

1

Time perspective

In those days it was hot to make computers do things other than the usual spreadsheeting, PacMan’ing, word processing and ASCII art doodling. It was the exciting era of the BBC Micro, the Acorn Electron, Philips MSX and the first IBM PC clones starting to appear in households and in electronics engineers’ workshops. It was a time also when computers were totally accessible in terms of hardware and software. As long as a computer had a port of some sort using an easy to obtain connector, engineers, British school children and Elektor trainees got into developing peripherals the computer manufacturers could not have foreseen. There was a lot of POKE(16xxx) going on at that time.

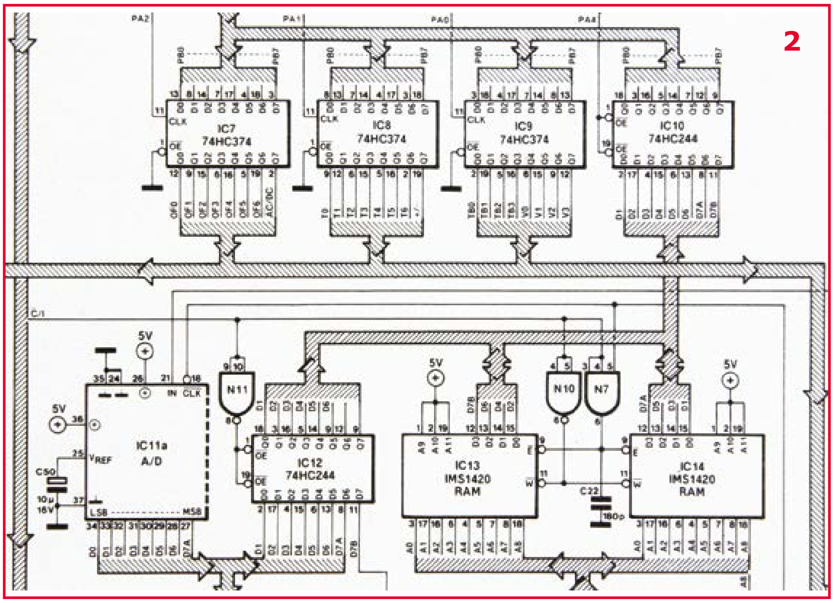
In the case of the Elektor ComputerScope, the idea was to make a personal computer handle the visualization of measured data on its monitor with composite video input. Paradoxically, that monitor had a CRT just like the traditional oscilloscope, only larger and more colorful, so the crux or cost advantage of the computerized ‘scope over, say, a refurbished Tek I find hard to grasp.

In good Elektor tradition for large projects from the lab, the magazine article consisted of two instalments. The first in September 1986 gave the circuit diagram, the basic method of operation and some screendumps showing not too complex waveforms. In the October 1986 edition the construction, adjustments and software aspects were discussed, and the project was carried on the front cover of the magazine

(**Figure 1**). Note the visually implied hierarchy of two home computers pictured: the BBC Micro majestically in front and a Commodore C64, well, also visible.

The design

As a peripheral the ComputerScope requires a fast and wide highway into the computer's memory and display systems. However, these are digital, while the 'scope probe will pick up analog signals mostly, so ADC-ing is called for. The port traffic is not one-way either, as the 'scope input settings including the AC-DC selector and attenuator/amplifier need to be controlled from the computer. A couple of Clare DIP relays were used for the purpose. There are no controls or knobs on the Elektor ComputerScope to fiddle with, hence the instrument looks insipid in its grey case except perhaps for the stylized S.

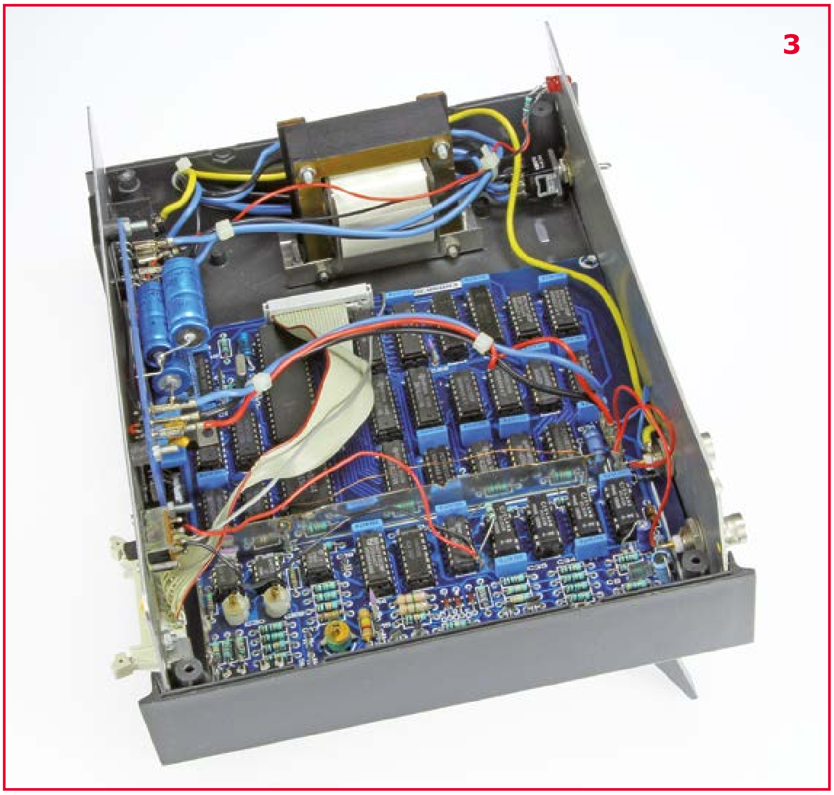

2

Compatible on paper with Acorn Electron, BBC Micro, C64, MSX, IBM PC?

The crux of the circuit is found in the "fast" ADC and DAC inside the UVC3101, and a small memory section based on Inmos IMS1420 RAMs. These parts were rare and expensive at the time—fortunately some advertisers in the magazine started to supply kits of the project.

The ADC and RAM section of the schematic is reproduced in **Figure 2**. The DAC (not visible here) was used to add an offset to the input signal if required. The datawidth from the ADC was 7 bits; bit 8 was the trigger indicator. The memory area actually used for data buffering was 512 bytes. The RAM section had its own address counter built from TTL ICs from the 74HC series (no microcontroller in sight). The board was packed with 74HC ICs for that matter, and a few straggling 74LS and CD4000 ones, since a mass of control and timing functions had to be catered for—like the complete timebase. I counted 24 logic ICs (**Figure 3**), which would be labeled a *component grave* these days.

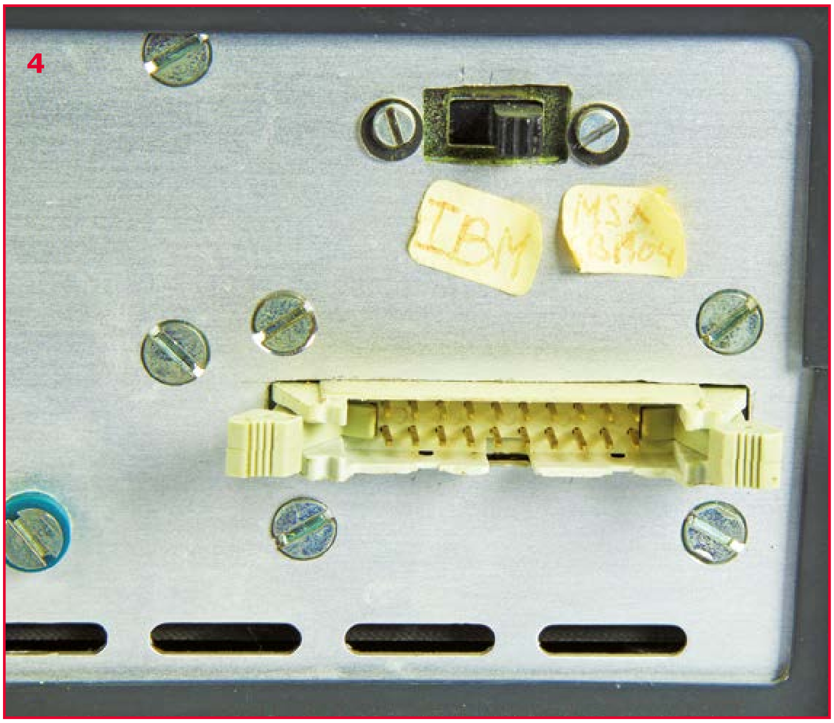
The lot was powered by a separate supply board type EPS 9968-5.


3

A small modification involving a slide switch on the back panel (**Figure 4**) allowed the instrument to be used with IBM (clone) PCs also.
Those of you yearning for the complete article from 1986 are advised that the Elektor 1980's DVD is about to be published; watch www.elektor.com or your weekly E-Post Newsletter.

Those Listings

If you ordered the ComputerScope board # 86083 through the Double Dutch named Elektuur Print Service (EPS) it came with program listings on paper for the Acorn Electron, the BBC Micro, the Commodore C64, and MSX machines. I remember stacks of this paperware on the shelves in our stores, alongside the boards, and supplications on my desk from readers all over the globe to send them the listings on disk, or without the board! To help owners of "other makes of computer" to compile their own program for the ComputerScope, a pitiful flow diagram was printed at the end of the October 1986 instalment.


4

Love story

Now compare the names of our two editorial secretaries duly printed in the October 1986 edition with those in November 1986—look on page 13. One surname changed. Besides passing his BSc. Electronic Engineering exam with good notes for the ComputerScope project, lab trainee R (for Rene) v(an) Linden, a silent, almost invisible worker, in the course of 1985 also managed to more than befriend "our" cherished secretary W (for Wilma) Wijnen.

Dumpster story

Elektor moved offices in 2006 and in an orchestrated attempt to "shake off the dark past" the technical staff and editors got strong advice to clear their stables and make a fresh start at Elektor Castle. One Friday afternoon, CEO attending, the old lab space in Beek (Holland) was cleared out rigorously by quasi volunteers, with a ton of stuff disappearing in an x cubic feet dumpster carefully parked on the driveway right under the lab windows. There was beer and pizza to celebrate the almost vacant building, and reward the workers.

Of the twenty or so lab projects and prototypes I was able to safeguard during *Operation Augias*, most—I admit—were of the 'finished' type, meaning there was a case around them. I managed to keep these out of harm's way and was happy to see that a few colleagues did the same for sentimental reasons. Today the small booty of that boisterous Friday afternoon is incorporated in the Retronics Collection, which is an "asset to the company" under the current management, and virtualized at www.elektor-labs.com/attic. Look at the item on the shelf straight above the Mugen Hybrid Amp—that's the final resting place of the 1986 Elektor ComputerScope.

(140034)

EST^{D} 2004

Retronics is a monthly section covering vintage electronics including legendary Elektor designs. Contributions, suggestions and requests are welcome; please telegraph editor@elektor.com

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PLEASE NOTE: *While we strive to provide the best possible information in this issue, pricing and availability are subject to change without notice. To find out about current pricing and stock, please call or email customer service for your region.*

COMPONENTS

Components for projects appearing in Elektor are usually available from certain advertisers in the magazine. If difficulties in obtaining components are suspected, a source will normally be identified in the article. Please note, however, that the source(s) given is (are) not exclusive.

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Hexadoku The Original Elektorized Sudoku

Nothing to solder, nothing to program? Why—for this month's hexadoku all you need is a pencil, some logic reasoning and you are active in electronics. Find the solution in the gray boxes, submit it to us by email, and you automatically enter the prize draw for one of five Elektor book vouchers.

The Hexadoku puzzle employs numbers in the hexadecimal range 0 through F. In the diagram composed of 16 × 16 boxes, enter numbers such that **all** hexadecimal numbers 0 through F (that's 0-9 and A-F) occur once only in each row, once in each column and in each of the 4×4 boxes (marked by the thicker black lines). A number of clues are given in the puzzle and these determine the start situation.

Correct entries received enter a prize draw. All you need to do is send us **the numbers in the gray boxes**.

Solve Hexadoku and win!

Correct solutions received from the entire Elektor readership automatically enter a prize draw for five Elektor Book Vouchers worth **$70.00 (£40.00 / €50.00)** each, which should encourage all Elektor readers to participate.

Participate!

Before July 1, 2014,
supply your name, street address and the solution (the numbers in the gray boxes) by email to:

hexadoku@elektor.com

Prize winners

The solution of the April 2014 Hexadoku is: **A0263**.
The €50 / £40 / $70 book vouchers have been awarded to: Arno Habermann (Netherlands), Eric Chamouardand (France), Pascual Alagon Luna (Spain), Tim Royall (United Kingdom), and Panagiotis S Krokidis (Greece).
Congratulations everyone!

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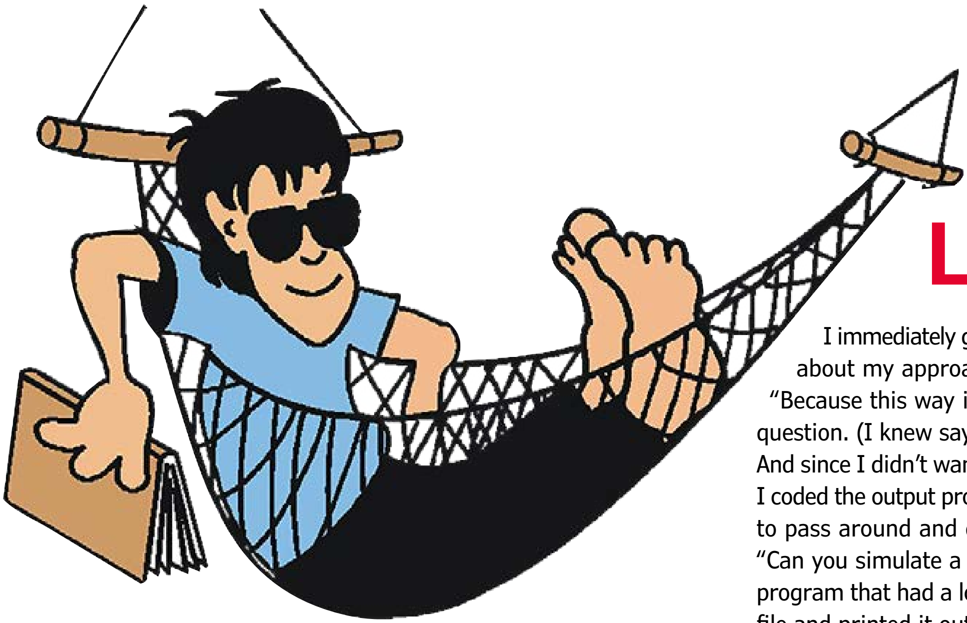

Lazy Days

By **Gerard Fonte** (USA)

Like most people I don't like working any harder than necessary to get the job done. I take pride in the fact that I can do more with less effort than most others and have raised laziness to a fine art. It takes a lot of dedication to be lazy.

Small Steps

I'm working with some people at a local university on a project. It involves analyzing a lot of data using some new statistical procedures. So instead or writing one large program to crunch the numbers. I'm writing a bunch of very small programs that only do one thing at a time. It's easy to write small programs. It's easy to debug small programs. It's easy to create test files for small programs. And it's easy for others to understand small programs. It's sort of like modular programming except that each module is a stand-along program.

I learned this technique ages ago when I was developing automated test procedures for printed circuit boards (PCB)s. But not for the PCB themselves. For something completely different. The NATO project director didn't like being dependent on this newfangled computer-thing to test these missile guidance boards. So he wanted the procedure written down so that they could be tested manually. The software code was thousands of instructions and converting that to plain language would be incredibly tedious. And assuming that there were no errors, it was clearly not practical for any technician to set up dozens of input and output connections and perform hundreds or thousands of tests, in order, without making any mistakes. Obviously this was a dumb idea. But he didn't think so and he was in charge.

Being lazy, I certainly didn't want to spend days or weeks writing down every step of these incredibly complicated tests. (No one else did either, including the company management.) I considered the problem for a while and realized that the test software was extremely structured in terms of syntax. So, it was very conceivable that a reverse-interpreter could be written that would convert the pseudo-assembly language commands into English text. I figured I could do it in about six weeks. Everybody liked the idea.

Since I had never written any type of interpreter before I broke down the procedure into a handful of simple programs and started working. I immediately got some criticism from someone in management about my approach. "Why not just make one large program?" "Because this way is easier." I replied—several times to the same question. (I knew saying "I'm lazy." wasn't the best response.)

And since I didn't want to re-write things because someone objected, I coded the output program first. I printed a page of simulated output to pass around and get comments. The immediate response was, "Can you simulate a whole program?" "Sure!" I said. I took a real program that had a lot of repetitive code, manually created an input file and printed it out. As I recall, it was about fifty pages long with every line being a test step (or about 2500 steps). (Typical manual test procedures are about 10 to 25 steps.)

They took the output, bound it with a boiler-plate preface and presented it to the project director as a sample document. After examining it he realized that a manual test procedure based on the software was not all that useful and dropped the requirement. In just a few days, my lazy approach had eliminated the need for dozens of silly and useless documents. And, of course, I didn't have to finish the reverse-interpreter either.

Repetitive Steps

Nowadays, I do a lot of product development jobs that usually include an embedded computer. My clients don't really care what microprocessor (µP) I use as long as it meets their requirements. So, being lazy, I use the same µP for nearly all my projects.

Of course, I re-use subroutines. But instead of placing them in an "include" file, I put them right into the µP as part of the program. This makes every program look and feel the same. They have the same subroutine names, same variable names and a similar layout. They're easy to program, debug, document, compile, test and follow. Modern µPs have loads of memory that's just wasted. So why not use it? I haven't run out of memory space yet. And if that time comes, all I have to do is "comment out" unused routines to free up space.

It's a bit more complicated for hardware. It's harder to create re-useable hardware modules that can be plugged into a Printed Circuit Board (PCB). However, since I use the same µP for most of my designs, I standardize the pin usage. And since most designs use common interface components (LCD display, LEDs, switches), the layout of these parts is very similar. I keep a basic PCB layout that I start with. It's easy to take out those things I don't need and then add in new parts. So each new PCB is really a modification of the same basic PCB.

I also keep a collection of useful circuits on hand. It saves me time and effort in the design stage. It's much easier to duplicate or modify a known working circuit than it is to design, debug and test a new one. Remember that your time is valuable and that it is a limited resource. Being lazy is just a way to optimize your work.

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The Ultimate Guide to LTspice IV

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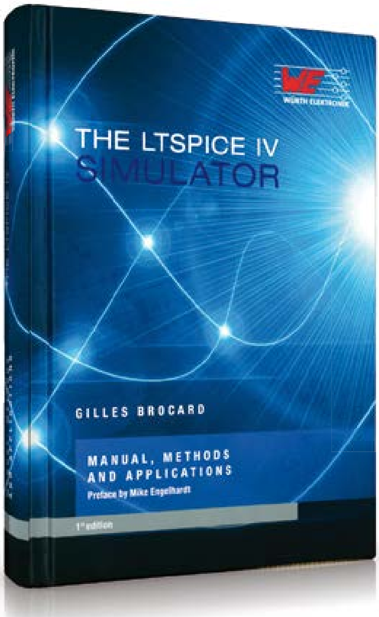

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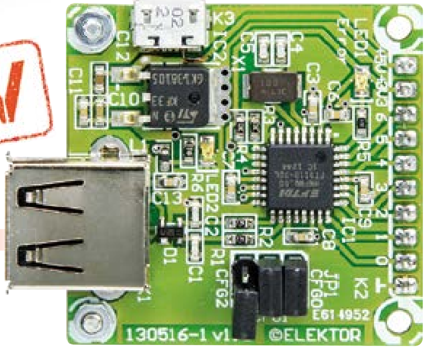

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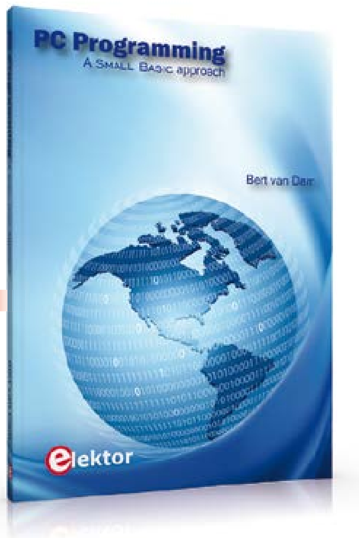

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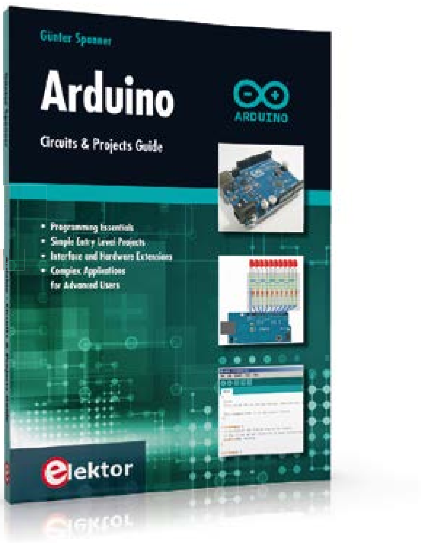

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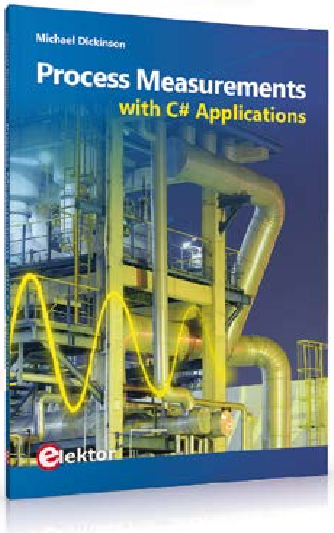

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Circuits & Projects Guide

9 Arduino

The Arduino user is supported by an array of software libraries. In many cases, detailed descriptions are missing, and poorly described projects tend to confuse rather than elucidate. This book represents a different approach. All projects are presented in a systematical manner, guiding into various theme areas.

In the coverage of must-know theory great attention is given to practical directions users can absorb, including essential programming techniques like A/D conversion, timers and interrupts—all contained in the hands-on projects. In this way readers of the book create running lights, a wakeup light, fully functional voltmeters, precision digital thermometers, clocks of many varieties, reaction speed meters, or mouse controlled robotic arms. While actively working on these projects the reader gets to truly comprehend and master the basics of the underlying controller technology.

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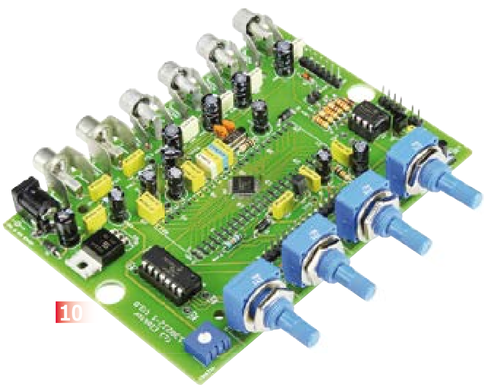
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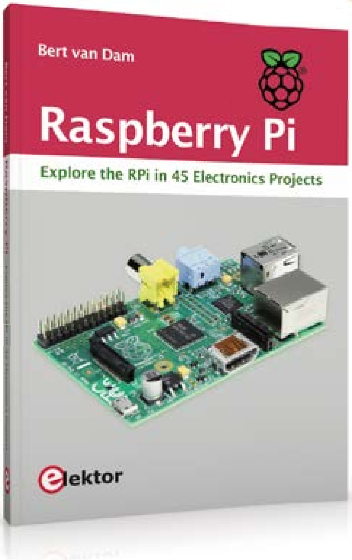
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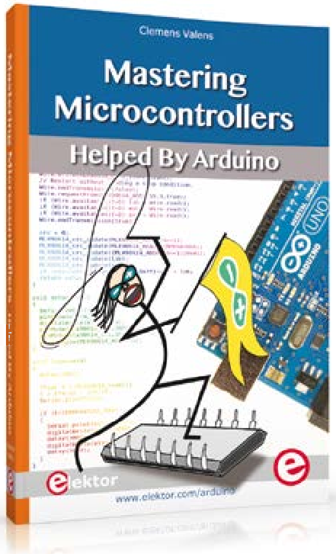
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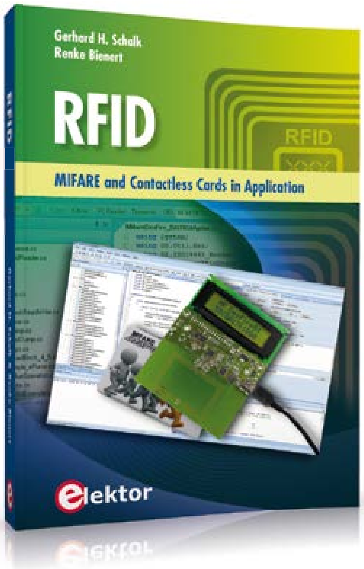

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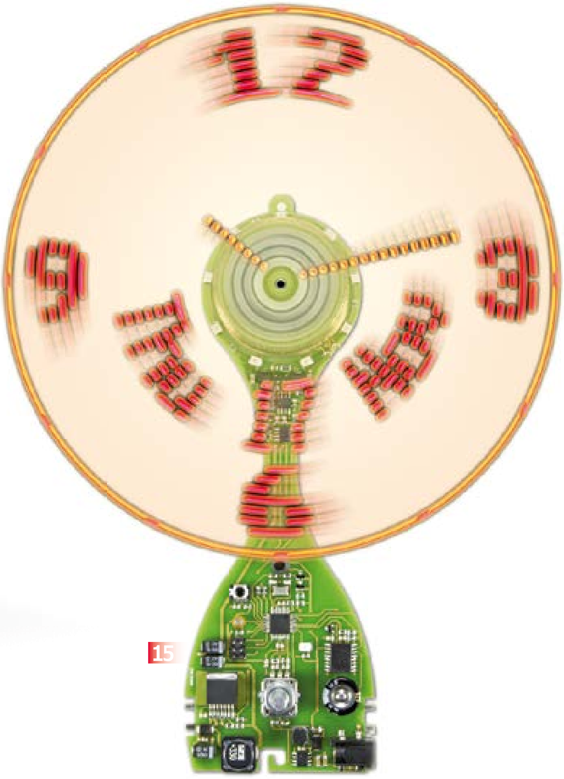

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complete design of a reader's hardware and software is described in detail. The reader's firmware and the associated PC software support programming using any .NET language. The specially developed PC program, "Smart Card Magic.NET", is a simple development environment that supports sending commands to a card at the click of a mouse, as well as the ability to create C# scripts. Alternatively, one may follow all of the examples using Visual Studio 2010 Express Edition. Finally, the major smart card reader API standards are introduced. The focus is on programming contactless smartcards using standard PC/SC readers using C/C++, Java and C#.

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NEXT MONTH IN ELEKTOR MAGAZINE

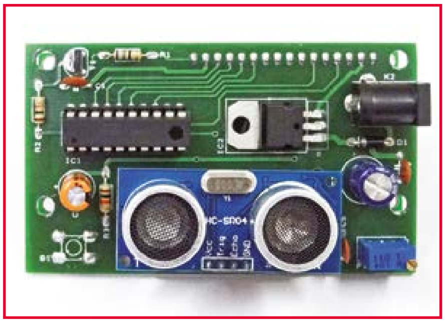
Elektor Project Generator Edition 2014 – The annual extra-thick edition with a bunch of circuits

Next month we publish the famed double issue for the months of July and August. Coveted, highly valued and collected by readers, Elektor's Summer PGE is dreaded by the competition who never managed to publish anything remotely similar. The edition contains a mix of large and small projects. Editors and designers are now burning their midnight oil to fill the 2014 Summer PGE with detailed high quality texts, illustrations, schematics, boards, programs and original electronic applications. Don't miss it, this Jumbo edition of Elektor packed with a ton of Elektorized electronic engineering.

Some large projects in PGE 2014:

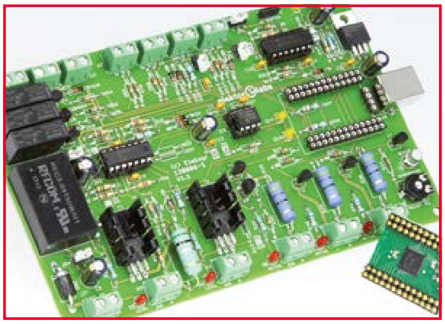
Switch-mode Lab Power Supply

An ingenious circuit incorporating a custom-designed flat transformer with PCB track windings. The PSU has two LED displays for the current and voltage readout. The output is interruptible using a relay, and capable of sourcing up to 30 V, 1 A.



Ultrasonic Distance Meter

A handy little meter built around the ATtiny4313 and using two standard ultrasonic sensors. A 2-line display indicates the measured distance in mm, cm, inches, feet or yards selected by the user.



IO-Warrior Extension Board

This multifunctional board offers vast number of inputs and outputs make it highly suited to a variety of measurement and control applications via the PC. The communication with the PC is effectively via an IO Warrior module, for which a demo program is available written in Visual Basic Express.

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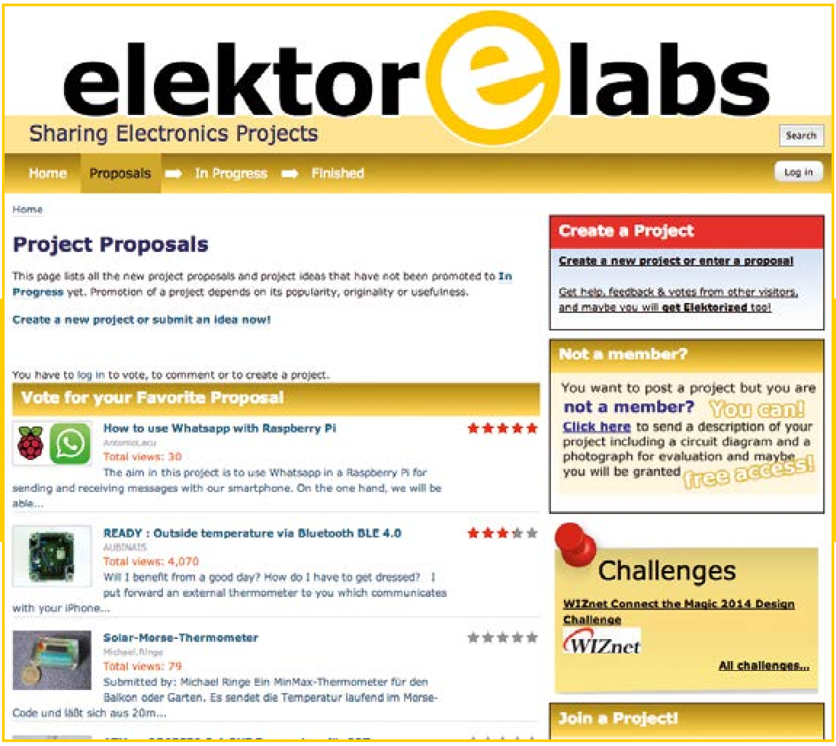

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Sharing Electronics Projects

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AntonioLacu
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AUBINAIS
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WIZnet Connect the Magic 2014 Design Challenge

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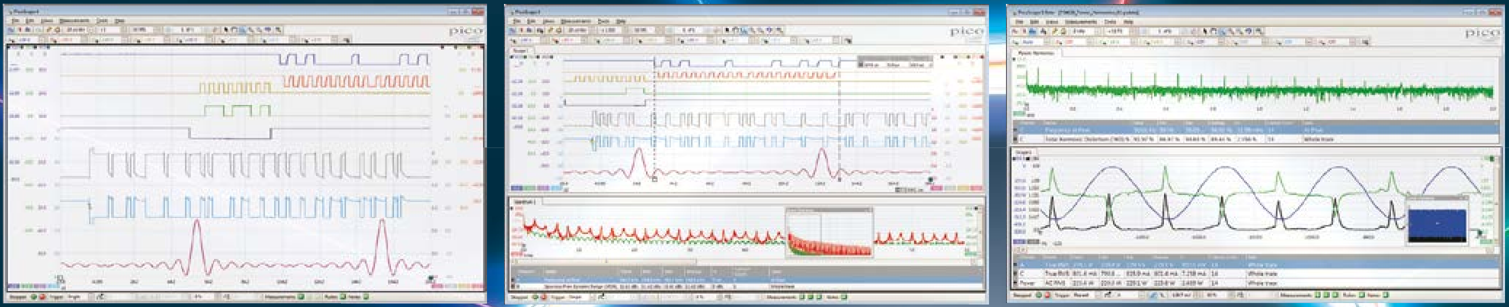

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