Edition 4/2015 | July & August 2015
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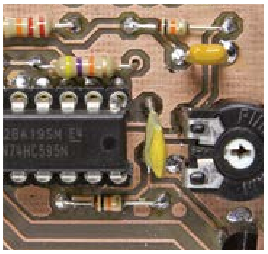

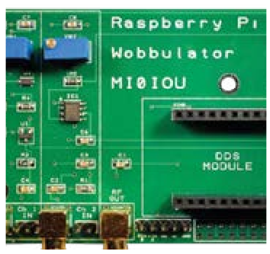

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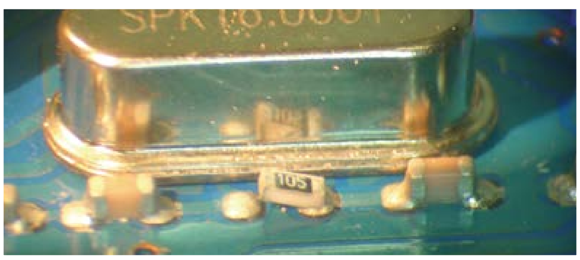

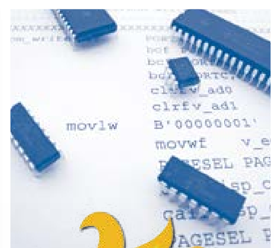

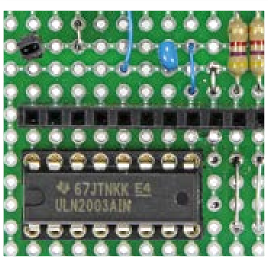

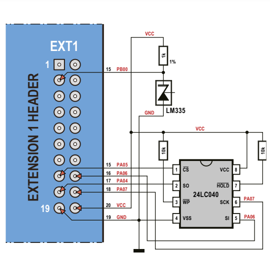

2-GHz Active Differential Probe • A Raspberry Pi Wobbulator • **Adding Connectors to a 3D Model** • Apps with Connections (1) • **Arduino as I²C Slave** • ARM Microcontrollers for Beginners (4): SERCOM • **Audio T-Board** • BL600 e-BoB (3) • **Cheap Accurate 12-V Battery Monitor** • **Connector Pinouts** • **Contact Soldering** • **Doepfer E510 MIDI Keyboard Scanner** • Electrifying Paintjob • **ELPB-NG** • MIDI Analyzer • Multi-Purpose 12-Key Capacitive Keypad • **Pelco-D Control for CCTV Cameras** • **PIC Assembler Crash Course (1)** • **Platino Solder Station** • Power Failure Audible Alarm • **Reliability of Electrolytic Capacitors** • **Resistance Measurement with the Arduino** • **Retronics Made in Germany** • Signal Amplifier for USB **Oscilloscope** • SmartScope • **Solar Panel Voltage Converter for IoT Devices** **... and more**

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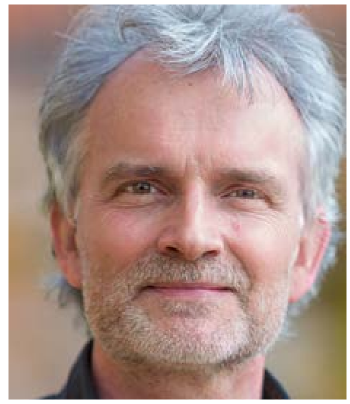

Fabled Schematics

Recently I noticed an increase in the number of Elektor readers enquiring how (on earth) one can make it to publication of a project on these here pages. Most enquiries did include a line or two asking whether Elektor and/or its Editor employ a closed circle of contributing authors, or if everything got designed by Labs?
On a few occasions, instead of replying with some guidelines for authors and their options to join the publication process, I entered into correspondence with budding authors to discover the origins of their 'closed circle' misconception. After a few emails and phone calls the answer appeared to be: "all schematics printed in your articles have a uniform look and feel, and basically the same applies to the texts. Also, most photos and other illustrations look so professional they can only originate from Elektor staff."
All this can be dispelled, and is due solely to the way the Elektor's editors, graphic and lab staffers, and even the printers, strive to bring you the highest possible quality.
We may well aim too high in this respect. Elektor's schematics are recognized from a mile because of their consistent appearance these past 40 years. Although we do use the "sheets" produced by CAD programs at the Labs level of a publication, these flat-looking documents do not normally appear in Elektor magazine. Their purpose is to kick off the internal PCB design process — which also marks the start of conversion to Elektor's house style schematics. The latter function is human, meaning our drawing expert Mart Schroijen is set to produce an attractive looking, lucid, and educational schematic for you. Mart wields an immense custom-made symbol library, which is not for sale, lease or hire. He also spots mistakes and inconsistencies in originals, even from Labs.
The perfection — if any — of this publication is apparent only, and should not withhold you from entering projects and feature articles into the LEARN–DESIGN–SHARE cycle. In the article acceptance phase, our focus is on content and ingenuity, rather than on text file format, native language, or the schematics tool you happen to use. *Ditto* for your camera. Let us enhance your input. For a few examples, inspect the articles in this edition marked by the READER'S PROJECT tab in red. You're welcome!

Enjoy reading this edition

Jan Buiting, Editor-in-Chief

The Circuit

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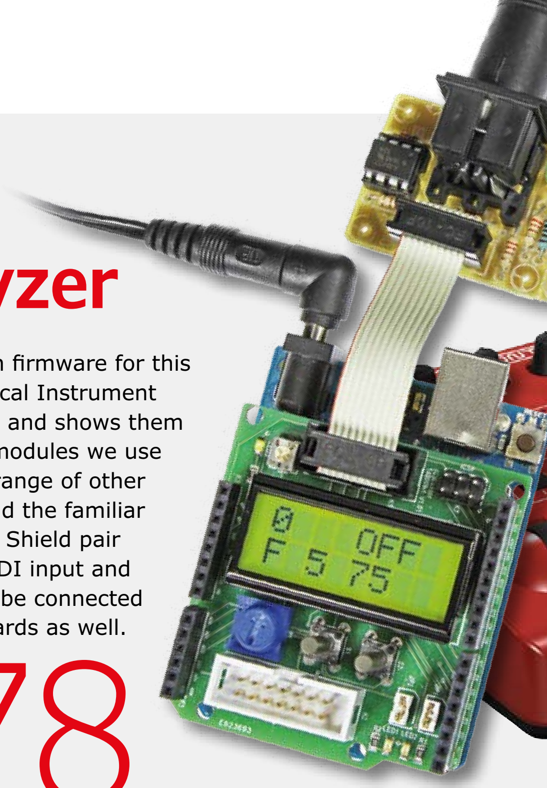

MIDI Analyzer

Although the demonstration firmware for this project decodes MIDI (Musical Instrument Digital Interface) messages and shows them on a display, the software modules we use lend themselves to a wide range of other applications. Here we extend the familiar Arduino / Elektor Extension Shield pair into a module offering a MIDI input and output. Its ECC allows it to be connected to other microcontroller boards as well.

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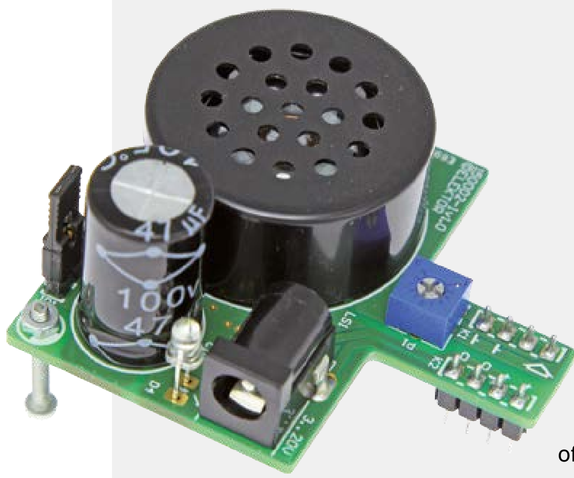

Audio T-board

Reflecting on analog circuitry that can be built on a breadboard, what do you think of a T-board with a small power amplifier and preferably also with a built-in speaker, so that you can make any audio signals audible immediately, without first having to build a separate circuit and then connecting some speakers to it?

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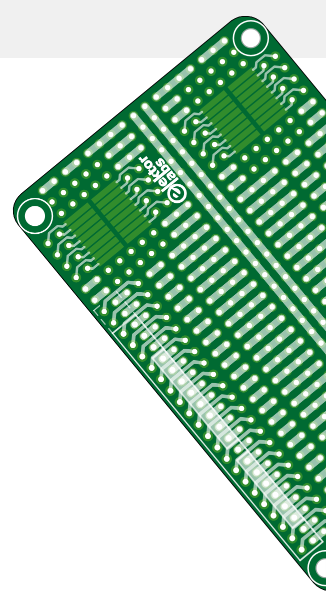

Multi-Purpose 12-Key Capacitive Keyboard

There are several types of touch sensitive sensor based on principles including optical, magnetic, inductive and capacitive. Today however the most popular clearly is the capacitive touch sensor. Although several different ways of 'doing' capacitive sensing got developed over the past years, all measure a change in time constant of some sort of (RC) circuit due to a variable capacitor whose value is affected by a nearby object (like a fingertip). Here, we make software do a better job.

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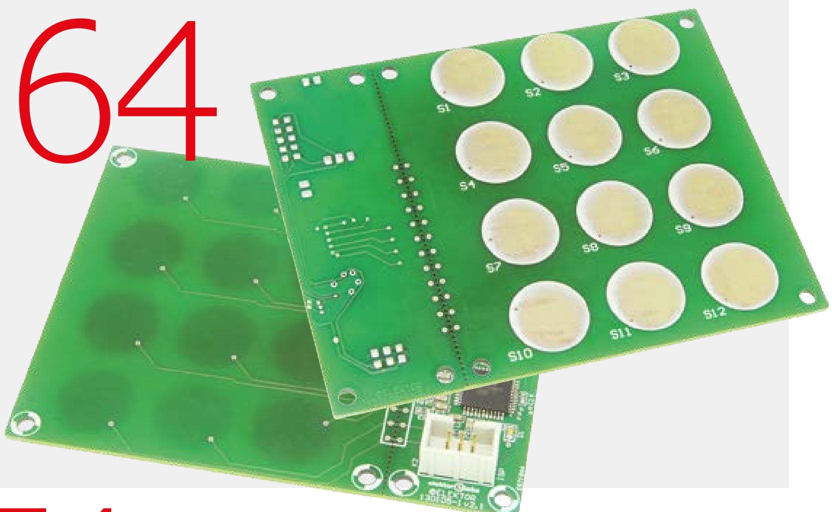

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NEXT EDITION

VFD Shield for Arduino

This plug-on board contains four vacuum-fluorescent display (VFD) tubes with matching control electronics. Using the specially developed software for the project, the display doubles as a strain gauge, voltmeter or a counter.

AC Power Meter

Based on the ADS1115 A/D converter e-BoB, we designed a measuring circuit with three power ranges from 0.1 W up to over 2 kW, an electrically isolated output, and readout via an Arduino.

Android I/O Board

In the next editions we describe a PCB that puts 22 I/O ports at your disposal within an Android app. The board can have contact with an Android smartphone or tablet via Bluetooth, Wi-Fi or USB.

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Connections Guide

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KCS TraceME

LoRa ™ Internet of Things

KCS has extended their successful TraceME product line with an advanced module, targeted for worldwide mobility in the Internet of Things era. The latest development of the TraceME GPS/GPRS Track and Trace module will combine the RF location based positioning solution with the LoRa™ technology. This combination offers 'smart objects' being even smarter, since LoRa™ enables long range, battery friendly communication in a wide variety of (M2M) applications. Supporting GPRS/SMS and optional 3G, Wi-Fi, Bluetooth LE, ANT/ANT+ and iBeacon™ provides easy integration with existing wireless networks and mobile apps. Other variants in the high/mid-range and budget-line will follow soon.

ANTI-THEFT module based on RF

KCS TraceME product line offers an intelligent location based positioning solution for indoor and anti-theft applications.The solution is based on RF with an intelligent algorithm of measuring the propagation time of transmitted (proprietary protocol) signals. Unique features are: minimum size (46x21x6.5mm), weight (7 grams for fully equipped PCB) and a standby battery lifespan of more than 10 years.'Listen before talk' algorithm makes it practically impossible to locate the module, which secures the valuable vehicle or asset. Supporting GPRS/SMS and optional 3G, Wi-Fi, Bluetooth LE, ANT/ANT+ and iBeacon provide easy integration with existing wireless networks and mobile apps.

www.Trace.ME

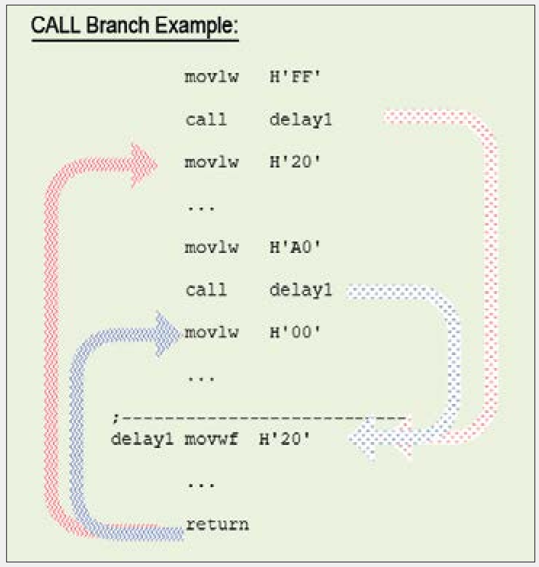
Welcome to the LEARN section

By **Jens Nickel**

Machine code

In this edition besides the popular series we're currently running on ARM microcontrollers we also have an interesting piece about programming Windows-Store apps, which can run on either PCs or Windows tablets. That is however not all we have for you under the heading of 'programming'. We are also starting out on a brand new Assembly Language crash-course.

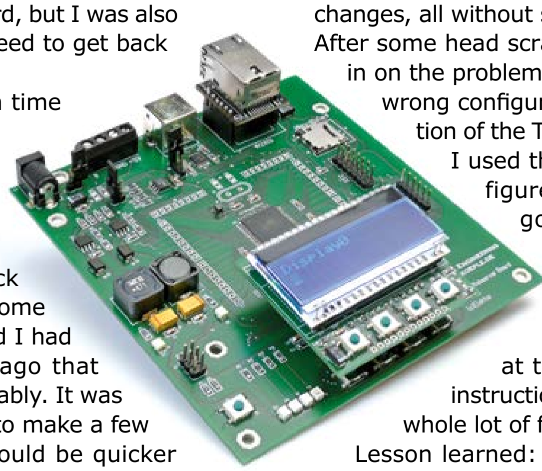
You may think that with all today's slick software development environments and powerful processors nobody in their right mind would choose or even need to write in Assembler. Here we point out some of the benefits of getting this close to the Metal. It gives you intimate control of registers at bit-level and allows optimal use of the processor's resources, in short, you will get to find out what makes the processor tick. During the editing process for the course it brought back memories of when I was a geeky youth and just beginning to appreciate what these fascinating things called microprocessors could do. It also reminded me of an idea I once had to make a small virtual machine, able to run the same bytecode on different microcontroller types to switch outputs really quickly. Who knows, I might get round to working on that some day…



The Web Server board

This weekend I took our Xmega-Webserver board out of the box where I keep some of the development tools I use at home. Actually I needed to port my Midi-Checker software (see article in this edition) to this board, but I was also beginning to feel the need to get back to work on the IoT.

I didn't have too much time available to get the job done; the aim initially was just to send some bytes over the network from the board to my new PC and back again. Luckily I found some programs for either end I had written about a year ago that would do the job admirably. It was going to be necessary to make a few modifications but it would be quicker than starting from scratch; I knew that the IP addresses of my home network were no longer valid. I managed to get the firmware to activate the TCP/IP module on the Xmega board (witnessed by the LEDs on the network socket) so I fired up a network scanner on the PC to take a closer look… For some reason the TCP/IP module was nowhere to be found on the network. I sent out characters, tinkered around and made a few changes, all without success.



After some head scratching I eventually zeroed in on the problem: The Xmega was using the wrong configuration data during initialization of the TCP/IP module. The last time I used the program I had also configured an Elektor bus but forgot to change the value of the memory index pointer which read the configuration data from an array. An appropriate comment at the corresponding program instruction sure would have saved a whole lot of frustration…

Lesson learned: Don't get lazy when commenting and documenting your software — you know it's going to save a whole lot of time in the long run, especially when making those quick and dirty patches! ◀

(150275)

The SERCOM module in I²C mode

From 8 to 32 bits:
ARM Microcontrollers for Beginners (4)

By **Viacheslav Gromov** (Germany)

In this installment we return to the SERCOM module, this time configured as an I²C interface, and use it to control an I²C port expander.

In the March & April issue of Elektor we saw the SERCOM module in use as a U(S)ART. Now we will look at the second of the three possible interfaces the module is able to implement, I²C. For our first experiments with I²C we will use a readily-obtainable low-cost device that is easy to control but which nevertheless has a wide range of applications: the MCP23017 port expander, offering 16 GPIOs. The MCP23017 is available to private customers via most of the usual (online) component retailers.

SERCOM as I²C

The SERCOM module can be used as an I²C interface as well as a U(S)ART. I²C is widely used and is best known for requiring only two wires (see text box). **Figure 1** shows the structure of the SERCOM module in I²C mode: on the left, as a Master and on the right as a Slave. The registers with names printed using upper case are accessible from the CPU, while the registers whose names are in lower case are internal to the SERCOM module and cannot be read from or written to by the CPU. In I²C Master mode the SERCOM module has a BAUD register, containing the settings for the baud rate generator shown below it which generates the clock on the SCL line. The clock is also fed to the shift register, which has the job of outputting the data from the TxDATA register synchronously with the clock signal, or likewise receiving data into the RxDATA register. It is possible to apply a digital filter to the signal on the SDA input. In Slave mode the SERCOM module also uses a shift register, either to receive data from the Master or to send data to the Master. In this mode it is the responsibility of the Master to generate the clock and so the baud rate generator is not used. The Slave must know, however, whether a given message is intended for it or for another Slave. To this end it compares an address received via the SDA input with its own address, specified by ADDR and ADDRMASK.

There is one further special feature: the SERCOM module also supports SMBus (‘System Management Bus’), an extension of the I²C bus protocol, and can for example send an ACK fully automatically when it (as a Slave) receives a matching address

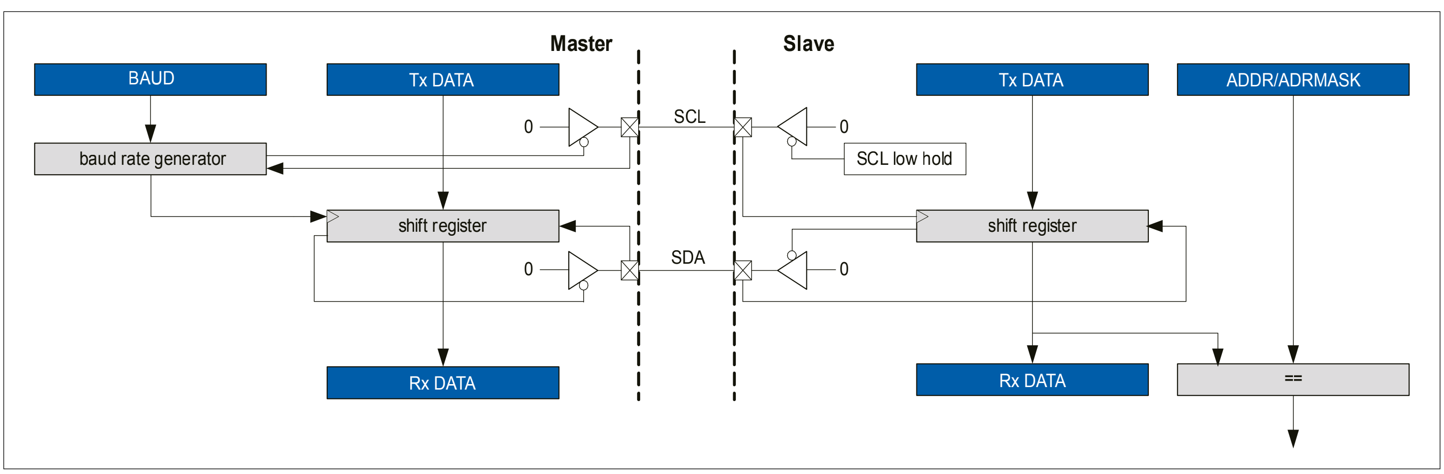


Figure 1. The structure of the SERCOM module in I2C Master and Slave mode (all screenshots and block diagrams courtesy Atmel).

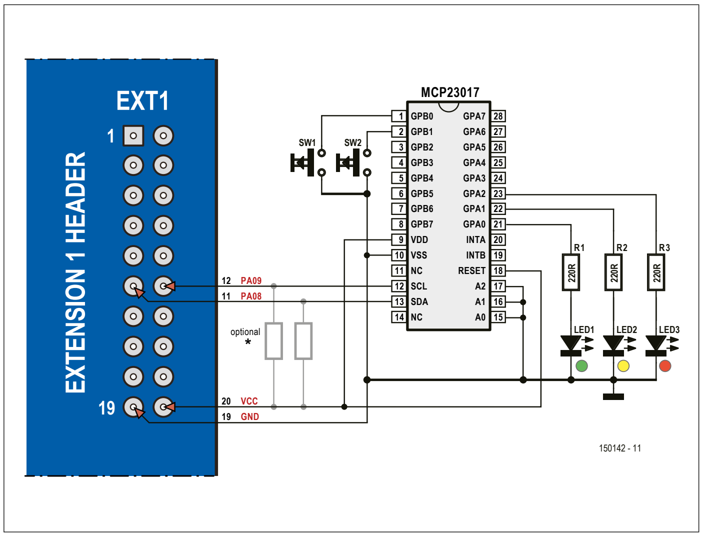


Figure 2. The circuit diagram for our I2C project. The optional 1.2 kΩ pull-up resistors should be fitted if communication does not function in the first instance.

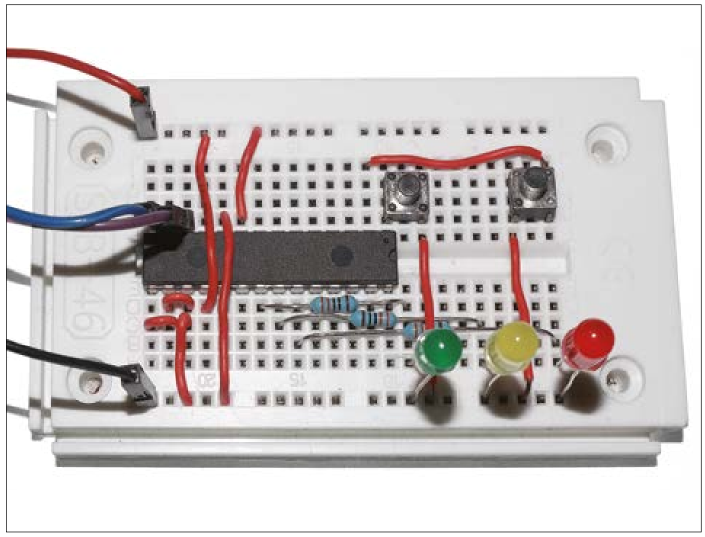


Figure 3. The circuit can be built on a breadboard.

byte. This saves code space and hence also the programmer's time. It is also possible to configure a timeout such that if the Master has to wait for more than a given time for an ACK from a Slave during an operation, it will be aborted. The SERCOM module offers a lot of flexibility in this mode regarding the selection of clock sources and interrupts, which can for example wake the CPU when the SERCOM module is addressed as an I²C Slave. Further information can be found in the datasheet [1] starting at page 394.

I²C in action

Let's begin with an experiment using the I²C bus, in which the SAM D20 will act as bus Master controlling the MCP23017 port expander. The circuit shown in **Figure 2** can be built on a breadboard and connected to the ARM board: the author's construction is shown in **Figure 3**. Our goal, as in the second part of this course, is to arrange to light the green LED by pressing button SW1, the yellow LED by pressing SW2, and the red LED by pressing both.

The first step is to learn about the port expander by reading its datasheet [2]. **Table 1** summarizes its most important registers, which we will be configuring later, along with the function of each. The MCP23017 has two ports, GPIOA and GPIOB, and a set of registers is provided for each of them. Values in the MCP23017's registers are written to in the same way as many other I²C interface devices: the first byte sent by the Master is the internal address of the register to be accessed, and the second is the value to be written.

To read a value from a register a data byte containing the address of the register in question is sent to the device, but without a stop bit at the end. Then a normal read operation is initiated, beginning with a start bit just as for the write operation. The device then sends back to the Master the value of the requested register and the Master completes the read operation by sending a stop bit. In this pattern of operation, where there are two start bits without an intervening stop

Table 1. Registers required to control GPIOs on the MCP23017.

Name (where 'x' is A or B)	Address (Port A/ PortB)	Function
IODIRx	0x00/0x01	The I/O direction register, as its name suggests, is responsible for determining whether the I/O pins are configured as inputs or outputs. If a bit in the register has the value 1, the corresponding pin is configured as an input; if it has the value 0, the pin is configured as an output. When the IC is powered up the register is set to 0xFF, and so all GPIO pins are configured as inputs.
IPOLx	0x02/0x03	Setting a bit in the input polarity register to 1 means that the corresponding bit in the GPIOx register will read as the inverse of the logic level on that pin (assuming the pin is configured as an input).
GPPUx	0x0C/0x0D	Setting a bit in this register ('GPIO pull-up') to 1 enables an internal pull-up resistor on the corresponding pin.
GPIOx	0x12/0x13	The level on the pins of the GPIOx port can be read from or written to using this register, depending on the state configured in the corresponding IODIRx register.

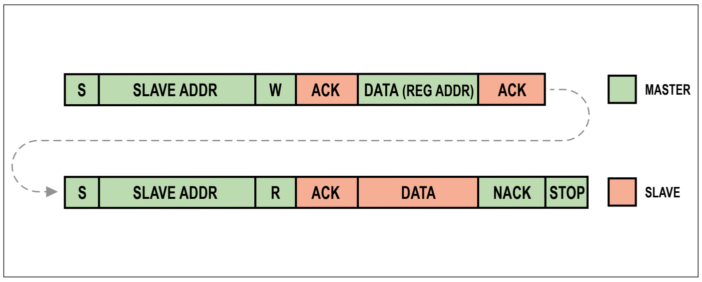


Figure 4. Reading a byte from a register with address 'REG ADDR'.

bit, the second start bit that introduces the read operation is called a 'repeated start'. This whole read operation is illustrated in **Figure 4**.

Now we know how to use the most important functions of the MCP23017 we can move to the code. As the Application Note on using the SAM D20's I²C bus interface in Master mode [3] makes clear, the ASF works in terms of so-called 'packets'. A packet is a structure which is filled with the array of bytes to be sent or bytes received, as well as a byte count and the Slave address. Alongside the configuration functions, the ASF I²C library includes five functions concerned with sending and receiving data as follows.

- send one packet
- send one packet, but without a final stop bit
- receive one packet
- receive one packet, again without a final stop bit
- send a single stop bit

These functions are available in polled versions as well as callback versions. Packets are transmitted following the pattern illustrated in **Figure 5**. If you open the project called 'First program with I2C' [4] and look at the beginning of the main file (after the header asf.h is included, the symbolic constant `SLAVE_ADDRESS` is defined, and the functions are prototyped) you will see six arrays which are declared and initialized such that when they are sent to the MCP23017 it will be correctly configured.

The two pushbuttons are connected to GPB0 and GPB1 and the LEDs are connected to port GPA, and so all pins of port GPB are configured as inverting inputs with pull-up resistors while all pins of port GPA are configured as outputs. So, for example, the array to configure the IPOLB register is declared as follows.

```
static uint8_t ipolb[2] = {
  0x03, 0xFF
};
```

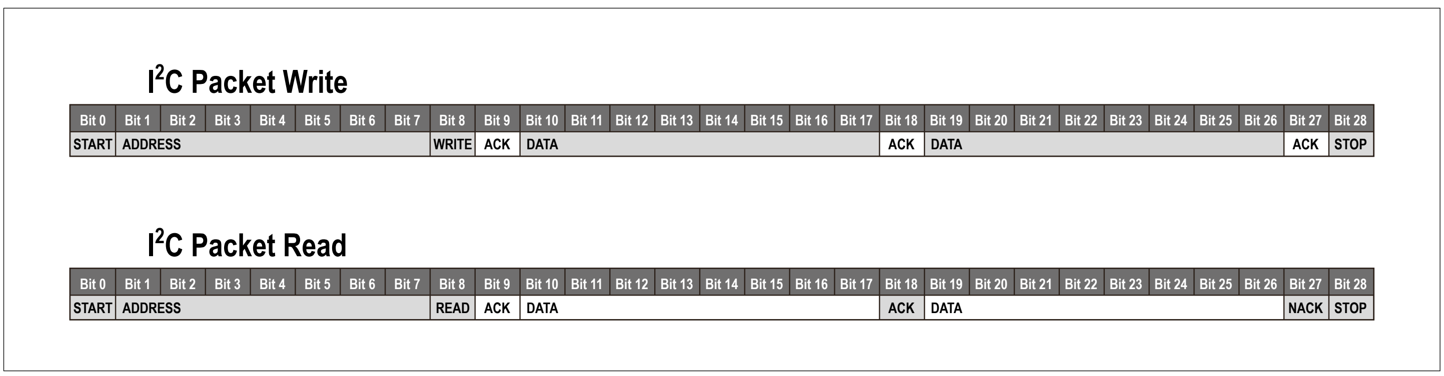


Figure 5. The protocol for write and read commands.

Listing 1. Configuration function for the I²C interface (as Bus Master).

```
struct i2c_master_module i2c_master_instance;

void configure_i2c(void) {
  struct i2c_master_config config_i2c_master;
  i2c_master_get_config_defaults(&config_i2c_master);
  config_i2c_master.pinmux_pad0 = SERCOM2_PAD0_DEFAULT;
  config_i2c_master.pinmux_pad1 = SERCOM2_PAD1_DEFAULT;
  config_i2c_master.baud_rate = 100;
  while(i2c_master_init(&i2c_master_instance, SERCOM2, &config_i2c_master) != STATUS_OK);
  i2c_master_enable(&i2c_master_instance);
}
```

The I²C protocol

An I²C bus includes a single Master and as many Slaves as required connected together via a single data line called SDA and a single clock called SCL. All devices are connected in parallel to the same pair of lines. Typically the Master might be a microcontroller and a Slave might be a temperature sensor with an I²C interface. The clock signal is generated by the Master during a write or a read operation at the selected clock frequency, and this determines the timing of the data bits on the bus. Master and Slaves only sample the state of the data line, and hence a data bit, on specific edges (rising or falling) of the clock signal. While the clock is the responsibility of the Master, all participants on the bus can drive the data signal. As with many other such bus systems, it is always the Master that initiates a read or write operation, and so the Slaves cannot communicate with one another independently.

The protocol is in essence standardized (see Figure 5): the Master always starts a communication with a start bit, a seven-bit address and finally a flag bit indicating a read or write operation. The Slave whose address matches that sent by the Master and hence knows that it is being talked to confirms the receipt of this byte with an acknowledge (ACK) bit. Thereafter the Master sends or receives (depending on the state of the flag bit at the end of the first byte) data bytes. If the Master is sending bytes, the Slave must acknowledge each by sending an ACK bit; conversely, if the Master is receiving bytes, it acknowledges the reception of each by sending an ACK bit to the Slave. In the case of a read operation, when the Master has received the required number of bytes it tells the Slave by sending instead a negative-acknowledge (NACK) bit. Immediately after that it sends a stop bit. In the case of a write operation the Master simply sends the stop bit after it has received the acknowledgement from the Slave of the last transmitted byte. It is also possible to combine write and read operations: see Figure 4.

CMSIS

The term ‘CMSIS’ (which stands for ‘Cortex Microcontroller Software Interface Standard’) comes up frequently when discussing ARM Cortex microcontrollers. This is a software library developed by ARM with the intention of helping to standardize the programming of Cortex-based microcontrollers, and hence making it easier to move from one member of a microcontroller family to another, from one IDE to another, or even from one manufacturer’s device to another. The standard includes libraries such as CMSIS-CORE (for the processor core) CMSIS-DRIVER for interfaces such as USB and I²C, and the CMSIS-RTOS (real time operating system) API. The CMSIS libraries can be found in the ASF in the directory src/ASF/thirdparty, and the ARM website provides a lot more information about CMSIS [6].

Listing 2. Declaration of the i2c_master_config structure.

```
struct i2c_master_config {
   /** Baud rate (in KHz) for I<SUP>2</SUP>C
   operations in
    * standard-mode, Fast-mode and Fast-mode Plus
   Transfers,
    * \ref i2c_master_baud_rate. */
   uint32_t baud_rate;
   /** GCLK generator to use as clock source. */
   enum gclk_generator generator_source;
   /** Bus hold time after start signal on data
   line. */
   enum i2c_master_start_hold_time start_hold_time;
   /** Unknown bus state \ref asfdoc_sam0_sercom_
   i2c_unknown_bus_timeout "timeout". */
   uint16_t unknown_bus_state_timeout;
   /** Timeout for packet write to wait for slave.
   */
   uint16_t buffer_timeout;
   /** Set to keep module active in sleep modes. */
   bool run_in_standby;
   /** PAD0 (SDA) pinmux. */
   uint32_t pinmux_pad0;
   /** PAD1 (SCL) pinmux. */
   uint32_t pinmux_pad1;
   /** Set to enable SCL low time-out. */
   bool scl_low_timeout;
   /** Inactive bus time out. */
   enum i2c_master_inactive_timeout
   inactive_timeout;
};
```

Listing 3. The infinite loop in the main function.

```
while (true) {
  i2c_master_write_packet_wait_no_stop(&i2c_master_instance, &gpiob_adress_packet);
  i2c_master_read_packet_wait(&i2c_master_instance, &gpiob_state_packet);
  switch (gpiob_state[0])
  {
    case 0 : gpioa[1] = 0x00;    //all LEDs are off
    break;
    case 1 : gpioa[1] = 0x01;    //green LED is on
    break;
    case 2 : gpioa[1] = 0x02;    //yellow LED is on
    break;
    case 3 : gpioa[1] = 0x04;    //red LED is on
    break;
  }
  i2c_master_write_packet_wait(&i2c_master_instance, &gpioa_packet);
}
```

The first entry in the array gives the address of the register concerned and the second gives the desired value. In this case, the value 0xFF configures all GPB pins as inverting. Two arrays differ from this example in that they are just one byte long: `gpiob_adress` and `gpiob_state`. These arrays are kept separate to make it easier subsequently to read the GPB inputs. In principle simple byte variables could equally well have been used here.

There follow several packet structures of type `struct i2c_master_packet`. Next the instance structure `i2c_master_instance` of type `struct i2c_master_module` is created, followed by the

Web Links

[1] www.atmel.com/images/Atmel-42129-SAM-D20_Datasheet.pdf

[2] http://ww1.microchip.com/downloads/en/DeviceDoc/21952b.pdf

[3] http://www.atmel.com/Images/Atmel-42117-SAM-D20-I2C-Bus-Driver-SERCOM-I2C_Application-Note_AT03250.pdf

[4] http://www.elektor-magazine.com/150142

[5] http://forum.elektor.com/viewforum.php?f=2698581

[6] http://www.arm.com/products/processors/cortex-m/cortex-microcontroller-software-interface-standard.php

configuration function for the I²C interface: see the fragment shown in **Listing 1**. As usual the configuration function starts with the declaration of the appropriate configuration structure with `struct i2c_master_config config_i2c_master`. The structure is then filled with the required settings. One handy feature is that if you want to see the range of possible settings (as well as the various elements of the structure), right-click on the text `i2c_master_config` and a menu will open: if you then click on the menu item 'Goto Implementation' you will be taken to the file 'i2c_master.h' where the structure is defined: see **Listing 2**. The definition is well commented, and so often provides useful information. The same goes for many other functions: for example in this case you can try it on the declaration of the function `i2c_master_get_config_defaults()`.

Back to the configuration function, which follows the conventional ASF pattern. First the configuration structure is declared, and it is initialized using the 'Init' function to the default settings for the SERCOM module. The structure `i2c_master_instance` will subsequently be used to access the I²C interface. We simply configure the pins for SDA (PA08) and SCL (PA09) by setting the relevant structure elements, and the clock frequency is set to 100 kHz. The settings in the structure can now be transferred to the SERCOM2 module in the usual way and finally the interface can be activated.

Now we come to the main function. Here we first call the familiar `system_init()` function to initialize the whole processor and then the I²C configuration function is called. The packet structures are now populated, each with their three parameters: the address, the data, and the byte count. For example, for the packet to initialize the IODIRA register the code is as follows.

```
iodira_packet.address     = SLAVE_ADDRESS;
iodira_packet.data_length = 2;
iodira_packet.data        = iodira;
```

When the three packets `iodira_packet`, `ippolb_packet`, and `gppub_packet` have been populated each is sent to the Slave over the I²C bus using the command `i2c_master_write_packet_wait(&i2c_master_instance, &xxxxxx_packet)`, which simply requires a pointer to the instance structure for the interface and a pointer to the desired packet structure. The code now enters an infinite loop (see **Listing 3**). Here two commands are used to read the GPIOB register of the MCP23017 as follows.

```
    i2c_master_write_packet_wait_no_stop(&i2c_master_
instance, &gpiob_adress_packet);
    i2c_master_read_packet_wait(&i2c_master_instance,
&gpiob_state_packet);
```

The first of these commands sends the internal address of the register to be accessed as a data byte (without a final stop bit), and the second reads a data byte containing the register value from the Slave and stores it in the array `gpiob_state`. As you might expect, the read functions use the same parameters as the write functions. A switch-case block follows that checks the value of the received byte and modifies the array variable `gpioa[1]` according to the desired LED levels. The new value representing these LED levels is then written into the register in the Slave IC using the function `i2c_master_write_packet_wait(&i2c_master_instance, &gpioa_packet)`, and as a result the outputs on port A will be set to the desired value and so the LEDs will light as required. The polled version of the I²C master library is used throughout the code, and this is without doubt the most appropriate approach in this example. The code can readily be tested by transferring it to the board. We do not have space here to look at a project using the I²C interface in Slave mode, but you can find out more at [5].

Until next time...

Until next time you will have the opportunity to investigate the capabilities of the MCP23017 in more detail and develop your own projects using the port expander: there is no real limit to the possibilities. In the next installment we will look at (among other things) how to use the analog-to-digital converter and the analog comparator.

(150142)

DesignSpark Mechanical
CAD Tips & Tricks (1)
Adding Connectors to a 3D Model

By **Neil Gruending** (Canada)

Learn how to add PCB connectors to a DesignSpark Mechanical 3D model.

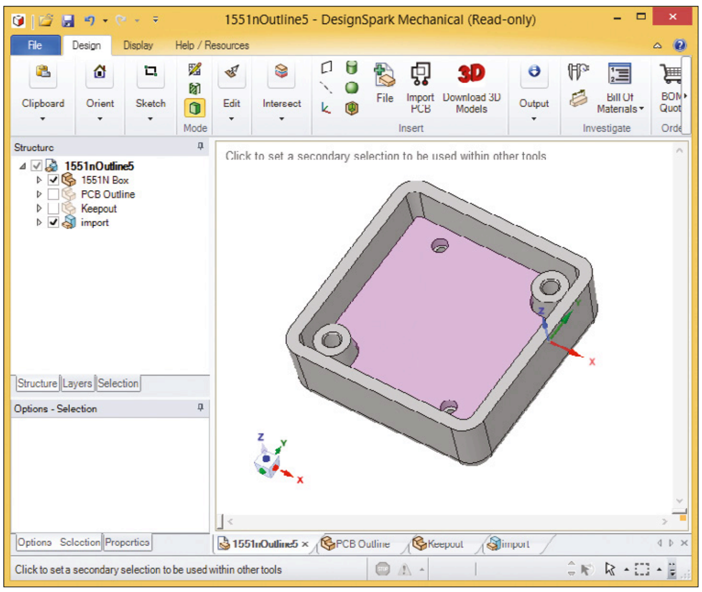


Figure 1. Initial 3D model.

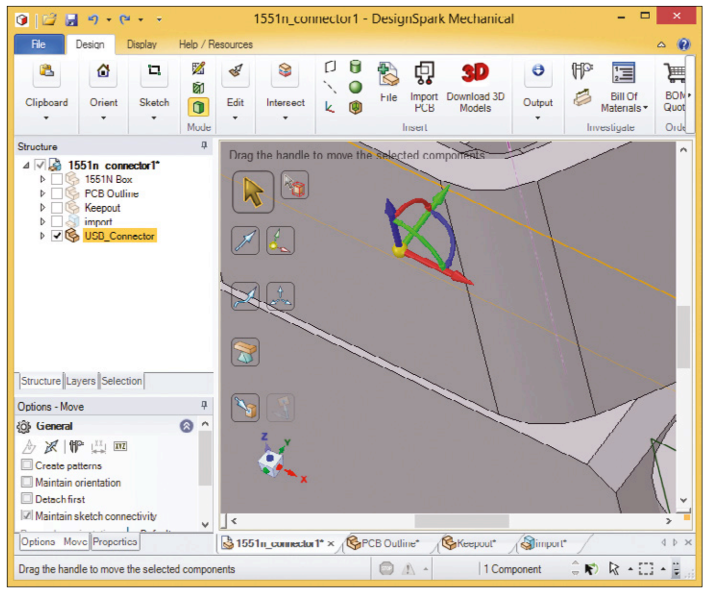


Figure 2. Connector handle.

It's a good idea to start any design with a 3D mechanical model to determine the shape of the circuit board and to line up all of the connectors. As an example, let's add a USB connector to the PCB shown in **Figure 1** that's inside of a Hammond Manufacturing 1551 enclosure [1].
First we need to decide on a connector and find a STEP model for it. I choose to use a Molex 56579-0576 [2] connector which also has a variety of 3D models available for it so make sure that you choose the STEP model so that DesignSpark Mechanical can import it. Once you have a model you insert it into your design by clicking on File icon in the Insert tab and following the prompts. Next we will position the connector so that it's on the top of the board and goes through the side of the case.

Positioning the connector

The first thing we have to do is rotate the connector so that it's parallel with the PCB and facing the right direction using the Move tool from the Edit tab. Then disable the rest of the model components in the Structure window by clearing their check boxes. Next, click on the connector component in the structure window to activate it and then zoom in until you see the handle like in **Figure 2**.

The handle is the red, green and blue arrows with the colored arcs between them. If you click on one of the arrows you can move the connector on that axis. Clicking on the arcs lets you rotate the connector in that plane around the handle origin which is the yellow sphere at the base of the handle. One really nice feature of DesignSpark Mechanical is that once you start moving a component, a little window pops up showing how far you moved it and you can manually enter a value with the keyboard. If you're moving in a straight line it will display the distance in mm and if you rotate it the amount of rotation is shown in degrees.

Next we need to line up the bottom of the connector to the top side of the PCB with the Move tool. Enable the PCB in the Structure window and then click on the connector so that its handle is visible. Now click on the Anchor button (sphere with two arrows) to pick a corner on the connector that will rest on the PCB. To pick the corner instead of an edge just hover the mouse pointer over the corner until you see a little blue circle over the corner and then click on it.two
Now click the Up To button (arrow pointing to a cube) to tell the Move tool how to move the connector. First, choose the direction you want to move using the anchor and then choose the

edge or face you want to line up. For example, I only wanted to move the connector upwards so I clicked on the Z axis and then then I selected the top face of the PCB. DesignSpark then moved the connector to the top side of the circuit board like **Figure 3**. Now it's easy to move the connector in the X and Y directions until it's placed where you want it. In my case I used the Up To tool to line up the black squares under the connector shield which are the recommended solder footprint pads with the edge of the board. Once you're happy with the position it's time to make a cutout in the plastic for the connector.

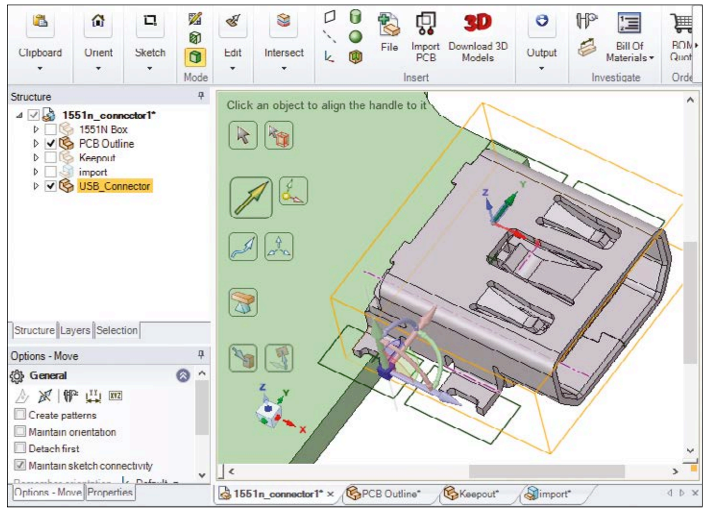


Figure 3. Rotated connector.

Modifying the housing

Unfortunately we have to modify the enclosure component so that DesignSpark Mechanical will let us modify it because it's an imported STEP model. Right click the enclosure component in the Structure window — 1551N Box for this example — and then choose Open Component which opens the enclosure in a new tab where we can edit it. Now the trick is to draw a solid shape near the enclosure. I did this by drawing a 2 x 2-mm square and then I used the Pull tool to make it into a 2-mm cube. Then go back to the full model tab and right click the enclosure again and clear the Lock checkbox that was preventing us from editing the enclosure.

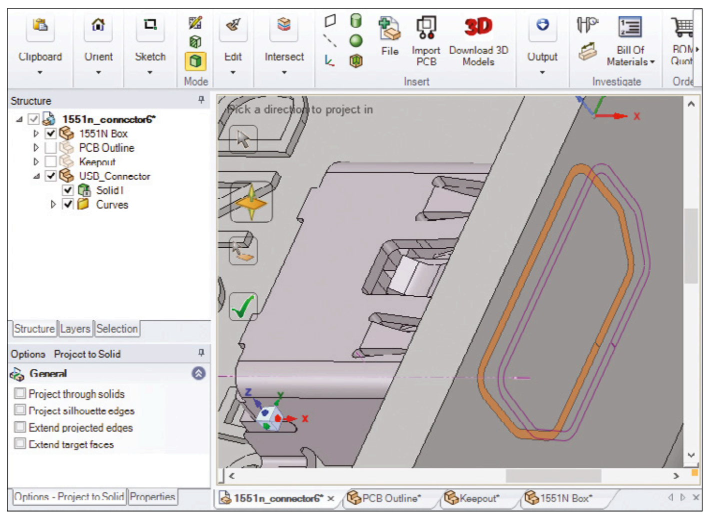


Figure 4. Connector projection.

Now we can make a cutout for the USB connector using the Projection tool from the Intersect tab to project the connector shape onto the enclosure's outer face. First, select the front connector face so that it turns orange. Then click the Select Target Faces button (single arrow with a rectangle) and click on the outside face of the enclosure to get the purple projection on the outside of the enclosure like in **Figure 4**. For our example I had to hide the enclosure to see the front connector face and made it visible again to select the outside face. It's hard to see in the figure but the bottom of the projected connector image has a small gap that we will need to remove. Use the Pull tool to push the projected connector from the outside of the enclosure to the inside until it is deleted. That leaves the inside of the connector suspended by a very narrow piece left behind from the connector gap. The Pull tool can now get rid of the narrow piece by pulling one side to the other to shrink it away. Now just the middle remains which you can also remove with the Pull tool like before and you are left with **Figure 5**.

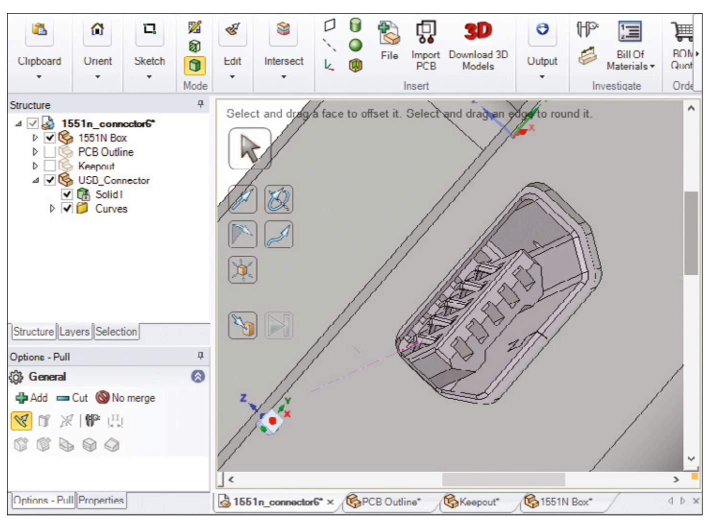


Figure 5. Connector hole.

The final model can now be used to know where to place the connector on the PCB and to also know the enclosure needs to be modified. You can also add other items like LEDs the same way.

(150136)

Web Links

[1] www.hammondmfg.com/dwg9.htm

[2] www.molex.com/molex/products/datasheet.jsp?part=active/0565790576_IO_CONNECTORS.xml

SmartScope: Multi-Platform Measuring Instrument

Clever and distinctive USB scope

By Harry Baggen (Elektor Netherlands Editorial)

Most USB oscilloscopes have been designed for use in combination with a Windows or Linux PC. The SmartScope is an exception to this: it works just as well with an Android tablet, an iPad or an OS X system. The software has been designed to make the user interface appear identical across all platforms. We've tried one out on a PC and a tablet.

A fair number of (USB) oscilloscopes have previously been reviewed and tested in Elektor. However, the SmartScope is a measuring instrument that differs significantly from the competition, in both hardware as well as software. Before we take a closer look at the SmartScope, we'll first find out how this project got started.

History

When electronic engineer Riemer Grootjans acquired a number of different USB scopes for use at work and at home, he wasn't very pleased with these devices. He started to think about designing one himself, which would have all the features he expected of a USB scope: versatile, portable, easily extended, and with an intuitive user interface. He started to design the SmartScope along with two of his friends and set up a Kickstarter campaign. Within a month their company (LabNation) achieved over $300,000 of funding, which was sufficient to start planning the production of these devices. A lot of hard work was still ahead of them in the following few months. Although the design for the hardware was completed before the Kickstarter campaign, there turned out to be so much demand for a sample buffer in the hardware that they decided to create a completely new design. They succeeded after many sleepless nights, and by the end of 2014, all of their 1500 backers had received their SmartScope (the production started in August 2014).

Hardware

The hardware for the SmartScope consists of a small metal enclosure (for good shielding), with a pair of full-sized BNC connectors on the front for the analog inputs, and a 16-pin header at the back, for the 8 digital inputs of the logic analyzer, 4 digital outputs, and the output of the built-in arbitrary waveform generator (AWG). Also on the back are a mini and

a micro USB connector. The mini-USB is for connecting to a tablet, smartphone or computer, the micro-USB is used to connect an external power supply, or for daisy-chaining several SmartScopes together. This last feature has not yet been implemented, so the SmartScope currently operates with 2 channels.
The printed circuit board contains a powerful Xilinx Spartan 6 FPGA, which takes care of the main tasks (such as processing the received measurement data and creating the AWG signal). The conversion of the input signals is taken care of by an A/D converter with 100 Msamples/channel and a resolution of 8 bits. A RAM chip provides a buffer capacity of 4 Msamples/channel. A PIC controller takes care of the communications with the computer via de USB connection. There are several relays and opamps at the inputs for the range and AC/DC selections. The bandwidth of the analog input section is 45 MHz. This is quite large compared to the sample frequency of 100 Msamples/s. This was done on purpose in order to minimize the attenuation of the input signals as much as possible. The usable input range is up to about 10 to 20 MHz (which is also stated by LabNation).

Figure 1. The SmartScope hardware works eminently with a tablet.

Software

One of the most important goals that the developers had in mind was that the software should run under almost any operating system, with an identical user interface. This is something they've certainly accomplished. As far as we know, this is the only scope that works on virtually all operating systems: Windows 7/8, Linux, OS X, iOS (jailbroken) and Android 4.0+. It can therefore run on a standard PC or a laptop, but also on a tablet or a smartphone.
The developers also felt that the controls on most USB scopes were somewhat limiting. The user interface is usually some sort of copy of that found on hardware scopes, which has been in existence since the fifties. The whole control panel including the knobs is often simulated on the screen, or pull-down menus are used for all kinds of settings. This was thought to be a bit out of date, and found not to be very intuitive.
The software for the SmartScope had to be different and should make use of modern interfaces such as touchscreens. This didn't appear to be very difficult at first, but it required a lot of thought and hard work before a functional alternative was created. The result is a control surface that reminds you of your first experience with a tablet or smartphone: it is a bit strange to start with, but it soon feels right. It's as if you've given somebody their first tablet: they'll play with it for a bit and after quarter of an hour it looks as if they've been using it all their life. The same happens with the software for the SmartScope. It takes a little bit of time to get used to it, but then it becomes so obvious that you don't want to return to the old-fashioned methods.

Functionality

The software was installed on a Windows PC and an Android tablet. The Android device needs to be running Android version 4.0 or above, and requires USB-host support. All of the software versions are available from LabNation's website [1]. The Android app can also be found on Google Play. For a tablet you will also need a micro-USB OTG cable (which costs a few dollars) to connect it to the SmartScope. The combination of a tablet and SmartScope creates a very useful mobile measuring instrument, since the scope is powered by the tablet, which means you can use it away from the mains supply.
When the software starts, it first loads the complete 'firmware' for the SmartScope into the FPGA. This takes just a single second. With this method you can be assured that you will always have the most recent version. You won't need a bootloader or flash memory in the device either.
The software looks the same on both systems and always starts in oscilloscope mode (**Figure 2**). On the left is the main menu with all the settings. At the bottom are a few of the most commonly used settings. The rest of the screen is taken up by the scope display with a scale, where the measured signals will be displayed. These are the two analog inputs or the eight digital inputs when in the logic analyzer-mode; when one of the built-in serial decoders is used, the decoded data will also be displayed.
Up to now, there's been nothing really special. What is remarkable is the absence of control knobs and buttons. Instead of using menus and knobs, almost everything is done via mouse clicks or (in case of a touchscreen) by swiping your fingers.

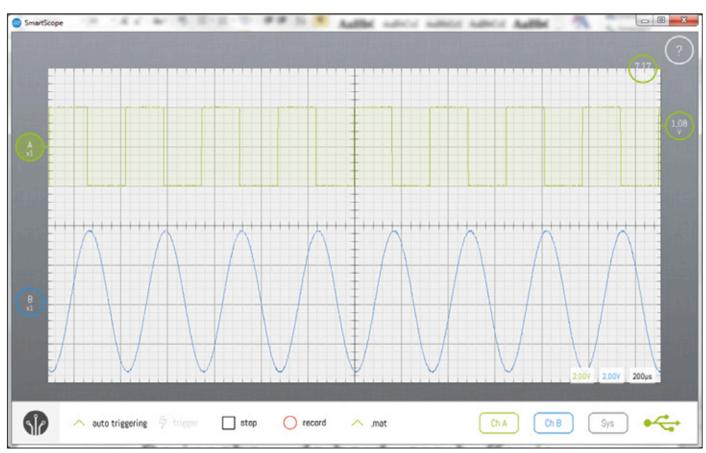


Figure 2. The standard oscilloscope display has very few control elements, as most settings are done via the touchscreen or mouse.

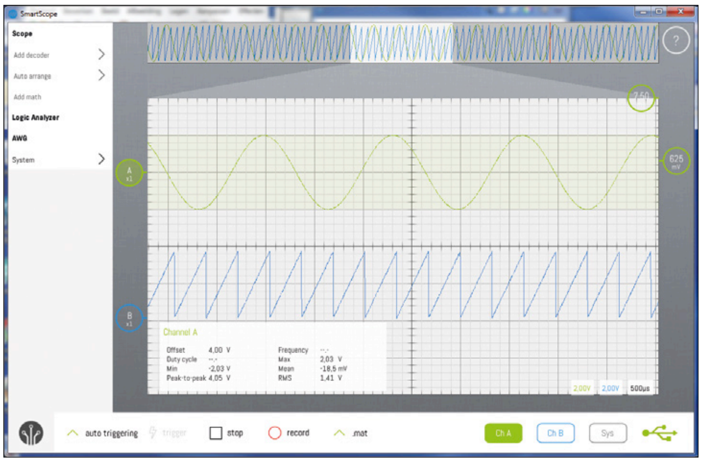


Figure 3. The contents of the hardware buffer can be shown at the top of the display, from where you can select a section and zoom in on it.

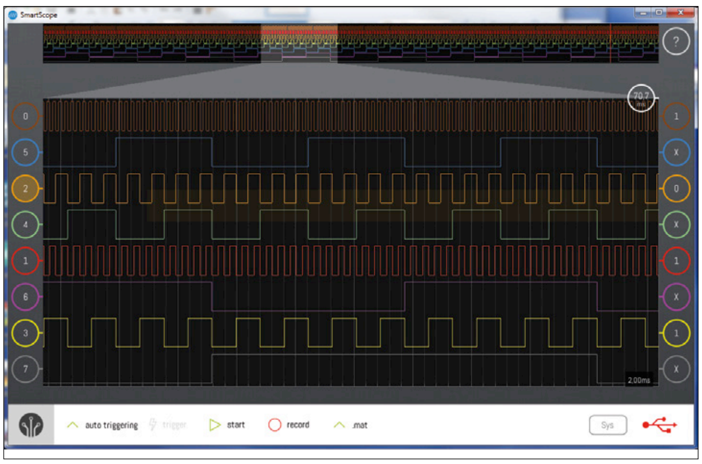


Figure 4. The logic analyzer with its 8 channels. You can easily access the 4 million measurements in the hardware buffer and inspect them in detail. The background is now black to make the waveforms easier to see.

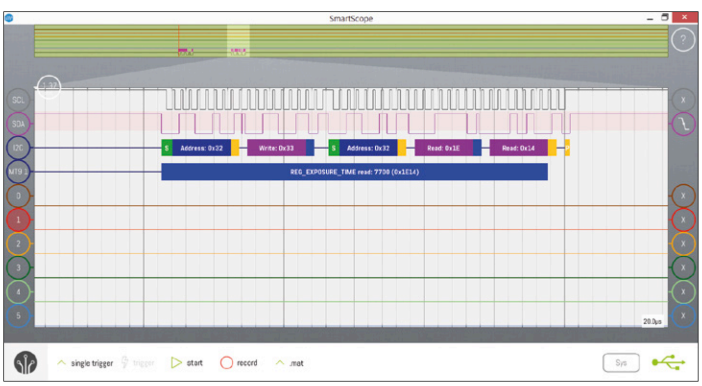


Figure 5. In this screenshot the signals on the I²C bus have been processed by a standard I²C decoder. The results have then been converted by a custom decoder into an easily readable format.

This does take some time to get used to. But once you've found out how to change a setting (such as changing the input gain using a pinch/stretch gesture with two fingers) it soon becomes second nature.

Each signal has an identically colored circle to the left of the grid, which hides a number of functions. When you touch it or click on it with the mouse a small menu appears that lets you set up the AC/DC coupling, triggering, probe attenuation or hide the signal. There is a similar circle at the right of the grid. The menu associated with this lets you select the trigger channel and either the rising or the falling edge for triggering. A status box can be displayed that shows the settings and a lot of detailed information about the signal. When it is no longer required, you can just drag it off the screen.

At the top of the display you can call up the hardware memory buffer. This shows the full contents of the buffer (4 Msamples). From here you can quickly and easily select a section that interests you so you can look at it more closely.

The menu on the left has a section that lets you set up the AWG. At the moment the user can choose from a number of standard wave forms, or import a user-defined signal from a CSV file, which can be stored in Dropbox or a local hard drive.

One thing that stands out is that a number of digital decoders are included as standard with the software. It's unusual to see this for products in this price range (you would expect to pay for these as an extra). These decoders are used to unravel different types of digital formats and to display things such as the actual values and addresses of the data. At the time of writing, there are decoders for I²C, 3-wire and 4-wire SPI and UART included with the software, and there are more to follow. It is also possible for users to write their own decoder, and to make it available to the SmartScope community. Such a decoder consists of a single DLL file, which should be added to the SmartScope system folder. This has been set up in such a way that it can work across all platforms without modifications.

It's quite possible that some features have not been mentioned, but at least you should now have a good idea what this scope is capable of.

In practice

We've now come to the stage where we connect the device and start using it in earnest. The PC version of the software was tried out first, and it took a while to get used to it. To start with, we regularly found ourselves looking up instructions from the Help, or tried to discover where a particular function was. It will take some time before you'll be able to operate the software like a pro. However, with the tablet versions things progressed much more quickly. You'll soon find out that the program was developed for use with a touchscreen. In this case, it took only several minutes to find out how to operate it, and it was also much easier to try things out.

In both cases it was noticeable how quickly the scope responded. You get the same experience as if you were using a 'standard' scope. It is often the case that USB scopes experience a delay between the scope hardware and the processing and displaying of data on the computer. You don't notice any delay with this device, so that's a job well done by LabNation. The time and voltage scales can be adjusted via pinch/stretch gestures with your fingers or with the scroll wheel of your mouse. The scale is updated immediately, going to the next, rounded,

The built-in hardware buffer is unique in this price range

value. It is even possible to set a different voltage scale for each analog input signal.
The panorama bar is a very useful feature, which can be made to appear at the top of the display. This shows all of the 4 million samples stored in the hardware memory. From here you can select any section using touch or the mouse, which will then be displayed on the main scope screen. The complete contents of the memory can also be exported and stored in a file.
The AWG can create several waveforms as standard, which have a number of adjustable parameters. The slide controls for these are quite small, which makes it difficult to adjust the values to a precise figure, especially for the frequency. An extra (numerical?) input method would be a welcome addition here. You can create your own waveforms by putting values into a CSV file, but this is not a very user-friendly method. The developers have indicated that they're continually adding to the functionality, so this is one area that should see some improvement in the future.
The logic analyzer is just as easy to control as the scope section. Many electronic engineers rarely use these functions on a standalone device because the operation is so tricky. However, it's a piece of cake in this case. You can set an 8-bit trigger word by clicking/touching the circles on the right of the display. Further development of this section is planned for the future as well.
The digital decoders in the SmartScope can be used on both analog signals as well as digital signals to decode various protocols. Some of the more popular ones have already been included. A small test with an I²C bus quickly revealed how useful these decoders are. Without too much effort, you'll be able to see the values or addresses on the screen. It is even possible to set up two decoders in series, where the second one processes the results produced by the first decoder. An example of this is shown in **Figure 5**, where the data in the hardware buffer has first been decoded by the standard I²C decoder. Its output is then processed further by the second decoder, which displays the results in an easily readable format: It shows the register number followed by the value of the next two bytes, combined as a word.

Conclusion

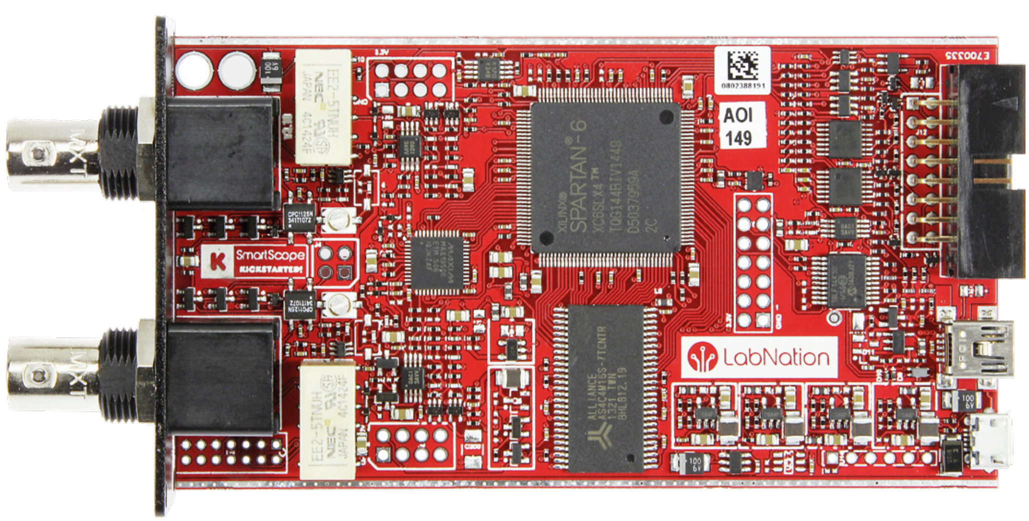
Although the specifications and features of the SmartScope at first appear similar to other devices in this price range, it soon becomes apparent that it has several features that none of the others has, such as the built-in hardware buffer and the digital decoders. This instrument provides you with an extensive measurement arsenal: Not only do you get two analog inputs, but there also eight digital inputs, four programmable digital outputs and last but not least, the AWG. When you consider the number of accessories that are included as standard (two probes, connection cables for the AWG and digital inputs/outputs, test clips and a USB cable) it becomes clear that the SmartScope is a successful measuring instrument that is certainly worth its €230 price tag ($/£ pricing is conversion dependent).
The software is unique in that it can run on virtually any platform. The interface does take some time to get used to, and may not appeal to everybody, but we're certain that it will become better, more flexible and extensive in the future. The people at LabNation are continuously developing the software, and several items were added or improved during the time we evaluated the scope.
The best way to control the SmartScope is with a touchscreen, since that is much more preferable than a mouse. However, since electronic engineers can't do without their laptop or PC, my choice is easy. I'm going to my boss and ask if there's room in the budget for a Windows 8 laptop with a touchscreen. This seems to me the ideal combination for use with the SmartScope!

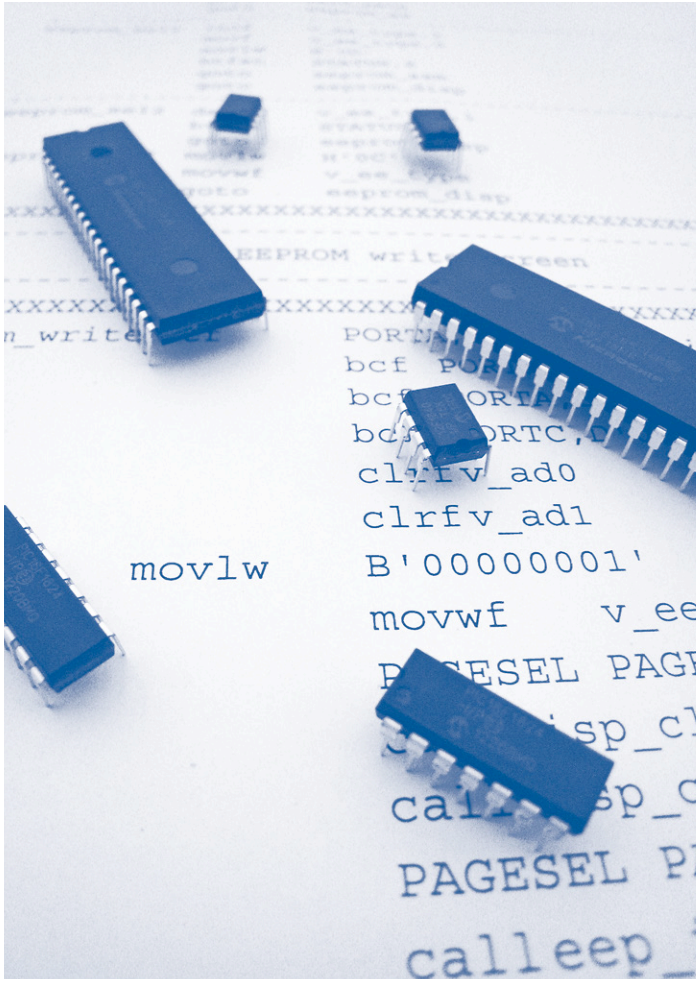
(150153)

Since the SmartScope is so versatile and has such a good price/quality ratio, we've decided to make this instrument available via the Elektor Store, see www.elektor.com.

Web Links

[1] www.lab-nation.com





PIC® Assembler Crash Course (1)

Your first program in machine language

By **Miroslav Cina** (Germany) miroslav.cina@t-online.de

In this day and age should we still be bothering ourselves with Assembler? Absolutely yes in our opinion; with 8-bit controllers it definitely pays to keep our code short and snappy to maximize execution speed. Our crash course — featuring a small PIC controller — is based on the customary mix of theory and practical matters.

Assembler (also called *assembly language*; *assembly code*) is very much a hardware-dependent programming language and this in itself brings with it a number of advantages and disadvantages. When we use a high-level programming language it's the compiler software that determines how effectively the source code is interpreted. In Assembler it's the job of the programmer him or herself to secure the most efficient outcome — both in terms of code length and also execution speed. This is because the conversion of assembler code into machine language (or hex code, as appropriate) is defined very strictly.

Program length is a significant factor, particularly when you are using a 'small' microcontroller (a PIC10F200 for example provides only 256 words of programming memory). In complex calculations performance can play a crucial role, since under certain conditions a C compiler can generate total nonsense. In cases like this, where you need tight control over the operation, it can even make sense to process only certain vital parts of the program directly in Assembler. Here's another advantage: for time-critical operations you can calculate pretty accurately how many clock cycles (in other words how long) an Assembler routine will take to run.

Assembly language is also the best way of getting to know your hardware right down at detail level. Higher-level programming languages tend to conceal the actual operation of registers and similar things from the programmer.

Nevertheless in Assembler you really do end up doing everything yourself — even multiplying two small numbers can require some serious thinking.

Hard and software

For our course I have selected one of the smallest PIC controllers, the PIC12F675 [1], a choice made having been involved with PIC controllers from Microchip for many years. The target price of this microcontroller lies in the 1-euro/dollar/pound range and for many simple applications this device is totally adequate.

For these experiments you will need a PICkit2® programmer and a small experimenter board (both of these are frequently sold together as the PICkit2 starter kit). In the next part of the course we'll see how you can produce a simple experimenter board yourself. I should mention you can naturally also use the current PICkit3 programmer for this course.

The software used comes gratis. In Windows we can easily put together the source text with the help of a text editor (Notepad), and afterwards use the program MPASM.exe (a constituent part of the Microchip MPASM® suite) to assemble it (in other words convert it into machine language). The MPASM suite is in turn a constituent part of the MPLAB IDE software packages (IDE = Integrated Development Environment). The MPLAB IDE can be downloaded free from the Microchip website [2].

The hex file produced after Assembling is finally ported into the microcontroller using the PICkit2 software. And that's it.

The Registers

First of all we need to find out a little about our microcontroller and learn a few Assembler commands. Don't panic — the first package of theory is easy to manage. With that out of the way, we can now press on.
The PIC12F675 is an 8-bit microcontroller from Microchip's 'midrange' family. The microcontroller is available in a PDIP-8 package (other options exist). Six out of its eight little legs are usable as general-purpose digital port pins (GP0 to GP5). GP3 can be used only as an input, with the remaining pins being either inputs or outputs. The chip includes 1024 words of flash program memory plus 64 bytes of SRAM for general (undefined) use and 128 bytes of EEPROM.

When you program in Assembler, you need to involve yourself with registers, which in this case are 1 byte-large memory modules having a specific logical function. Some registers belong to the core (kernel); for calculations these can accommodate 8-bit values for instance, or else they may provide information on the state of the controller. Other registers have responsibility for the peripheral blocks of the controller, such as the GPIO register, which represents the status of the inputs and outputs.

With PICs you always have (at least) four core registers:

- W register
- Config register
- Option register (OPTION_REG)
- Status register (STATUS)

The 64 bytes-large SRAM is for unrestricted use, and almost all the registers are accessed at defined memory addresses. Using an address that's 8 bits long we can address a total of 256 memory locations. Looking at the so-called memory map (**Figure 1**) you can spot that not all 256 memory locations are in fact available. Taking the status register for example, this can be accessed not only at address 03h but also at 83h.

On this map we can also see that the GPIO register (which we are about to get involved with) can be found at memory location 05h. At the same time it can be seen that the application memory (64 bytes) is accessed at memory addresses 20h to 5Fh.

The exceptions are registers that don't have memory space. Included in these exceptions are the Option register, also the W register.
The W register is the 'register-in-chief' of the microcontroller (W = working). All arithmetic operations are performed using the W register for instance.
The Status register is divided into individual bits (see **Figure 2**). Crucial at this stage is bit number 5 (RP0), the 'register bank select bit'. This toggles between the two memory banks; the bit has to be set or cleared before you provide an address as a parameter of a command that follows. Access to memory locations 80h to FFh needs this bit to be set; if RP0 = 0, then we are addressing memory locations 00h to 7Fh.
The Config register is used for flashing the controller (described later on). It determines, for instance, whether the internal oscillator of the controller is to be used.
At this stage we will skip the Option register altogether. We shall now briefly concern ourselves with three further registers that, in contrast to the registers just mentioned, are responsible for peripherals.

TRISIO, GPIO and ANSEL

The TRISIO, GPIO and ANSEL registers are used for I/O control. Right now the only thing we need to know about the ANSEL register is that for our initial experiments we need to set it at 00h in order to deactivate the analog functionality.
The TRISIO register controls the direction of communication. Whether a port pin functions as an input or output depends on how the relevant bits of the TRISIO register are set. Value 0 signifies output, 1 is input. If the first bit is zero for instance (written TRISIO<0> = 0), pin GP0 is used as an output.
The sole exception is, as already mentioned, port pin GP3 (this also has the function MCLR = Master Clear), which can be used only as an input. The relevant bit of the TRISIO register is consequently always 1.
We can manipulate the inputs and outputs directly with the help of the GPIO register. A write action to the GPIO register controls the pins configured as outputs directly; the inputs can be scanned by taking a read action from the GPIO register.

First commands

Now it's time to get to know a few Assembler commands (the basic commands, so

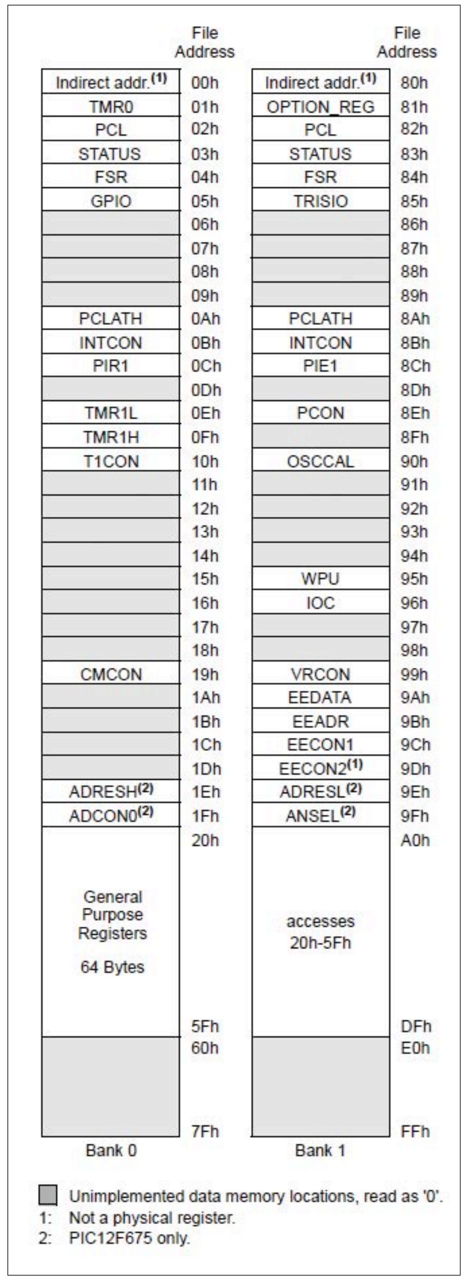


Figure 1. The memory map displays the addresses of the registers and memory locations available for undefined use.

IRP	RP1	RP0	$\overline{TO}$	$\overline{PD}$	Z	DC	C
bit 7							bit 0

Figure 2. The various bits of the Status register.

to speak).
Our PIC12F675 belongs to the RISC (Reduced Instruction Set Computer) group of controllers — only 35 commands need to be mastered here.

MOVLW and MOVWF
The command MOVLW loads an 8-bit value into the W register. The value itself can be entered either in binary, hexadecimal or decimal.
The syntax of this command looks like this:

```
movlw   k
```

...in which ‘k’ is a value within the range 00h to FFh (1 byte).
Incidentally, whether you use large or small letters in Assembler commands is unimportant, so we could also write:

```
MOVLW k
```

The following examples show how we write values in binary (prefix B), hexadecimal (H) and decimal (D) format:

```
movlw   B'10011110'
movlw   H'9E'
movlw   D'158'
```

All three commands are identical and will each load the value 9Eh into the W register.

The command MOVWF copies the contents of the W register into a memory location:

```
movwf   f
```

...where ‘f’ is a value between 00h and 7Fh and stands for the destination address (as already described, we need to have previously set or cleared (as appropriate) the 5th bit of the status register in order to toggle between the two memory banks).

So, if we wish to write the value 9Eh into the address 20h for example, the command sequence looks like:

```
movlw   H'9E'
movwf   H'20'
```

The first command loads the value 9Eh into the W register and the second command then writes the content of the W register into memory location 20h.

CLRF
This command sets the contents of a memory location to 00h (CLRF = Clear f).
The syntax of the command is:

```
clrf    f
```

...where ‘f’ is a value from 00h up to 7Fh and represents the destination address.

So, for instance:

```
clrf    H'20'
```

...means the value 00h is written into memory location 20h.

Just to sum up the commands MOVLW, MOVWF and CLRF, here’s another short example. We have the following code:

```
movlw   H'9E'
movwf   H'20'
clrf    H'20'
```

Figure 3 show how memory locations are governed (at the outset we have no idea which values are contained in the W register and the memory location 20h).

BSF and BCF
In contrast to the commands mentioned up till now, which always operate with bytes, the commands BSF and BCF work with bits. BSF is actually an abbreviation for ‘Bit Set f’ and by analogy BCF is short for ‘Bit Clear f’, wherein ‘f’ stands for the address of a memory locations. The syntax description is:

```
bsf     f, d
bcf     f, d
```

Here ‘f’ is a value from 00h to 7Fh and ‘d’ a number from 0 to 7.

These commands either set (bsf) or clear (bcf) a single bit of the byte to a memory location. In this example:

```
bsf     H'03', H'05'
```

...the command sets bit 5 (d = 05h) in memory location 03h (f = 03h) to 1.

GOTO
Just as in many other programming languages you can interrupt the linear program sequence with GOTO in order to continue from another point in the code (as specified in the GOTO command).
The syntax of the command is:

```
goto    k
```

...where ‘k’ is an address in the program memory. Actually ‘k’ can take any value from 000h to 7FFh, but as our microcontroller contains only 1024 words of program memory, values above 3FFh will not make sense.

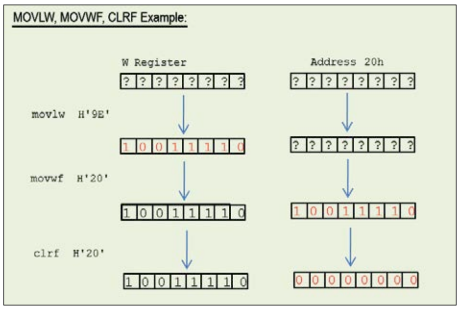


Figure 3. Operation of commands MOVLW, MOVWF and CLRF.

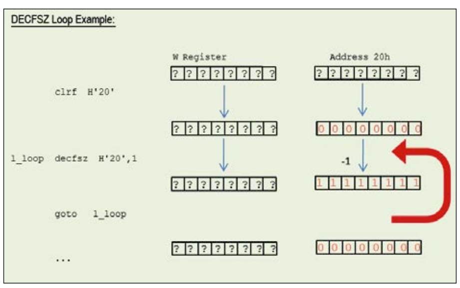


Figure 4. Loops can be implemented using DECFSZ.

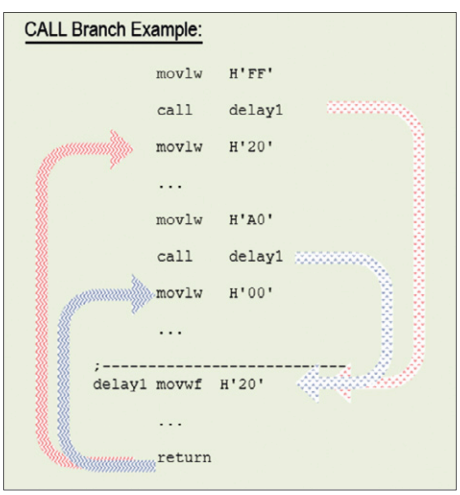


Figure 5. CALL looks after sub-programs.

Instead of 'k' you can also give a label, a designation for a specific program memory location. This label must be defined at another location in Assembler code, which you could simply write ahead of the corresponding command to be invoked. Consistency is vital here, either uniformly upper or lower case!

DECFSZ

This command is an abbreviation of 'DECrement F and Skip if Zero', which we could also call 'Loop command'. It is responsible for the conditional execution of the command that follows. First the value of memory location 'f' is decremented (reduced by 1) and after this we either execute the next command (if the result differs from zero) or the next but one (if the result is exactly zero).
The syntax is:

```
decfsz   f,d
```

…where 'f' is the address of a memory location and 'd' defines where the result of the operation (the decrement) is to be stored. If d = 0 the results is stored in the W register and the memory location itself remains unaltered; if d = 1, the result is written back into the memory location (and the W register remains unaltered).

Figure 4 shows how we can use this command to create a loop. In the first line we set the contents of the memory location 20h to 00h. Immediately after this the command DECFSZ is executed with the add-on '1'. In this way the result is written back into the memory location. In the first pass we subtract a 1 from 00h; the result is called FFh, as we always count bytes because we always count bytes unsigned. A decision is then taken whether the result is equal to 00h. Here it's not, so the next instruction is executed. Incidentally, the decision as to whether the result was equal to 0 was scored on the basis of the so-called zero-bits of the status register. This bit would have been 1 if the result of the subtraction had been 00h.

As you can see in Figure 4, the second line is also flagged with a label 'l_loop'. Straightaway in the next line we can use 'goto l_loop' to jump back to the DECFSZ command. Here 1 is subtracted again and written back to 20h. The current value is thus reduced to FEh, and so forth.
In this way we have realized a loop that in this example is executed 256 times. Once the value in 20h finally becomes 00h, the GOTO command is skipped and we exit the loop. By the way, we didn't have to use the W register here.

A loop of this kind can be used, for example, if you want to incorporate a waiting time in the program sequence (e.g. for making an LED flash).

CALL / RETURN

Just as we know in other programming languages, CALL serves to invoke a subroutine and RETURN is used to end the subroutine again and continue the main program.
The syntax of the command is very similar to that for GOTO:

```
call     k
```

…where 'k' here again is an address in program memory, located in the range from 000h to 3FFh.
It goes without saying that here too you can apply a label. For this it is best to use a meaningful name for our sub-program, for instance 'Delay'.

With RETURN no parameters are provided:

```
return
```

The self-same subroutine can be invoked from varying program locations using CALL (see **Figure 5**). Once processing is completed and RETURN has been performed, we carry on with the next command following the respective CALL.

NOP

There is one of these in Assembler too. This command simply does nothing at all; you can use it to create a delay. In our practical example we shall make use of this.

Defining constants

In Assembler you can declare constants using the keyword EQU, so as to make your code more readable and portable. For example, if we declare at the very start of the code:

```
STATUS        EQU  H'0003'
```

…then later on in the code we no longer need to state explicitly the memory location at which the Status register is accessed. For example we can write:

```
bsf      STATUS,H'05'
```

…instead of

```
bsf      H'0003',H'05'
```

…in order to set the fifth bit in the Status register. Let's do exactly that and straightaway also declare:

```
RP0        EQU  H'05'
```

Now we can use:

```
bsf      STATUS,RP0
```

…and

```
bcf      STATUS,RP0
```

…to set the fifth bit of the Status register, then clear it — and in this way toggle between the two memory banks.

Doing it this way also makes our code simpler to port from one type of controller to another (say, from a smaller PIC to a larger one). In a different type of controller the Status register might be accessed at a different memory location, so in this case we need change only the constant declaration, with the remaining code remaining unaltered.

__CONFIG

This statement (a so-called directive), in contrast to the commands mentioned previously, is not turned into machine code that is processed at run time. Instead it is used to specify the contents of the Config register.
The Configuration register is one of (very few) registers, that you cannot define under an address in memory. The value of the Configuration register is already defined when you flash the microcontroller.

The __CONFIG directive is normally found right at the beginning of the source code, e.g.:

```
__CONFIG      B'00000110000100'
```

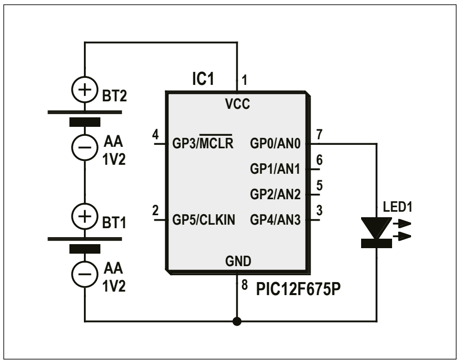


Figure 6. Making an LED flash on and off could not be simpler.

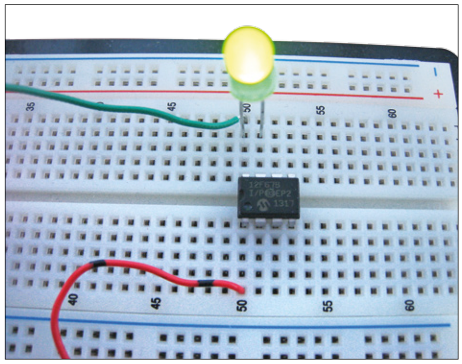


Figure 7. The circuit can be assembled on a breadboard.

In this example the bits named indicate that we wish to use the internal oscillator without an external crystal, no data or program memory protection should be activated, the watchdog function is switched off, and so on.

You can always find details of the individual bits in the data sheet, normally in the chapter covering special features of the CPU – configuration bits.

Comments

A comment begins always with a semi-colon (;). Everything that follows the semi-colon (right up to the EoL — End of Line) is ignored by the Interpreter and is treated as commentary.

If the line of code begins with a semi-colon, the entire line is regarded as commentary.

Our 'Hello World'-type sample application

We have now arrived at the stage where we know everything necessary for a simple application program. So let's get on with it.

Our task is (relatively) simple. To begin we will simply hook up an LED to GP0 and make it flash on and off.
In hardware terms the solution is extremely easy to implement. We'll make use of the internal clock oscillator (4 MHz) without the need for an external crystal. The LED can be connected direct to GP0 (yes, even without a resistor). The microcontroller itself restricts the output current to around 20 mA (for 5 V supply), simply using the internal resistance of the port (**Figure 6**).

The circuit can be constructed on a breadboard (**Figure 7**). As power source you could use two 1.2-V rechargeable batteries for instance. But any other source providing at least 20 mA at 2 to 5 V will do.

Source code

How might our Assembler program look now? What's the minimum we must do to write a program that will run?

As already mentioned above, for our example we can take a simple text editor such as Notepad, type in the code and save the file. The file name extension must always be '.asm' (change this manually after saving if necessary). As file name we can use '01_LED_v_1p03.asm' for example. On the project page for this article [3] you can download the ready-made file.

Figure 8 shows the first part of the code. To make the program more readable (and more meaningful to other users too) let's be generous with comments. We wish to work with constants too. Declarations like

STATUS EQU H'03'

…will make the code easier to port over too, if we decide to try it out in a larger PIC later on.

Fortunately we don't have to write these constant definitions into our code each time. In the file P12F675.INC, a component part of the MPASM suite, you can find all the essential definitions (register addresses, bit positions and so on) for our type of controller.

```
;*************************************************************************
;*                          Blinking LED                                 *
;*                        v 1.03 - 09.03.2015                            *
;*************************************************************************
;*           Hardw.: PIC12F675 used                                      *
;*           OSC.......: Internal osc. used     POWER.....:  5V          *
;*************************************************************************

;-----------------------------------------------------------
;Pins connection:
;----------------------
;GP0 --> LED output
;GP1 --> N/C
;GP2 --> N/C
;GP3 --> N/C
;GP4 --> N/C
;GP5 --> N/C
;-----------------------------------------------------------

 INCLUDE "P12F675.INC"

_U002                                      EQU     B'00000110000100'              ;MCLR = input
              __CONFIG        _U002

;=========================================================================
;       Variable Definition
;=========================================================================
TIMER1                        EQU            H'20'                        ;Used in delay routine
TIMER2                        EQU            H'21'                        ; "            "            "

;=========================================================================
```

Figure 8. Comments serve an important purpose in Assembler also.

```
;==========================================================
;
;       Register Definitions
;
;==========================================================
;...
;-----Bank0------------------
INDF                 EQU  H'0000'
TMR0                 EQU  H'0001'
PCL                  EQU  H'0002'
STATUS               EQU  H'0003'
FSR                  EQU  H'0004'
GPIO                 EQU  H'0005'
PCLATH               EQU  H'000A'
INTCON               EQU  H'000B'
PIR1                 EQU  H'000C'
TMR1                 EQU  H'000E'
TMR1L                EQU  H'000E'
TMR1H                EQU  H'000F'
T1CON                EQU  H'0010'
CMCON                EQU  H'0019'
ADRESH               EQU  H'001E'
ADCON0               EQU  H'001F'
;-----Bank1------------------
OPTION_REG           EQU  H'0081'
TRISIO               EQU  H'0085'
PIE1                 EQU  H'008C'
PCON                 EQU  H'008E'
OSCCAL               EQU  H'0090'
WPU                  EQU  H'0095'
;...
;...
```

Figure 9. Register definitions in the Include file.

Web Links

[1] www.microchip.com/wwwproducts/Devices.aspx?product=PIC12F675

[2] www.microchip.com/pagehandler/en-us/family/mplabx

[3] www.elektor-magazine.com/130483

We incorporate this file at the very beginning of our code using an INCLUDE directive. It functions just as it would in all other typical programming languages, the result being identical to if we had used 'copy & paste' to insert the code of the INCLUDEd file in our program. **Figure 9** provides a look into the file of controller-typical constant definitions.

In Figure 8 you can see that we define two more byte variables (i.e. memory locations in SRAM), namely TIMER1 and TIMER2. We use these in our delay loop. The rest of the program is shown in **Figure 10**. It uses only commands that we have discussed already. In the illustration you can see the various registers together with all the bits. A black question mark in the bit position indicates that the value of the bit is not relevant here.

In the main loop you can see a small red spot, which indicates the location where the LED is switched on. The black spot denotes the command that extinguishes the LED. The arrows represent branches. The small subroutine 'delay_r' is responsible for a delay. You might figure out immediately how it functions. Hint: two interleaved loops are involved.

At the very end of the file do not forget to include the directive 'END'.

Assembling the code

Once we have written the program, we can assemble the code. For this we employ the program MPASM.EXE (a component part of the MPLAB IDE).

After starting the program (**Figure 11**) we select our text file (in the field 'Source File Name'). In the 'Processor' window we need to select the type of microcontroller we are using. The other fields can remain as their default values. Once we press the 'Assemble' button the ASM file is created from our code.

A hex file is generated now (plus a couple of other files that we can ignore for the time being).

The PICkit2 Tool includes the program PICkit2V2.exe. Before starting this program we need to connect the kit to the computer by USB cable, also plug the controller into the programming socket of the experimenter board. When you start PICkit2V2.exe, the chip is recognized automatically (see **Figure 12**). Next we use 'File – Import Hex' to load the hex file and the 'Write' button to flash it into the microcontroller. Job done.

EoL for now — I hope you enjoyed this entry into Assembler. Next time we shall take a look at the complete instruction set of the PIC12F675. Our real-world training exercise will be to construct and program electronic dice.

(130483)

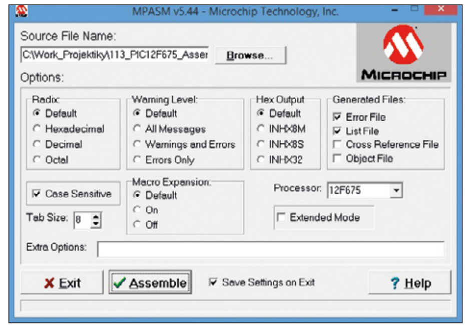


Figure 11. Screenshot of the MPASM Assembler converting code into a hex file.

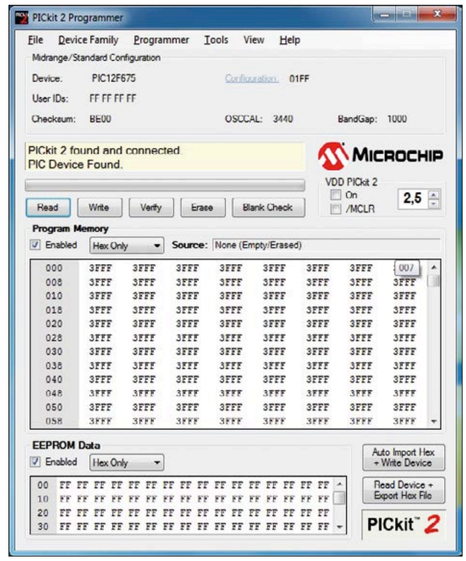


Figure 12. We employ PICkit programming software to flash the program into the controller.

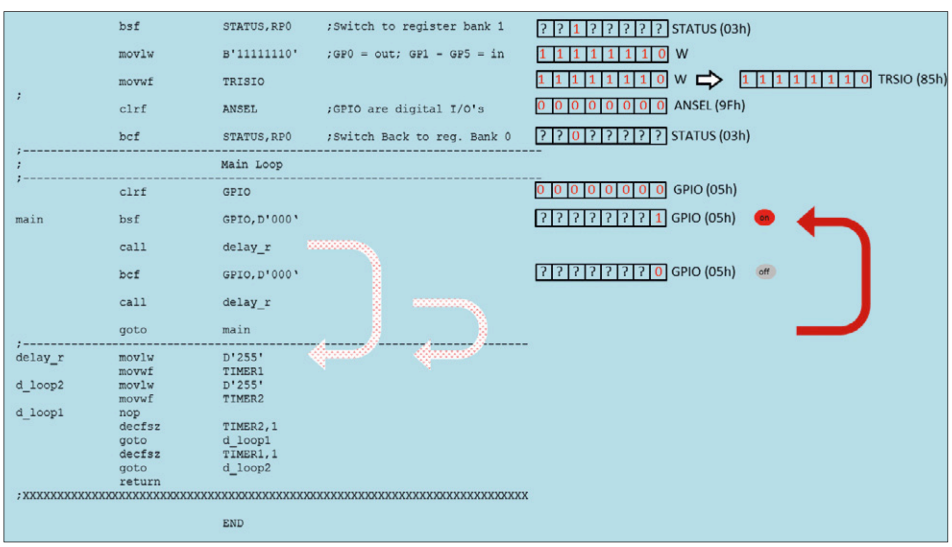
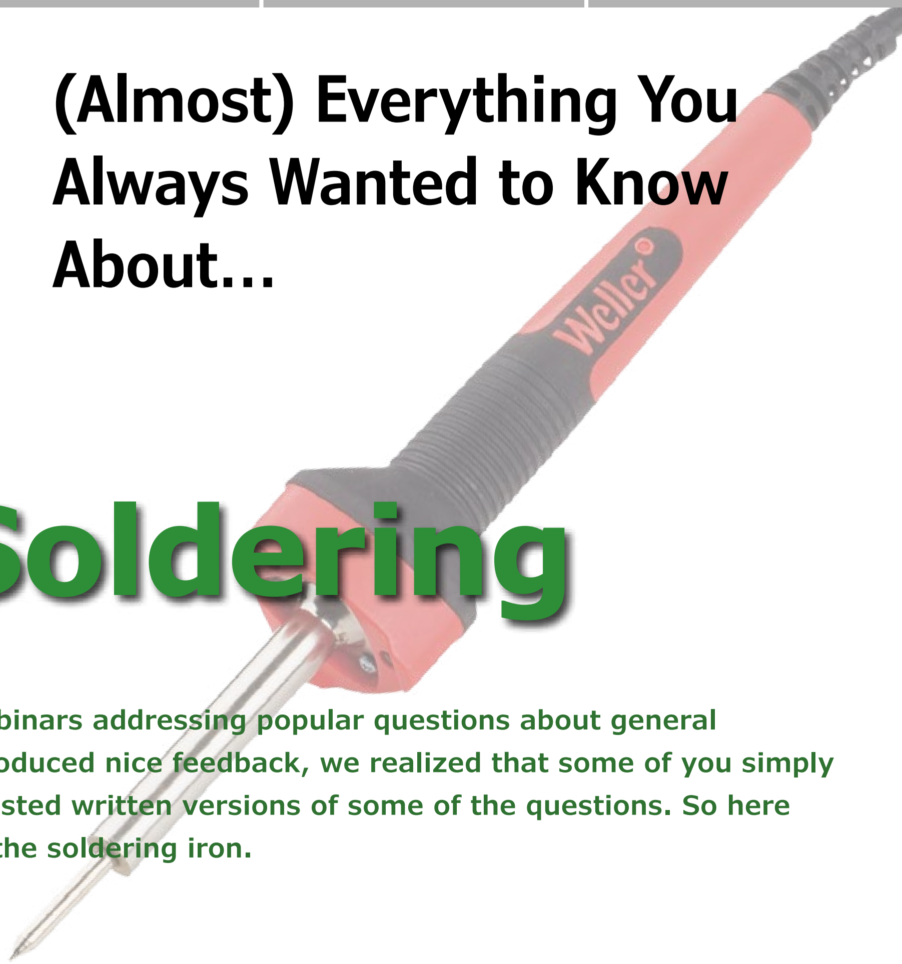


Figure 10. To produce delays we use a sub-program.

Q&A

(Almost) Everything You Always Wanted to Know About…



Contact Soldering

By **Jan Visser** and **Jaime González-Arintero**

Some time ago the two of us did a few webinars addressing popular questions about general electronics. Although these mini shows produced nice feedback, we realized that some of you simply could not attend the live events and requested written versions of some of the questions. So here they are, printed, some tips for the tip of the soldering iron.

No lip-sync, just live (for better or worse)

Some time ago Jan V and Jaime G-A did a short series of webinars addressing different topics: Jan explained, and Jaime learned a lot. Feeling curious too?

Navigate to [po.st/soldersoldiers] to watch the entire session.

Q. ***QFN's are frustrating to reflow-solder in home labs due to tombstoning. Any advice to get these tiny guys securely positioned using contact soldering techniques?***

A Although we'll address contactless soldering techniques in an upcoming installment, this is an interesting question that also involves the good old soldering iron! But first, let's explain what "tombstoning" means. Figure 1 shows the effect with an SMD resistor, since this way it's easier to understand: the different reflow times of the pads the component sits on (i.e. the solder paste on one pad melts before the other) produces a torque, causing the component to tilt like a tombstone. Only nice at Halloween!

With QFN's, the issue can get trickier. However, these packages include a thermal/ground pad that may be very useful secure them down on the PCB before soldering the pins. If we're lucky enough, the pad on the PCB will have a hole (**Figure 2**).

Now, with a piece of Kapton tape we can easily fix the component on the board, and solder it through the back of the PCB, with the soldering iron tip in the hole. The Kapton tape will easily withstand the temperature, and after that the QFN will be perfectly fixed, so we can proceed to solder the pins on the front side.

Q. ***Any tips on using the drag method, please?***

A Drag soldering is easy-peasy to experts, and frustrating to newcomers. Preventing bridging in pins is quite challenging, and some components may (literally) get fried if we're not quick enough. The tip of a mini spoon can ease the job (e.g. JBC's C245-931 cartridge), since you'll be able to "load" the tip with solder, and release it gradually. You may need to experiment with the angle (as shown in Figure 3), gently turning the tip as the solder is transferred to the pins. To keep the solder fluid, apply flux generously and make sure that the tip is not oxidized. Besides, lead-free solder has a different viscosity, and may be more difficult for beginners to handle.

Finding the right speed for the iron (across the pins) and the solder feed can be tricky. Try feeding the solder slightly above the tip, that is, not melting the solder right at the ede of the tip, but one or two millimeters away.

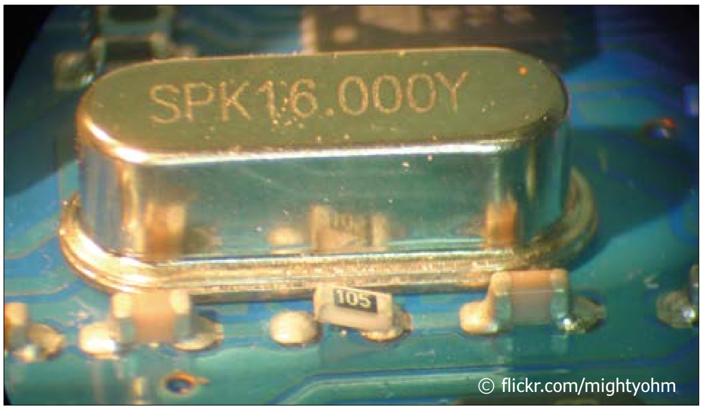


Figure 1. A clear case of tombstoning. That resistor wants to rise from the dead.

Q. ***What's a flux?***

A A flux is a chemical agent that cleans solder and facilitates its flowing, and most importantly, reduces metal oxides as well as lowers the surface tension, making soldering considerably easier. The flux used in electronics reworking is mainly rosin flux — other acidic fluxes should always be avoided. For instance, if applied on a PCB, the flux dad used to solder copper pipes may corrode the leads, rendering the board useless.

For convenience, most solder wire comes with a rosin core, and that's enough for the majority of applications. However, additional flux can be useful in reworks, and it's usually necessary when soldering fine pitch SMT components. For their convenience, we recommend liquid flux pens and syringes. If you usually work with lead free solder, you may also find some fluxes specially for these types of alloys.

Q. ***How does dip soldering work? And wave soldering?***

A In the case of dip soldering, components are placed on the board (generally through-hole parts), a layer of flux is applied, and the board is then left — not entirely submerged — in a solder bath. The solder will thus be "absorbed" by the pins, creating the electrical connections in all pads. Dip soldering is usually carried out manually and it's handy for the production of small series of boards.

The working principle of wave soldering is similar, but automated. However, in this case the whole board is not in contact with the solder bath at one time (i.e. not all the pads at the same time). Rather, a wave of molten solder goes across the board until it is applied properly on all the pads. The board sort-of surfs the crest of a solder wave, which sounds quite cool, by the way. ◄

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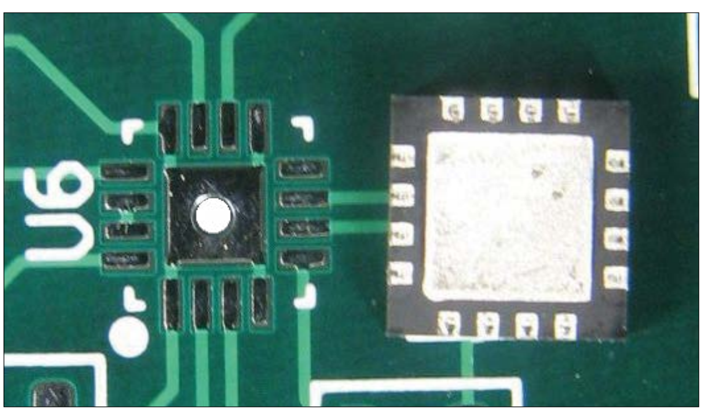


Figure 2. Hole in a pad for a Quad Flat No-leads Package.

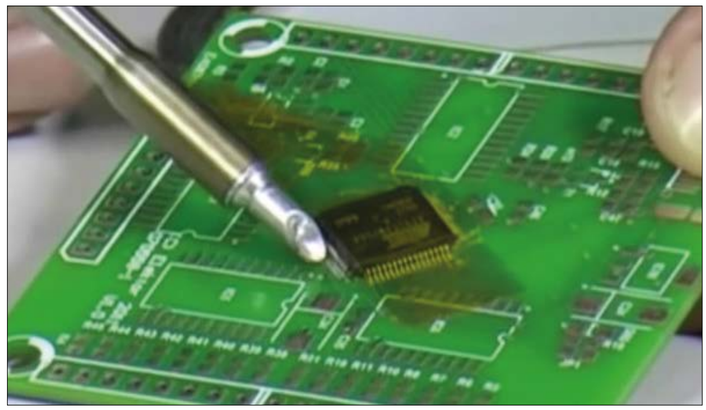


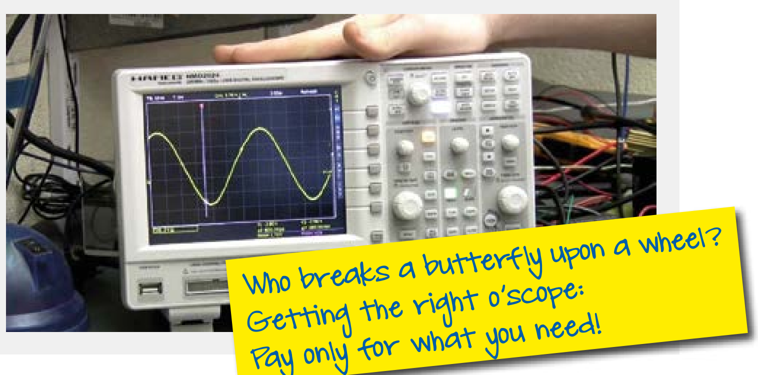
Figure 3. A mini spoon soldering cartridge.

Still having unanswered Q's? Don't panic!

This subject is so wide, that it wouldn't be possible to address all doubts in one shot, so we will get back to the subject in upcoming editions. Got any question? Don't hesitate to let us know. The *A*'s are on their way!

Stay tuned!

Q & A's next edition will cover...



Apps with Connections

Part 1

Windows app programming for electronics enthusiasts

By **Dr. Veikko Krypczyk** (Germany)

Apps — small applications with intuitive user interfaces, often designed for touchscreens — are all the rage nowadays. Apps that run on tablets as well as desktop PCs can also be programmed for Windows 8.1. In the first article of this series we present a get-u-going guide for app programming, and in the second article we show you how to control external hardware with an app.

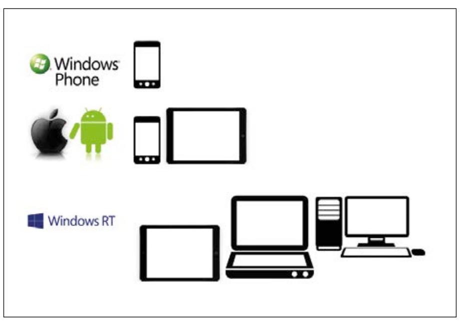


Figure 1. Operating systems for apps and their target platforms.

Nowadays apps are available for virtually every sort of use and application area. Before you start programming apps, it's a good idea to learn more about the possible target platforms and resulting application areas. In common language, apps are small application programs for mobile devices. The target operating systems for apps are Android (Google), iOS (Apple), Windows Phone and Windows 8.1 (both Microsoft). Android and iOS run on smartphones as well as tablets, but Microsoft has two different operating systems for these two hardware platforms. Windows Phone is intended for smartphones, while Windows 8.1 RunTime is intended for tablets. However, Windows 8.1 RunTime is also available on all PCs (desktop or notebook) with a current version of the Windows operating system, where it runs more or less in parallel with the conventional Windows desktop OS (**Figure 1**). A characteristic feature of apps is that they focus on a single task. The user interface (UI) is always intuitive and designed for touch operation. Along with functionality, the design and user experience are critical factors (**Figure 2**). Windows 8.1 runs not only on tablets but also on conventional desktop and notebook PCs, which allow external devices to be connected (usually over USB).

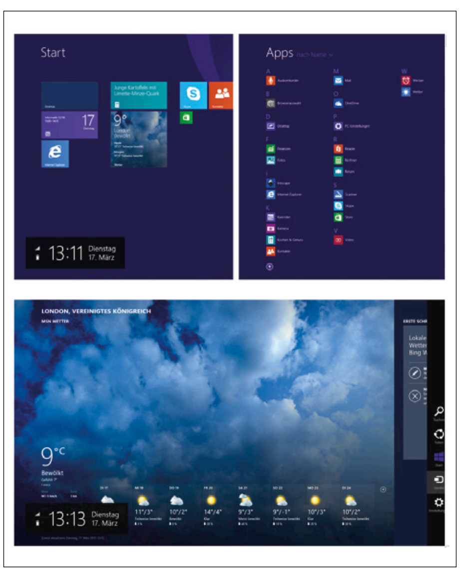


Figure 2. The Start screen of Windows 8.1 is the "home base" for all apps. The user interface is always intuitive and based on the content; the software is only there for support. Example: a weather app (photo montage).

With their focus on the essential content and their modern design and user interface, apps appear to be ideal for controlling external electronic devices. For instance, they can enable users to perform switching operations (output) or monitor specific environmental parameters using sensors (input). All of this should be done intuitively; the software is only there for support. Microsoft plans to expand the app concept for Windows 10, with the aim of having a single application for all device classes from smartphones to desktop PCs.

This two-part series provides an introduction to the programming of Windows 8.1 apps, which are also called Windows Store apps because that's where you can buy them. Here the technical approach is closely allied to Windows Phone apps. Universal apps can be used to provide apps for both platforms from a common code base, which minimizes platform-specific code.

There are several approaches to building apps of this sort, as illustrated in **Figure 3**:

- User interface definition using the XML-based description language XAML, with C# or VB.Net as the programming language. A specific form of the .Net framework called .Net for Windows Store Apps is used as an intermediate level.
- User interface definition using XAML and logic programming in C++. Here the underlying system services are called directly.
- User interfaces design based on the DirectX graphic interface. This option is a good choice for games.
- User interface design based on HTML and CSS, with logic implemented in JavaScript. Internet Explorer components are used to access Windows runtime system libraries.

The combination of XAML and C# is recommended for application-oriented apps. If you already have some experience with Windows desktop application development based on Windows Presentation Foundation (WPF), a lot of the following will sound familiar. Let's start by setting up the work environment.

Preparatory activities

First you need an integrated development environment (IDE), which in this case is Visual Studio (VS) 2013. A strong point of this IDE is that free versions of VS are available from Microsoft for semi-professional development projects. You can download VS Community 2013 or VS Express 2013 at [2].
The Express version is adequate for our purposes. With the Community version you can also create development projects for other target systems, such as desktop PCs or the Web.
After downloading the software, proceed as follows:

1. Update the operating system if necessary. You must have Windows 8.1 if you want to develop apps for the Windows platform; Windows 7 is not suitable. Windows 8 can be upgraded to the current version of Windows 8.1 for free, either from the Windows Upgrade control panel or in the Windows Store.
2. Install the Visual Studio IDE software, including any desired language pack.
3. Run the operating system update again.

Restart the computer at the end of this process. This procedure avoids problems later on, as well as subsequent requests to update your system. Installation may take a while because a lot of software has to be installed, including the .Net framework and system libraries as well as Visual Studio. Be patient.

The first time you run the program, you have to register with Microsoft as a developer. You see this request directly in the IDE. Registration is necessary because only developers are allowed to install apps directly on a computer, with the exception of what is called sideloading. The usual way to register is in the Windows Store. The license is free and must be renewed periodically.
If you do not already have a Microsoft account, you will have to create one. After completing these preparatory activities, you can run Visual Studio 2013 (**Figure 4**).

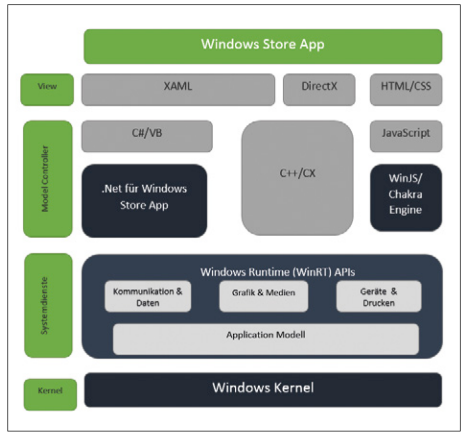


Figure 3. Technical options for the development of Windows Store apps [1].

Your first app

To get started, let's build a simple app (the same idea as the ubiquitous "Hello World" demo programs) to get acquainted with the structure. After launching Visual Studio, select the menu path

File → New → Project….

The templates listed in the dialog are arranged by programming language. Select the entry

Store Apps → Window Apps

under the *Visual C#* node. Then select the entry *Blank App*. Enter a name for the app and the storage location. Leave the *Add to source control* option disabled

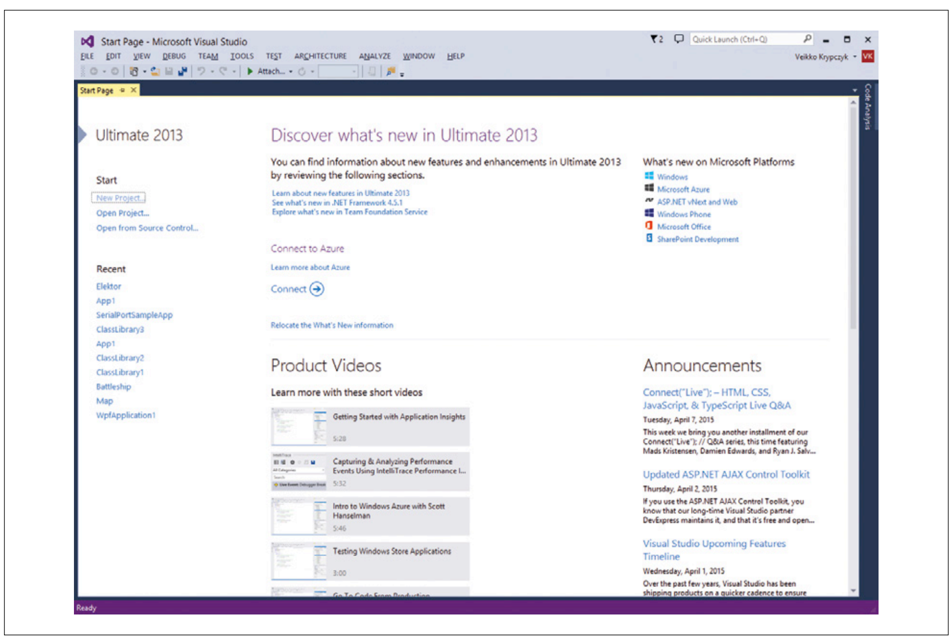


Figure 4. Start screen of the Visual Studio 2013 development environment.

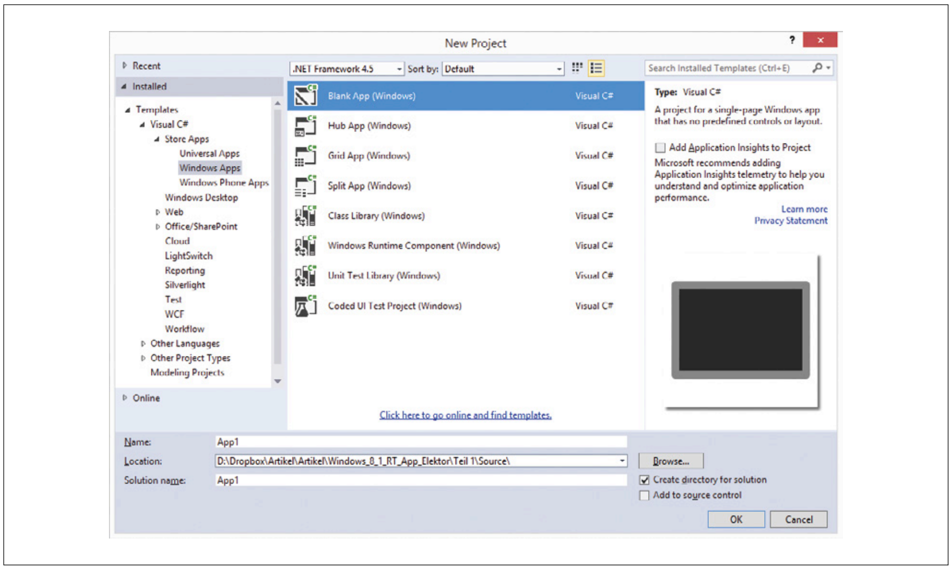


Figure 5. The Visual Studio project assistant offers templates for app creation.

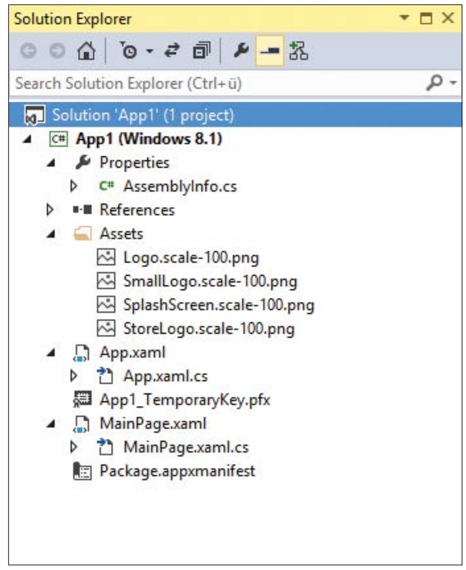


Figure 6. The structure of the app in Solution Explorer.

for now (**Figure 5**). After you click *OK*, the IDE starts generating the framework code for the app, and then you can install it on your local machine (green arrow on the taskbar) to run it. You do not need a tablet PC or an emulator to test the app, since Windows Store apps can be run directly on the development computer. Of course, the newly launched app

Table 1. Elements of a Windows Store app

Project element	**Brief description**
Properties	Contains the basic project properties in the file AssemblyInfo.cs. There is no provision for direct editing. The settings can be modified in a dialog (Project | {app_name} Properties). This includes the version number.
Links	This where the libraries needed by the app are linked in.
Assets	This is where the resources for the app are stored, such as the bitmaps for the tiles. Other resources should be stored below this folder or organized into subfolders.
App.xaml | App.xaml.cs	The source code files for running the program code. Manual changes are usually not necessary.
{AppName}_TemporaryKey.pfx	Apps should be signed with a unique certificate. This can also be generated directly in the IDE.
MainPage.xaml | MainPage.xaml.cs	The XAML files that describe the screens that form the user interface. There is a file for each page. The code belonging directly to the UI elements can be saved in the associated .cs file — for example an event handler that is executed when a button is touched.
Package.appxmanifest	A package manifest must be created for app distribution in the Windows Store. Double-clicking this entry opens the associated editor. The settings include the name of the app, the display orientation (portrait or landscape), and the basic permissions such as access to the Internet or location services.

Table 2. Important layout containers

Important layout containers	**Brief description**
DockPanel	Specifies the docking positions (Top, Bottom, Left and Right) of the control elements to be arranged. The most recently added control fills all of the remaining space.
Grid	The elements are arranged in a grid. The number of cells (rows) and columns in the grid must be specified. The grid structure is referenced when the lower-level elements are declared, which means the desired row and column for the element position are specified. The associated properties Grid.Column and Grid.Row must be configured for each embedded element.
StackPanel	The lower-level control elements are arranged side by side or stacked vertically. The orientation direction is specified by the "Orientation" property.

only shows a black screen in the preview pane. You can view the structure of the app in the Solution Explorer window by selecting the menu path *View > Solution Explorer* (**Figure 6**). In this case the Solution Explorer only shows one project, which contains the Windows Store app. It's a good idea to divide relatively complex software projects into several subprojects. The main elements of the project are described in **Table 1**.

Designing the user interface

The user interface of Windows Store apps is based on a subset of the WPF. The WPF is entirely vector-oriented, with many different options for shapes and colors. User interfaces can be defined with the XML-based description language XAML. This enables complete separation from the logic of the program code. The relative layout, which provides a choice of various containers (see **Table 2**), is more or less built in.

Relative positioning of the components is unavoidable because the apps have to run on devices with very different displays in terms of screen size and resolution. The purpose of a layout container is to hold all the control elements of a screen page. The base class of all layout containers is the Panel class. One of the important properties is "children", which holds the elements inside a layout container. The positioning of the elements is not explicitly defined, but instead determined automatically. Although most of the elements have width and length properties, these properties should be used only rarely (for example, with buttons). The size of an element is usually determined by the combination of its content and the size of the surrounding container. You can use the integrated Visual Studio design tool to lay out the user interface (**Figure 7**). The touch operation requirements are implemented very nicely. The control elements contain the necessary events. To allow apps to be run under mouse and keyboard control if desired, signal processing elements for mouse and keyboard navigation are also available.

WPF for Windows Store Apps provides a very large selection of control elements for creating attractive, modern user interfaces. They are arranged in a tree structure classified by how they are use (**Figure 8**).

To get started with UI design using XAML, see **Listing 1** and the following remarks about the design of the demo app. In the second part of this series we systematically extend this design to allow external hardware to be operated with the app.

- The Root element is called "Page". It encompasses exactly one page.
- Next comes the page header, which links in the libraries and includes any

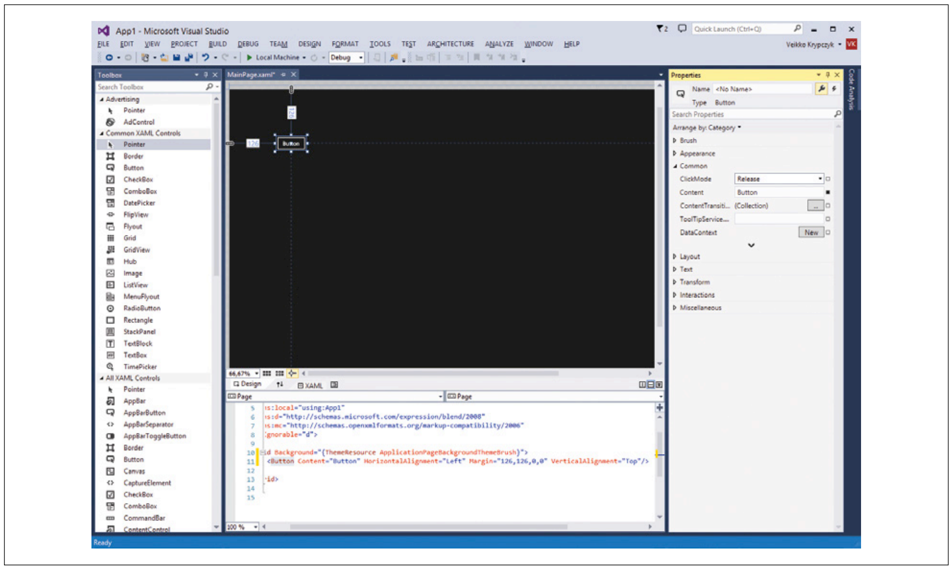


Figure 7. You can create the UI graphically by simply selecting and dragging control elements to the display pane.

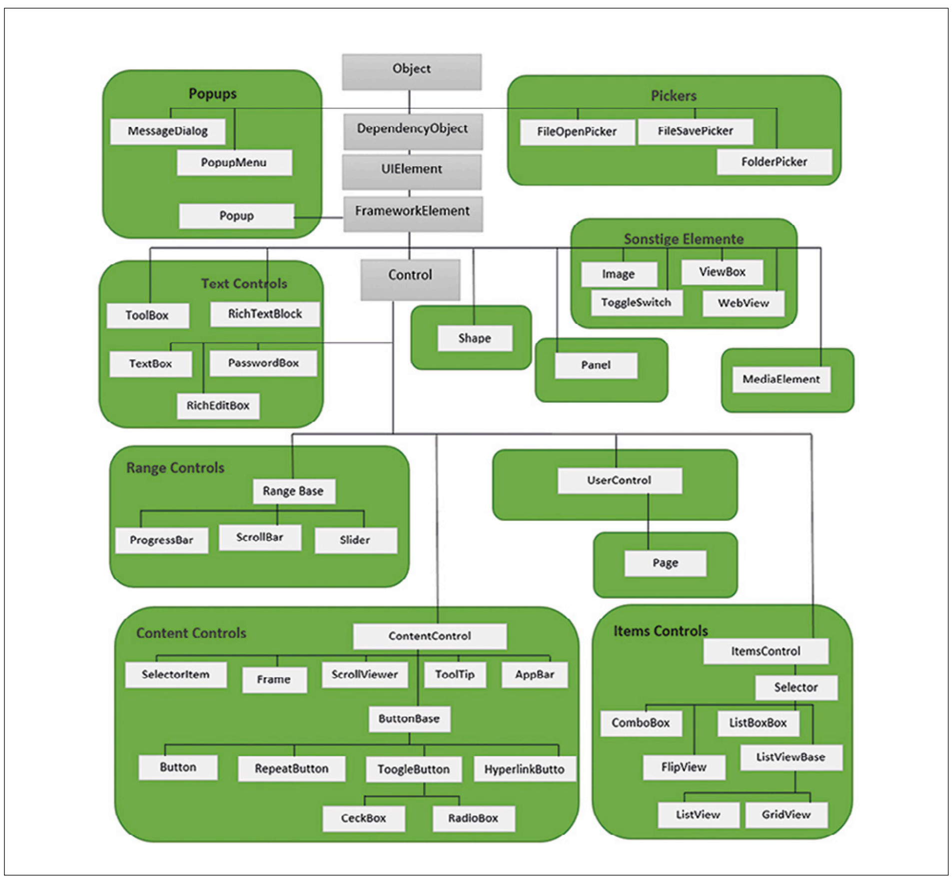


Figure 8. Tree structure of the UI elements for Windows Store apps.

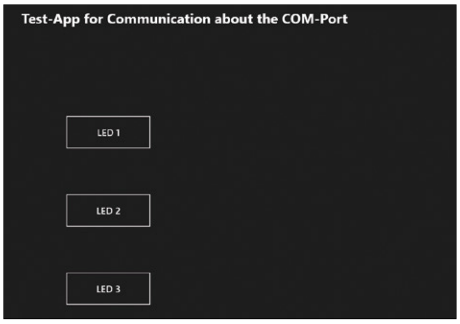


Figure 9. The user interface of our demo app.

necessary instructions for the graphic designer.

- All control elements for the page are linked to a higher-level layout container. Here we use a control element of type Grid, but without defining the number of rows and columns. It's a good idea to keep this layout container in your projects. The lower-level elements can also be linked to other layout containers (arbitrary nesting). This results in an easily adaptable structure. The top-level layout container can be used to define the background of the app ("Background" property).
- We added an element of type TextBlock for the heading and three buttons of type ToggleButton to the code for the demo app. The buttons are grouped in their own container of type StackPanel. That way this block of switches can be placed or relocated independently. The ToggleButtons are formatted with specific size (Width and Height), spacing (Margin) and font (FontSize). Since the same values are assigned to these properties for all three ToggleButtons, you could later define a template for this within the page or the app.
- If no alignment is specified for a StackPanel, its elements are arranged vertically, which is the default alignment.

The user interface of this simple app is limited to a simple message and three switches, which can later be used to switch LEDs on and off (**Figure 9**). The control elements are linked to the executable program code by linking them to the relevant events. For example, the Click event of a ToggleButton is linked to the corresponding program code. In this case the action is triggered by a mouse click or a touch gesture.

Implementing the program logic

The program logic is written in the object-oriented C# programming language. As already mentioned, another option is to use VB.Net. These two languages can be regarded as equivalent due to the language-neutral abstraction of the .Net framework and the subset available for Windows Store apps. They differ in the supported concepts and in how the program code is structured. We chose C# for this demo project. A full introduction to this language is not possible within the scope of this article, so we limit ourselves to a few key aspects (**Table 3**).

The language has continuously evolved over time, with the result that features such as functional elements are now available in C#. It strengths really come to the fore in combination with the diverse classes of the .Net framework. Ready-made solutions are available for many specific tasks, so there's no need to reinvent the wheel every time. Libraries can also be linked in easily to expand functionality. The source code editor provides every imaginable function in a modern development environment, such as comprehensive syntax detection and formatting as well as smart refactoring.

Distributing you apps

A few remarks on this subject are in order. As usual with apps, there are no explicit means for direct distribution from

Listing 1. XAML code of the user interface of our demo app.

```
<Page
  x:Class="Elektor.MainPage"
  xmlns="http://schemas.microsoft.com/winfx/2006/xaml/presentation"
  xmlns:x="http://schemas.microsoft.com/winfx/2006/xaml"
  xmlns:local="using:Elektor"
  xmlns:d="http://schemas.microsoft.com/expression/blend/2008"
  xmlns:mc="http://schemas.openxmlformats.org/markup-compatibility/2006"
  mc:Ignorable="d">

  <Grid Background="{ThemeResource ApplicationPageBackgroundThemeBrush}">
    <StackPanel>
      <TextBlock Margin="50" Text="Test-App for Communication about the COM-Port" FontSize="32" FontWeight="Bold" />
      <StackPanel Margin="100">
        <ToggleButton Margin="50" Width="200" Height="80" FontSize="22">LED 1</ToggleButton>
        <ToggleButton Margin="50" Width="200" Height="80" FontSize="22">LED 2</ToggleButton>
        <ToggleButton Margin="50" Width="200" Height="80" FontSize="22">LED 3</ToggleButton>
      </StackPanel>
    </StackPanel>
  </Grid>
</Page>
```

developers to users. All apps have to be installed from the App Store. Nevertheless, for testing you can use a development license to enable installation on other test computers in addition to the development computer (which is what we did). It is also possible to bypass the App Store by using sideloading to distribute the apps to target devices. However, once your app has left the test phase and may be of interest to a larger audience, it should be made available in the App Store. For this the app must comply with a number of formal conditions, such as making image resources available to the app in a defined form and embedding them in the right places (for displaying the tiles, for example). Finally, the app has to pass a final test run with a Microsoft certification tool. After this you should upload your app to the Windows Store and provide the associated formal data (age restrictions, privacy protection, license conditions and price). A short while later Microsoft will send you confirmation of acceptance, and your app is available for all interested parties. It's all easier than it sounds, and the process is well documented at [3].

Conclusion and outlook

There's a lot more that could be said about programming apps. Detailed information is available in [1]. In the second article of this series we describe how to control external hardware over a virtual COM port and USB, which should be very interesting for electronics enthusiasts. Our hardware platform for this is the well-known Arduino Uno with the Elektor Extension shield. On the software side we have to deal with the difficulty that apps actually run in a protected environment called a sandbox, with very limited communication options for security reasons. But don't worry — we have found a way around that!

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Table 3. Important language features of C#

Language construct	Keywords	Syntax / Example
Comment in source code	One-line: // Multi-line: /*…*/	// This is a simple comment /* This is a multi-line comment */
Elementary data types	byte int float double decimal string	int quantity = 5; string text = „character string“;
Basic operations	+ – * /	int total = addend1 + addend2; float product = factor1 * factor2;

Loop instructions	for loop	for (int i = 0; i < upper_limit; i++)
		{
		// loop body
		}

	while loop	while (condition == true)
		{
		// loop body
		}

	do loop	do
		{
		// loop body
		} while (condition == true)

	foreach loop	foreach (type variable of enumerated type)
		{
		// loop body
		}

	break	for (int i = 0; i < upper_limit; i++)
		{
		// loop body
		} if (condition2 == true) break;
		}

	continue	for (int i = 0; i < upper_limit; i++)
		{
		// loop body
		} if (condition2 == true) continue;
		}

Selection instructions	If else if else switch (…) case	If (a==3) a=5;

User-defined data types	struct	struct record
		{
		int age;
		string name;
		}

User-defined classes	class	class MyClass: BasicClass
		{
		int AnAttribute;
		private void AMethod(…)
		{
		….
		}
		}

Reference Documents & Web Links

[1] Huber, T. C.: Windows Store Apps with XAML and C#, Galileo Press, 2013.

[2] www.visualstudio.com/downloads/en-us/download-visual-studio-vs.aspx

[3] https://dev.windows.com/en-us/publish

Tips and Tricks

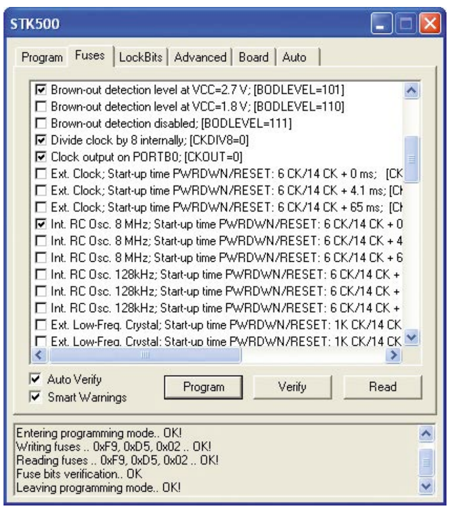
From readers for readers

Here are some more neat solutions from our readers, sure to make life a little easier for engineers and electronics tinkerers.

ATmega168 Oscillator output

From Burkhard Kainka

Recently while developing an application using a Mega8 microcontroller I hit the memory buffers — memory full. Switching to the Mega168 went without a hitch and now I had 16 KB to play with. Whilst programming the fuses I was curious to notice an option which had previously not been available on the Mega8 namely: 'Clock output on PORTB0'. With a frequency counter hooked up to PB0 it should now be possible to quickly check the accuracy of the RC oscillator without the need for any additional software. No sooner said than done: 11059 kHz, oh yes I was using an external crystal for the clock source. After that I selected the internal 8 MHz-RC oscillator with a 1:8 prescaler, the reading was now 1001 kHz, with some variability of the value after the decimal point. The oscillator easily keeps within the specified 1 % tolerance for this clock source. The same experiment using the 128-kHz oscillator showed significantly poorer accuracy.



Make Contact with Magnets

From Peter Bitzer

As a regular Elektor reader who can go way back to the first edition in 1970 I have never seen this helpful hint in print before: Standard battery recharger units are not usually able to accommodate some common NiCd cells sizes such as those with a diameter of 32.5 mm and a length of 90 mm. To recharge these I used to use flying leads and croc clips to make contact with the battery solder tags.

It was always a bit hit or miss and sometimes when I returned, a croc clip might have pinged off, leaving the batteries only partly charged.

The outer contact surfaces of battery electrodes are made of steel; we can put this to good use… I'm sure everyone is familiar with those small, low cost, very strong neodymium magnets that you can pick up quite cheaply on the Internet (they come in all shapes and sizes). The magnet's surface is electrically conductive and they make really good contact pads for rechargeable batteries (see photos).

The advantages are:

- *Reliable contacts*
- *Less hassle*
- *No problem with croc clips springing off*
- *No need for a battery holder*
- *They also work on batteries without solder tags*
- *You save on clips (two batteries can be linked with one magnet).*

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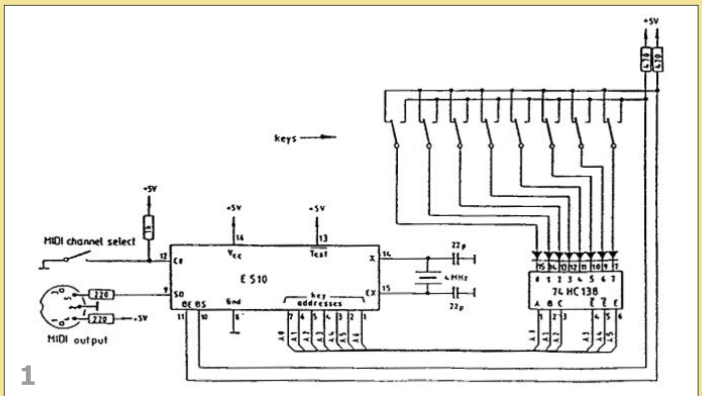
Got a neat solution for a tricky problem? Using components or tools in ways they were never intended to be used? Think your idea to solve a problem is better than the usual method? Have you discovered a workaround that you want to share with us and fellow makers? Don't hang around; write to us now, for every tip we publish you'll earn 40 pounds!

Doepfer E510 MIDI Keyboard Scanner

Peculiar Parts, the series



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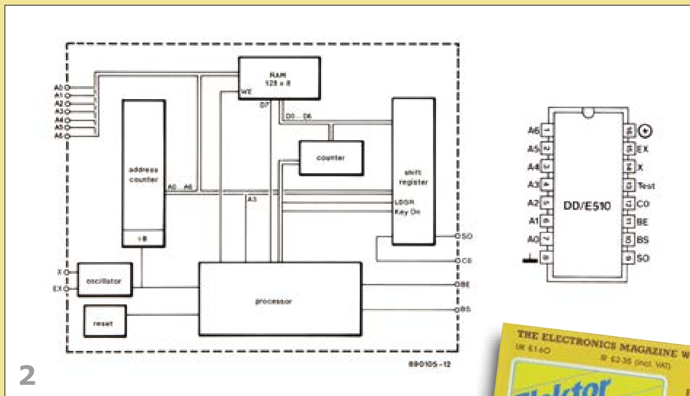


2

By **Neil Gruending** (Canada)

Electronic music keyboards need to scan a lot of keys to know which notes to play. Some models just detect on and off key presses but others also try to determine how quickly a key is pressed to increase the sound fidelity. A classic solution for this is the Doepfer E510 MIDI keyboard scanning IC from 1988 (approx.), which can do both. Co-developed with German electronic organ giant, Böhm, and made by Elmos, the E510 was marketed by Dieter Döpfer. It was an instant hit in e-DIY Land thanks to an Elektor publication written by Dieter and ORG'ed by *maestro* Denis Meyer [1].

Music keyboard keys are usually made with a single pole double throw (SPDT) switch per key to minimize cost. The normally closed (NC) contact is active when the key isn't pressed and the normally open (NO) contact will be active when the key is fully pressed. This technique makes it possible to detect when a key is pressed (the NO contact opens) and how quickly the key is pressed by timing how long it takes for the normally open contact to close. The keyboard can then use the extra velocity information to control how loudly a note is played. **Figure 1** shows a typical key arrangement and how they connect to an E510 chip. Remember, you are looking at late 1980s technology.

One of the really neat features of the E510, whose block diagram and pinout appear in **Figure 2**, is that it supports up to 128 keys in a novel way. The E510 samples each key individually by first putting the key address (0 to 127) on its address output pins which is then decoded using external 74HC138 3-to-8 decoders so that only one key is enabled at a time. The disabled keys will have a logic 1 from the decoder and an active key will have a logic 0. The diodes are used to isolate the keys from each other so that you don't get phantom key presses. The E510 then uses its BE (normally closed) pin and its BS (normally open) pin to read the state of the key. If the BE pin is open then the E510 will also measure the velocity by counting down from 127 until the BS pin closes. This process is repeated for all of the remaining keys.

Once the E510 has finished sampling a key, it then loads the results into a large shift register that is then shifted out in a MIDI compatible format. The MIDI data stream then gets read by the music processor to know what notes to play. The sample rates and timing resolution are controlled by the input clock frequency. For a typical 4-MHz crystal, the output data rate 31250 baud with a velocity resolution of about 256 µs.

You will find the E510 in a variety of keyboards like the Doepfer MMK2 but unfortunately the device is no longer available. That's because these days you can recreate all of the E510's functionality with a microprocessor or a CPLD, so a dedicated ASIC like the E510 isn't really needed anymore. And in fact that's the approach that several boards have used to try to mimic the E510 in older keyboards. So while the chip itself is obsolete and now in the Elektor Hall of Fame, the techniques it used are still relevant today. Dieter Döpfer is still active in the DIY electronic music instrument area [3]. Thumbs up to him for that E510 chip and for the Alt-[num]148 workaround for all of us outside Germany. *Döpfer* or *Doepfer*, we never got our tongues around that vowel. Same with *Böhm* — Inspector Clouseau, help please! ◄

(150228)

[1] Universal MIDI keyboard Interface, Elektor Electronics June and July/August 1989 (on Elektor 1980-1989 DVD)

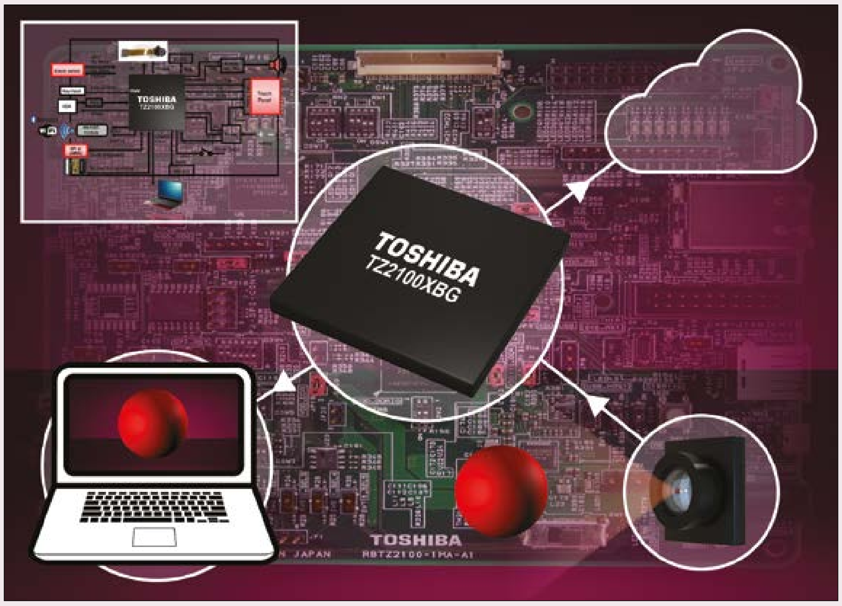
[2] www.cedos.com/datasheets/E510.pdf

[3] www.doepfer.de

Please contribute your Peculiar Parts article, email neil@gruending.net

ARM Cortex-A9 Based Starter Kits for TZ2100

Two new starter kits from Toshiba, the RBTZ2100-1MA and RBTZ2100-2MA enable rapid development of applications using ApP Lite™ processors. The TZ2100 group supports enhanced audio and image data-mining, communications and security functions with a single-core ARM Cortex A9 core and a clock rate up to 600 MHz. It is suitable for a wide range of applications, such as small embedded devices, handheld devices, industrial equipment and gaming equipment for amusement arcades and casinos. The RBTZ2100-1MA and RBTZ2100-2MA development starter kits include reference boards and drivers that allow devices to be effectively evaluated in their final application environment. This can reduce the usage of developer resources and shorten the overall development schedule.



These kits help users to effectively evaluate function and performance, and carry out advanced software development. The RBTZ2100-1MA, fitted with 512MB DDR3L SDRAM and 16MB SPI Flash ROM can use a Media I/F for a camera or LCD panel and comes equipped with a microSD slot and 10/100 LAN connector. The RBTZ2100-2MA is capable of using an external bus I/F and is equipped with 256 MB DDR3 SDRAM and 256 MB Parallel Flash ROM, with an I2S connector for audio.

(150145-12) www.toshiba.semicon-storage.com

Wireless Power Receiver

IDT's new P9027 magnetic induction receiver offers 80 percent peak system level efficiency and improved overall thermal performance. The high-efficiency architecture enables higher power transfer rates, translating into shorter charge times for portable devices such as smartphones and phablets.

Supporting the Wireless Power Consortium's Qi standard, the P9027 is an 8-watt receiver featuring an ultra-compact solution size — approximately 37 square millimeters — and requiring six fewer capacitors than competitive products. The result is less board space and a lower bill of materials cost.

The device's proprietary alignment guide optimizes inductive coupling with the transmitter to maximize coil-to-coil power efficiency. The 3 V to 7 V adjustable output voltage range is capable of driving a variety of downstream power management ICs, while proprietary foreign object detection (FOD) ensures safe operation in the presence of metal objects.

(150145-9) www.idt.com

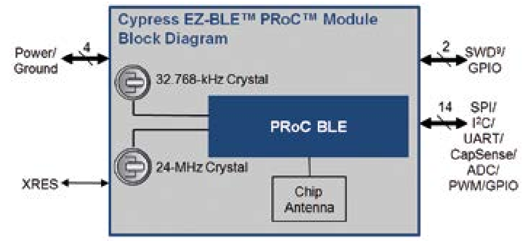
Small Cells for Use on Lamp Posts

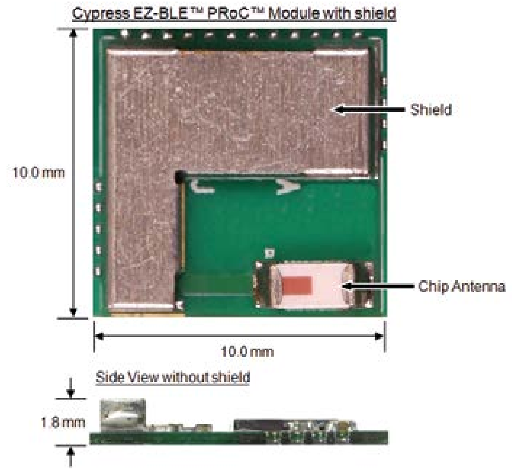
With demand for cellular data continuing to rise and outdoor small cells seen as an essential element in the long-term delivery of high-capacity urban networks, TTP has come up with a new small cell designed specifically for deployment on lamp posts. The use of lamp posts enables the acquisition of many thousands of suitable sites through negotiation with a single city authority. TTP's new eNodeB is simply fitted into a lamp post's standard photocell socket, providing the quickest possible installation without any modification to the lighting column or its power supply. And because the compact design meets *de minimis* planning requirements, it also simplifies planning consents. TTP's prototype eNodeB is based on the Freescale BSC9131 QorIQ Qonverge processor and will be shown for the first time at Mobile World Congress next month on the Freescale stand. It incorporates LTE Access Point software from ip.access and has been demonstrated with the Quortus EPX Core evolved packet core. It is targeted at 50-meter (150-ft) cells, supporting up to 32 active users at downlink rates of up to 100 Mbps.

(150145-13) www.ttp.com

ESC Boston May 6-7 ... NXP LPC Expresso Dev Boards ... NXP + Freescale = a Broader, More Powerful Portfolio ... Newark/element14 says Gizmo 2 is Here ... Microchip's CAN Flexible Data-Rate Transceiver ... Saelig's New Picoammeters ... Toradex: Next Generation SoC addition to Apalis ... FlowPaw from

$49 Bluetooth Low Energy (BLE) Pioneer Development Kit from Cypress





The EZ-BLE PRoC module integrates the programmability and ARM® Cortex®-M0 core of PRoC BLE, two crystals, an on-board chip antenna, metal shield and passive components, all in a compact 10-mm x 10-mm x 1.8-mm form factor. Customers designing with the module can apply to add the Bluetooth logo on their products by referring to Cypress's Qualification Design Identification (QDID) 67366, a unique serial number assigned by the Bluetooth SIG. Additionally, the module is compliant to wireless regulatory standards in the U.S., Canada, Japan, Korea and Europe.

Cypress has abstracted the Bluetooth Low Energy (BLE) protocol stack and profile configuration into a royalty-free, GUI-based BLE component that can be dragged and dropped into designs using Cypress's PSoC® Creator™ integrated design environment (IDE). PSoC Creator enables complete system design in a single tool.

The $49 BLE Pioneer Development Kit gives users easy access to the Cypress Bluetooth Low Energy devices, while maintaining the design footprint from the popular PSoC 4 Pioneer kit. The development kit includes a USB Bluetooth Low Energy dongle that pairs with the CySmart master emulation tool, converting a designer's Windows® PC into a Bluetooth Low Energy debug environment. The EZ-BLE PRoC module can be quickly and easily evaluated with the EZ-BLE PRoC Module Evaluation Board, which plugs into the BLE Pioneer Development Kit.

(150273-1) www.cypress.com

Capacitors for Energy Harvesting

Farnell element14 (US: Newark element14) is launching the Vishay hybrid storage 196 HVC ENYCAP™ capacitors which are portable, compact, and facilitate high-energy storage.

Priced from £13.39 with price breaks for higher volumes the capacitors have the industry's highest energy density (13 Ws/g) as well as polarized storage capacitor with high capacitance (up to 90 F).

Ideal as a storage device for energy harvesting, the capacitors are an alternative to rechargeable backup batteries as they can hold 70% of their charge for as long as a month.

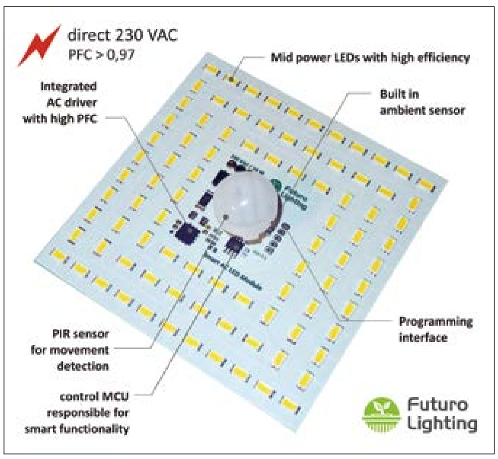
They support voltages ranging from 1.4 V (single cell) to 2.8 V / 4.2 V / 5.6 V / 7.0 V / 8.4 V (multiple cells) and are available as stacked through-hole (STH, radial), surface mount flat (SMF) and lay-flat configurations (LPC) with wire and connectors.

Their low profile (2.5 mm) means they are the right size for portable and compact designs.

Hybrid Storage 196 HVC ENYCAP™ Capacitors are part of Vishay's famous Super 12 range and are available with next day delivery.

(150145-14) http://uk.farnell.com/vishay-126hvc-capacitors

12-watt Smart AC LED Module



FuturoLighting's new smart AC LED module operates directly off the 230 VAC network. The module integrates an AC driver with high PFC exceeding 0.97, offering On/Off and dimming functionality with stand-by consumption under 0.5 W. The module was designed in several versions covering basic, triac dimmable, analog dimmable and smart functionality. Dimensions of the module are 100 x 100 mm with a height of 5 mm for the basic version, and 25 mm for the smart version.

It is claimed as the first integrated approach of an AC driver together with movement sensor and smart behavior. Practically these modules are electrically behaving as real incandescent bulb (resistive load). Smart version offers corridor functionality with adjustable delay time, where stand-by level can be adjusted from 0 to 80% through programming interface directly on the module.

www.futurolighting.eu (150273-2)

DSPRobotics ... IFixit Tears Down Galaxy S6 ... SurfLight Technology in Vishay IR Emitters ... XJTAG Goes Dynamic ... Dual-Frequency NFC/EPC from EM Microelectronic ... Linear Technology 60V 4A LED Driver ... Yugo Systems Ready for FPGA Debug ... Tektronix 45GHZ Optical Modualtion Analyser

Reliability of Electrolytic Capacitors

Aluminum electrolytic capacitors (a.k.a. ‘e-caps’; ‘electrolytics’) are vital to the function of many electronic devices. Ever-increasing requirements for energy-efficiency, the expanding utilization of renewable energy, and the growth of electronic content in modern automobiles have driven the spread of these components significantly over the past decades.

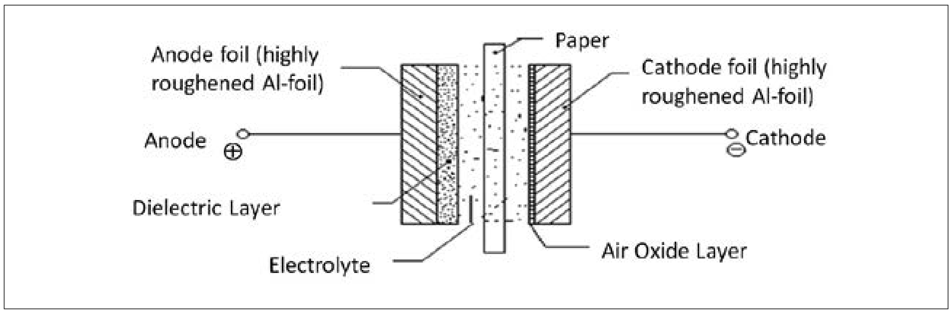


Figure. 1. Construction of an aluminum electrolytic capacitor (simplified cross-section).

Construction and Manufacturing Process of Electrolytic Capacitors

Aluminum electrolytic capacitors combine voltage proofs ranging from several volts to about 750 volts and a wide capacitance range from 1 μF to above 1 F, while offering a compact size. A highly roughened anode foil is being completely covered by a thin dielectric layer and contacted by an exact fitting cathode, the electrolyte liquid. (**Figure 1**).

The manufacture process of e-caps comprises the following major production steps:

- **Etching** — high purity aluminum foils of thickness 20 ~ 100 μm are the base material for the later anode- and cathode foils. The etching enlarges the total surface area of the anode material up to a factor of 140 (**Figure 2**), compared to their geometric surface.
- **Forming** — the anode foil bears the dielectric layer of the e-cap and consists of aluminum-oxide (Al_2O_3). It is deposited on top of the roughened anode foil by an electrochemical process called anodic oxidation or forming. The quality of the forming, i.e. the homogeneous and complete coverage of the surface area is essential for the high reliability of the components during operation. The further the forming voltage is above the rated voltage, the smaller becomes the probability of dielectric breakdown. Typical values for the ratio of forming voltage *vs*. rated voltage of Jianghai electrolytics range between 1.25 (low voltage) and 1.60 (high voltage). The thickness of the dielectric layer is approximately 1.4 nm/V; this amounts to about 900 nm for an e-cap with 450-V voltage proof (this is less than 1/100 of the thickness of a human hair).
- **Slitting** — the etched and formed foil comes on so-called mother rolls of about 50 cm width. By slitting, the mother rolls are cut into the widths needed for the anode and cathode material.
- **Winding** — attachment of electrical contact tabs to the foils (stitching, cold welding) and winding of anode, paper (spacer, multi-ply if needed), and cathode foil.
- **Impregnation** — the pores of the spacer paper in the wound cell and the complete surface area of the anode foil are covered by electrolyte, the liquid cathode.
- **Assembly** of the capacitor wound cell into the can, electrical connection between contact tabs and soldering or screw terminals and riveting of the can for a tight seal.
- **Post-forming** (‘Burn-in’) to heal the cut edges of the foil.
- **100% in-line control** of the vital electrical parameters (capacitance, dissipation factor, and leakage current.

Figure 2 shows the electron micrograph of the surface of an etched high voltage anode foil. The homogeneous distribution and the large free diameter of the etched pits allow for good coverage by the oxide layer and full access of the electrolyte to the complete surface are of the anode foil. Already at this early stage of the production it is determined whether the resulting e-cap will be suitable for demanding, pro-

By **Dr. Arne Albertsen,** Jianghai Europe Electronic Components GmbH

In many applications, lifetime and reliability of the electronics are directly linked to the corresponding parameters of the electrolytics [4]. While a previous article of the author [1] elucidated the topic of lifetime estimation for electrolytic capacitors, this article focuses on the reliability of electrolytics.

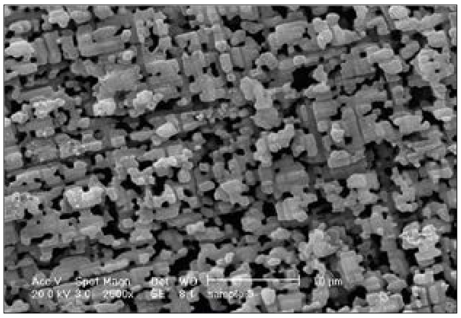


Figure 2. Top view of the etched anode foil.

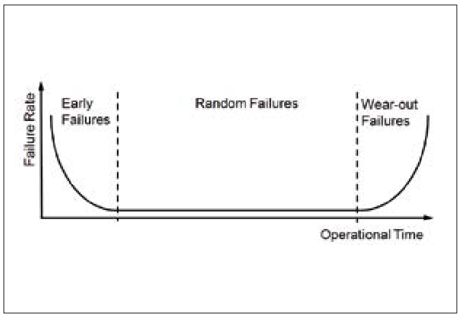


Figure 3. Failure Rate vs. Time – "Bathtub Curve".

fessional industrial applications with high requirements to reliability, ripple current capability, and long lifetime.

In particular, theb process steps 'forming' `and 'post forming' have great influence on the reliability of e-caps under operation. Jianghai pursues the target of maintaining a sufficiently high distance of the forming voltage from the rated voltage and a reasonable dwell-time during post-forming to ensure high reliability. As the forming voltage is commonly not indicated in the datasheets, the final user of the components has a hard time to use this parameter as a performance indicator. By asking the e-cap supplier and by comparing the leakage current ratings, the end user may draw his conclusions with respect to the design philosophy of the e-cap manufacturer. In times of rising material and energy prices, even some well-known manufacturers resort to lowering the forming voltages of running series. From a quality perspective, Jianghai considers these 'cost-optimization measures' being not acceptable.

Lifetime vs. Reliability

Electrochemical aging mechanisms limit the lifetime of e-caps to a value that can be estimated depending on temperature, ripple current and voltage during operation. During this lifetime, random failures may occur at any time. The absolute number of these failures depends on the size of the observed total lot. The existence of random failures is usually not related to the aging process, but it is rather the consequence of hidden, internal weak spots (e.g., in the spacer paper, the foil, or in the vicinity of the electrical connections). Often, these failures happen without any pre-warning and end up in a short circuit. Increased leakage currents as a result of a damaged dielectric layer may lead to such a big formation (that goes along with the buildup of hydrogen gas) that the overpressure opens the safety vent. Then, the e-cap dries up and fails with low capacitance.
The 100% end measurement of capacitance, leakage current and ESR on all produced components and the conduction of additional tests on samples drawn from all mass production batches ensure the high quality level of the products. Hence, early failures in the application are a rarely observed exemption [2].
There exist many definitions of the term „reliability" and depending on whether you ask a statistician, mathematician or an engineer, you may obtain a different answer. A common sense approach to defining reliability could be: the probability of an electronic device for satisfactorily fulfilling the requirements of its mission within a defined time period.

The typical time course of reliability density for e-caps follows the so-called 'bathtub curve' [3]. The failure rate (FIT; failures in time rate) λ designates the number of failures per unit time (failure density, measurement unit FIT = failure in time in 10^{-9} failures / hour.

The bathtub curve in **Figure 3** shows three distinct consecutive segments:

- the early failure period ('infant mortality') with a decaying FIT rate λ;
- the period within the normal lifetime has a constant FIT rate λ that describes the occurrence of random failures;
- the final segment with increasing FIT rates λ that originate from wear-out and changes beyond acceptable limits at the end or after the end of the regular lifetime.

Failure Modes and Mechanisms

The normal failure mode of a regularly aged e-cap is a parametric failure due to low capacitance or increased ESR (see

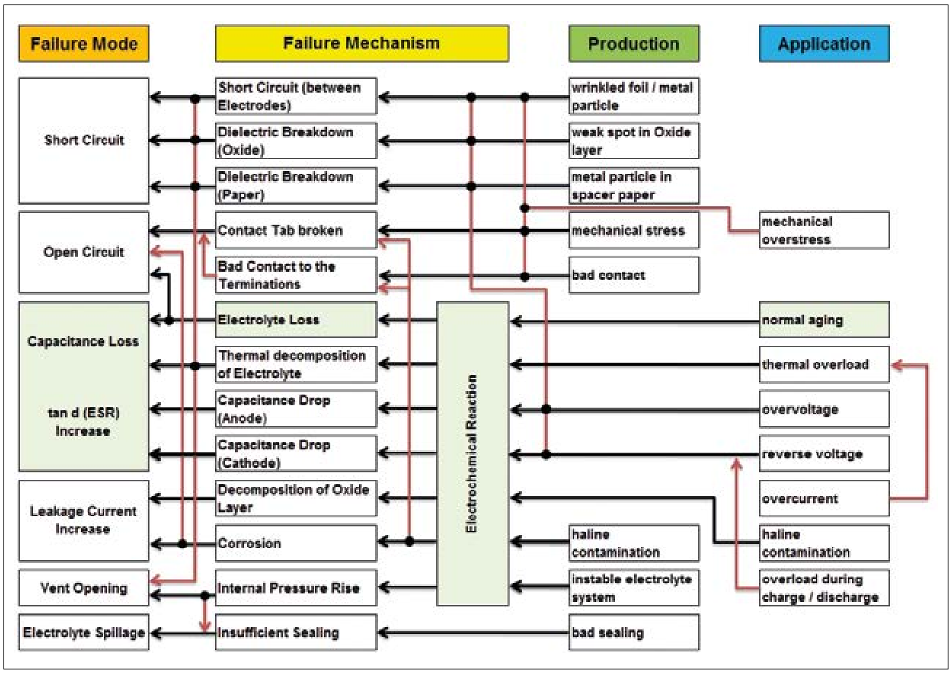


Figure 4. Failure Modes and Failure Mechanisms.

Figure 4, light green boxes).
The failure mechanisms shown in the overview (Figure 4) may originate from production or application related causes. In the field, production-related failures are rarely observed, because the purity of the base materials and the quality level of the mechanical production processes have been continuously improved over the past years. Often, failures can be traced back to arise from unfavorable operating conditions, because an overload in the application (e.g. ambient temperature, ripple current, operating voltage, vibration, mechanical stress, …) could sometimes neither be predicted nor be prevented.

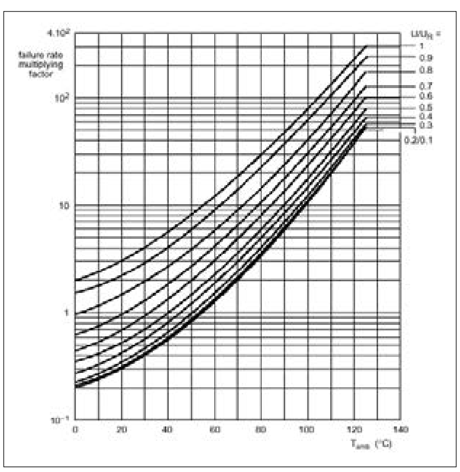


Figure 5. Failure Rate Multiplying Factors (MIL HDBK-217F).

Estimation of Failure Rates

Even when using best materials and world-class manufacturing processes in conjunction with an effective QA-system, random failures of components do exist in the field. In the context with the estimation of failure rates, the MIL-HDBK-217F is often referred to in literature, even though the handbook relies on component reliability data that has been devised some decades ago. The numerical values of the component failure rates found there often exceed the field failure rates observed with current Jianghai series by a factor of 10 ~ 100. Even in spite of these findings, the MIL-HDBK-217F data and the calculation schemes found there provide some insight into the dependency of failure rates on ambient temperature and actual operating voltage (**Figure 5**). The failure rates are being normalized to operation at an ambient temperature of 40 °C and at 50% of the rated voltage.
In order to obtain trustable reliability data from laboratory trials, a tremendous effort would be necessary. Experimentally gained test data from billions of unithours would be required, i.e. some 1 million e-caps should be tested at high labor cost. Jianghai rather uses the information on actual field failures at customers together with the typical application information (temperature, ripple current, operating voltage). Utilizing field data, the production data on quantities and types by technology, and laboratory test results, FIT-rates can be estimated at a reasonable effort. The order of magnitude for the estimated field failure rates is 0.5 ~ 20 FIT.
From the FIT-Rates, the MTBF (Mean Time Between Failures) can be easily calculated as its reciprocal: MTBF = 1 / FIT. Please note that the MTBF figure does not constitute a guaranteed minimum time until the first failure is observed, but rather indicates the mean time when about 37% of the initial e-cap population are alive (similar to the radioactive decay, the distribution function for the failure of components obeys an exponential distribution).

Factors affecting Reliability

Reliability (and also lifetime) of e-caps of any brand and type depend in a non-linear way on temperature, ripple current and operating voltage. Small changes in any of these parameters show great impact on the overall performance of these components. A carefully designed circuit is essential for obtaining the required reliability level of a device:

- **Complexity** – reducing the component count enhances the reliability.
- **Stress** – Temperature, ripple current and operating voltage, sometimes in combination with mechanical stress like vibration, requires compromises with respect to cost and size. Whenever possible, the thermal stress should be kept to the minimum: for each 10 K of temperature increase, the failure rate of e-caps doubles!
- **Reliability of individual components** – when selecting components, their individual reliability should be considered taking into account their cost. High reliable components are usually bearing a higher price tag.

Successful Application of Electrolytic Capacitors

The majority of field failures observed with e-caps are not related to classical random failures. Beyond the scope of influence of the e-cap manufacturer, the end user is obliged to safeguard proper operating conditions by ensuring robust design, careful handling and manufacture processes and moderate environmental influences. See the list below for some hints you may find useful for the successful application of e-caps in various circuits and applications:

Transport and Storage

E-cap cans (pure Aluminum) and e-cap seal (rubber) are soft and elastic. Obviously damaged (indented) components should thus not be utilized. Contamination by halines (in particular Bromide for sterilizing oversea shipments) are regrettably often found. This applies both to the shipment of individual components as well as to the transport of finished goods.

Mounting and Assembly

Pushing, pulling or bending of the terminals (in particular with radial e-caps) has to be avoided. Severe damage to the inner contacts of anode or cathode foil may result.

Glue, molding compounds and lacquers must be free from halines. In the vicinity of the e-cap's seal, an opening to the ambient should be maintained to prevent the build-up of a microclimate in a confined space beneath (risk of corrosion). Conducting tracks shouldn't be routed below any e-cap. Electrolytics must never be used as a „handle" for a PCB.

Soldering

The soldering temperature limits specified by the manufacturer must be kept to avoid damages (bulging, lifetime loss or thermal destruction of the electrolyte). This applies in particular to the processing of SMT e-caps in a lead-free reflow process (higher temperature soldering profiles).

Operation

When switching on or off, voltage transients from inductive loads beyond the forming or reverse voltage may occur. Even if only applied once, these type transients cause permanent damage to the electrolytic capacitor and must be avoided by proper design.

Mechanical overstress during operation (e.g., self-resonance) may cause breaking of connecting tabs. Gluing the e-caps to the PCB or placing them at a different location may solve the issue.

Any increase of ambient temperature by 10 K doubles the failure rate and halves the lifetime. Placing e-caps away from heat sources (heat sinks, power inductors, …) is thus beneficial.

Summary

By their individual reliability, aluminum electrolytic capacitors influence the reliability of the electronic devices they are mounted in. A thorough knowledge of some of the key parameters of these components are necessary to ensure the reliable design of electronic devices.

The definition of reliability and the most important influence factors on reliability are explained. A collection of practical hints helps as a guideline to the successful application of electrolytic capacitors. The applicability of the general guidelines depends on the specific product type and the particular application. Consultations with the supplier are essential to get guidance throughout the design project and to confirm any estimates.

(150250)

Company Profile

Jianghai Europe Electronic Components GmbH with office and warehouse in Krefeld (Germany) supports the European customers of Nantong Jianghai Capacitor Co., Ltd. (Jianghai) in Nantong, China. Jianghai has been founded in 1958 at the location of the present headquarters — about two hours by car north of Shanghai. In the early years, Jianghai developed and produced specialty chemical products (e.g., electrolyte solutions). In 1970, the production of electrolytic capacitors was launched and during the following years, low and high voltage anode foil production facilities complemented Jianghai's portfolio. Being the no. 1 producer in China, Jianghai is one of the world's largest manufacturers of radial, snap-in and screw terminal electrolytic capacitors.

Author

Dr. Arne Albertsen studied Physics with a focus on Applied Physics at Kiel University, Germany. Following his diploma (1992) and doctoral thesis (1994), both on stochastic time series analysis from a biophysical membrane transport system, he pursued an industrial career in plant construction of specialized waste water treatment and renewable energy generation technologies. In 2001, he started to work with leading manufacturers of electronic components like BCcomponents, Vishay, and KOA. He worked in managing positions in design-in, sales, and marketing for passive and active discrete components until he joined Jianghai Europe Electronic Components in November 2008. In his current position as Manager Sales and Marketing, Dr. Albertsen is responsible for the support of European OEM accounts and distributors.

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Welcome to Elektor Labs

Elektor Labs is the place where projects large, small, analog, digital, new and old skool are sketched, built, discussed, debugged and fine-tuned for replication by you.

Our offer: Become Famous

Most engineers and budding authors we come across are just too modest. If they do not see the attraction and beauty of a design idea scribbled on a coaster and worked out later at home, others may, and should. Let Elektor Labs help you hone your design to perfection, let the editors assist with text & graphics, and reap the rewards by seeing your name in print in Elektor magazine's celebrated LABS section. Sure, we are happy to negotiate payment, but the actual remuneration will be fame & glory in electronics land, and your name added to the long list of extremely successful e-authors. Our get-u-famous formula also applies to book authors, bloggers and video makers. Students and youngsters: being in publication is a current boost like no other in getting a job!

Our Experts and Designers

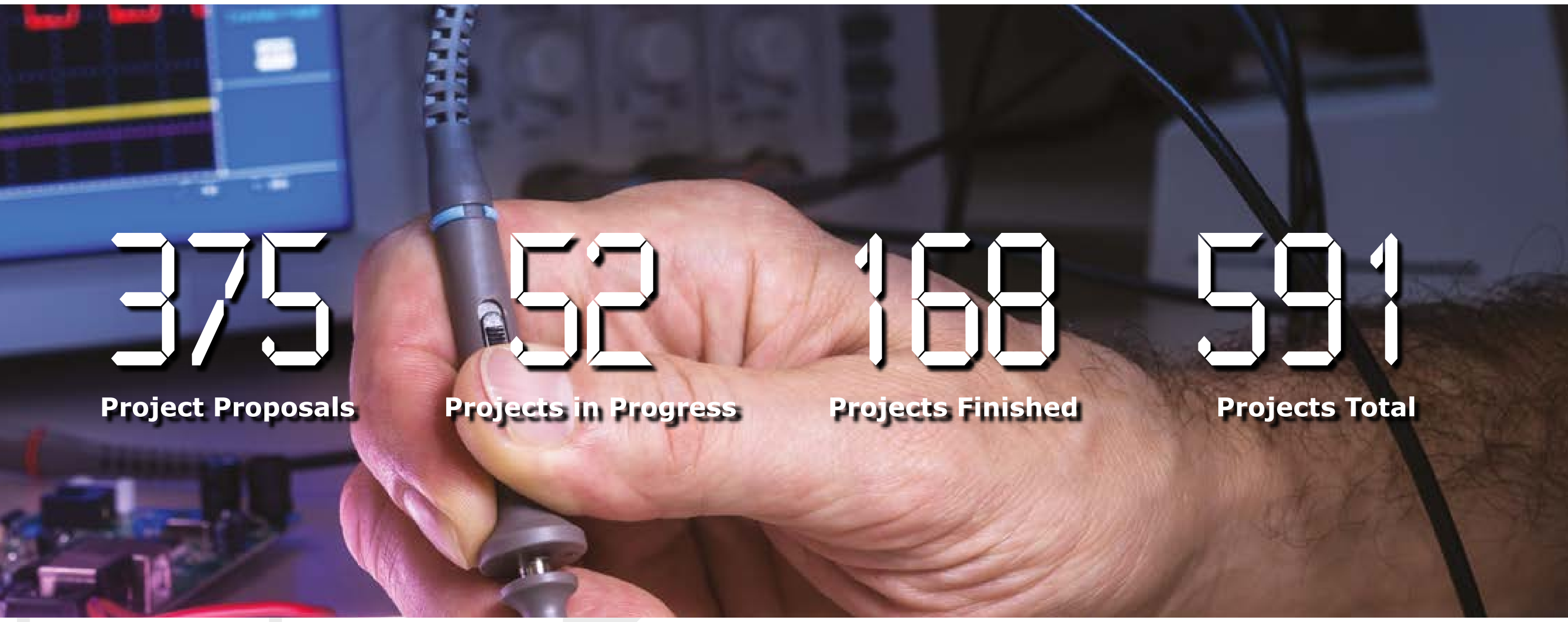
Besides experienced support staff and BSc, MSc qualified engineers with a total working life in electronics of about 200 years, the Lab has access to Elektor's vast network of experts for consultation, critical advice, and assistance with specialized assignments.

Our Facilities

We are sumptuously housed in three spacious rooms at Elektor House where we try unsuccessfully to keep our solder jobs and prototypes off our computer desks. We have water, 218 volts electricity and coffee nearby. PCB milling, prototype assembly, SMD reworking, audio testing, pizza cooking, and mechanical work are deferred to converted cellars in the basement.

Our Standards

All projects and products going through the Labs pipeline are produced to high engineering standards. In practice, prototypes of projects labeled LABS in the magazine must be demonstrated to work to specification on certified, calibrated test equipment available locally. BOMs and schematics must match perfectly. Kits are sampled for completeness. We are ROHS compatible, lead free and comply with electrical safety standards applicable in our location. If engineering errors are found these will be put up for public notification.



Our Products

Our products are visible in Elektor magazine, as well as on the Elektor.Labs and Elektor Store websites. The range includes text write-ups for editors, prototype photography, PCBs including SMD-prestuffed, PCB files, project software, programmed devices, semi-kits, tools, modules, videos, and service desk information.

Our Webinars

The more talkative of our Lab engineers do not stop at testing prototypes, they happily share technology related problems, insights, get-u-going information, and design skills on live camera at Elektot.tv. Labs' webinars are free to attend and extremely interactive. They are announced in Elektor.POST, and webcast live from Elektor House in Holland. Do plug in!

Our History

The origins of Elektor Labs go back to the early 1970s when soldering and writing was a one-man, single-desk job. Ove the years Labs staff have not only witnessed the arrival of the transistor, the IC, the microcontroller, and the SMD, but actually jumped on these parts as soon as they were out of the professional-only woods. Once special branches, Audio Labs, Micro Labs, PCB Labs, and Mechanical have converged back again into a single activity.

elektor labs

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On our very own Elektor-Labs website, you can share and showcase your ideas and project proposals to thousands of other electronic engineers. The site also allows you to follow other specialists' activities, supply comment, and so push the projects forward. Here's the best part, the top projects are eligible for processing in our test lab, in preparation for publication in Elektor magazine.

Who's this for?

Although only members can log on to our Elektor.Labs website to publish projects and contributions, anyone can view along with the other projects. If you'd like to see your project published in Elektor magazine, which is published in four languages and read by tens of thousands of electronics specialists all over the world, then become a Green of Gold member (**www.elektor.com/member**) or log in as an existing member of our Elektor community!

SHARE DESIGN LEARN

Welcome to the DESIGN section

By **Clemens Valens,** Elektor Labs

Design to communicate — communicate to design

Some time ago I read a book about innovation. To illustrate the subject the author used the history of Bell Labs, the former R&D laboratories of the U.S. phone company AT&T. This lab was innovative to the extent that even the word innovation was invented there. Other examples of the boundless creativity of Bell Labs (note plural) are the transistor and the orbiting satellite. Although the book didn't teach me a lot about innovation, what did dawn on me was that most if not all progress in technology has its origins in communication.
Today's technology has been created because people want and need to communicate. People love to talk, sometimes even to each other, and so we spend enormous amounts of energy and resources into developing technologies that allow us to do just that. We want to share increasing amounts of information with an increasing numbers of people and so we keep pushing the technological boundaries further and further away. Sharing leads to new ideas that get adopted elsewhere, this is how technology spreads. The reason that you can cook a deep-frozen dinner in your microwave oven and eat it in front of your TV is because a few decades ago someone on the East coast wanted to talk to somebody on the West coast. This edition's projects have been made possible by technological advances driven by men's innate desire and need to communicate. All of these projects communicate in some way, just like we do. And we publish them out of our desire to communicate.

Universal Universal Parallel Peer-to-Peer

Ladies and gentlemen, a warm round of applause for USB Type-C! Introduced last year, this brand new standard not only supports SuperSpeed USB 10 Gb/s (USB 3.1) and power delivery up to 100 watts — one of its key characteristics is also its entirely new design. The new USB Type-C plug and receptacle will not directly mate with existing USB plugs and receptacles.

If I remember correctly, USB stands for Universal Serial Bus. Universal? Only if you consider having a different standard for every application a universal solution. Serial? USB Type-C has three signal pairs, isn't that kind of parallel? Bus? Two devices per cable, peer-to-peer, do we call that a bus? Actually, USB-C is a universal USB solution as it is compatible with A and B. Also, it is supposed to be future proof, so shouldn't we call it Universal USB? Or U-U-P-P-2-P? U²P²2P? Future proof until something better comes along that is — like USB Type-D…

DESIGNers, get your specifications here before they get changed again:
www.usb.org/developers/docs

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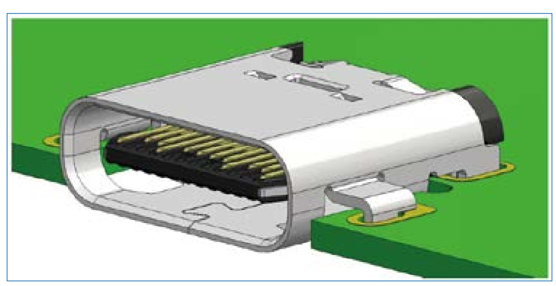
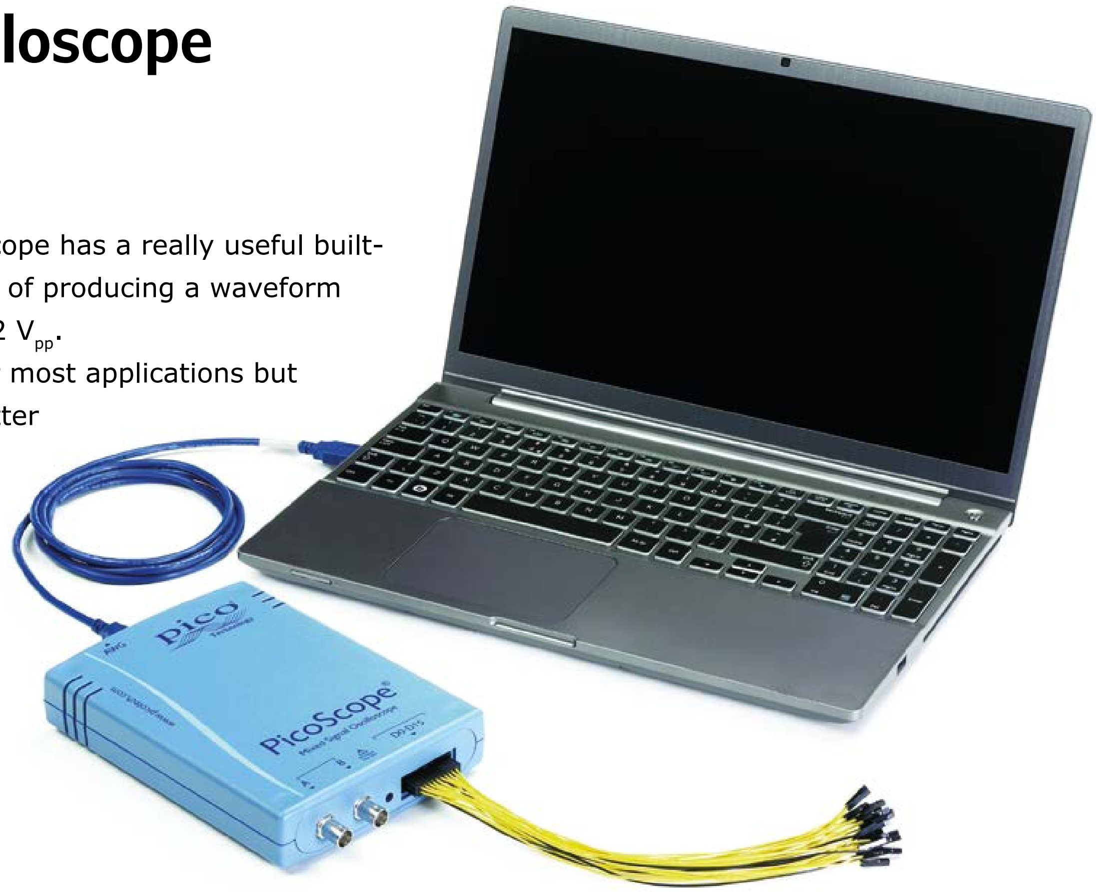


Signal Amplifier
for USB Oscilloscope

By **Christian Wendt** (Germany)

My PicoScope USB oscilloscope has a really useful built-in signal generator capable of producing a waveform with an output level up to 2 V_{pp}. This is usually sufficient for most applications but not always. It would be better if it could produce a higher output signal and have an adjustable DC offset, both controlled by manual pots. After searching fruitlessly for a ready-made solution it was time to grab the soldering iron.



The resulting circuit is made up of three parts. IC1A and its associated circuitry adds an offset level to the output signal. Switch S1 switches the offset on and off. The offset level is adjusted by P1. The second stage around IC1.B introduces a 180° phase shift of the input signal from the function generator connected to input K1, P2 provides adjustable signal gain. The third stage around IC2 acts as an output buffer and sums signals from the other two stages. The offset voltage is amplified by about three times (R8/R6), and the signal generator signal from IC1B is amplified around eight times (R8/R7). The circuit produces an output signal with adjustable offset and adjustable amplitude between −12 V and +12 V. The frequency range extends from DC to around 1 MHz.

Two BNC sockets are provided for the output signal, this makes it convenient to hook up a scope input with a BNC to BNC cable while the other output can connect to the circuit under test.

Power to the circuit is provided by an AC line supply module from Traco. These units are not particularly cheap but they simplify construction. A more economical supply could be built using a mains transformer, bridge rectifier, electrolytic capacitors and two voltage regulators. The circuit consumes less than 100 mA.

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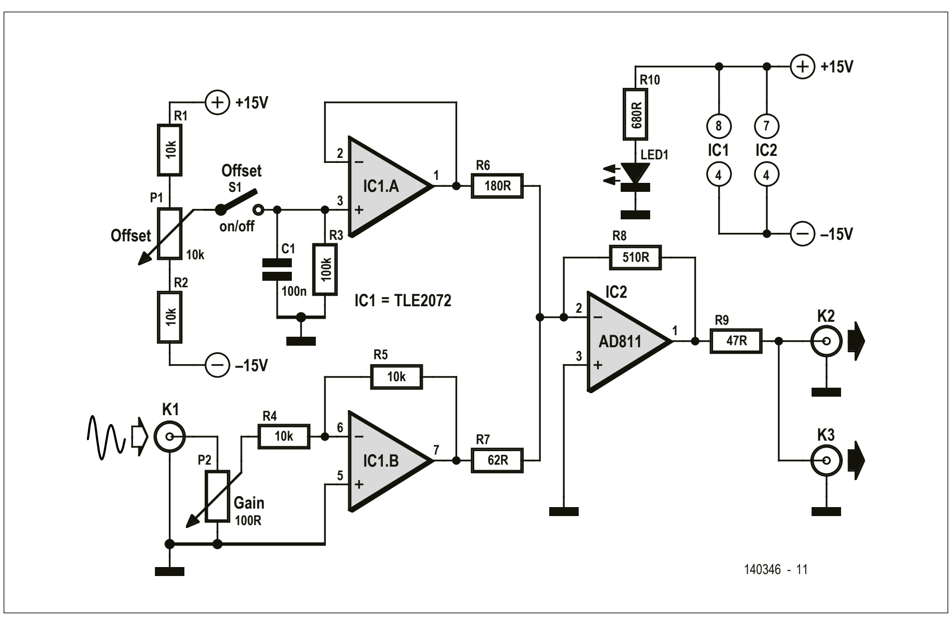


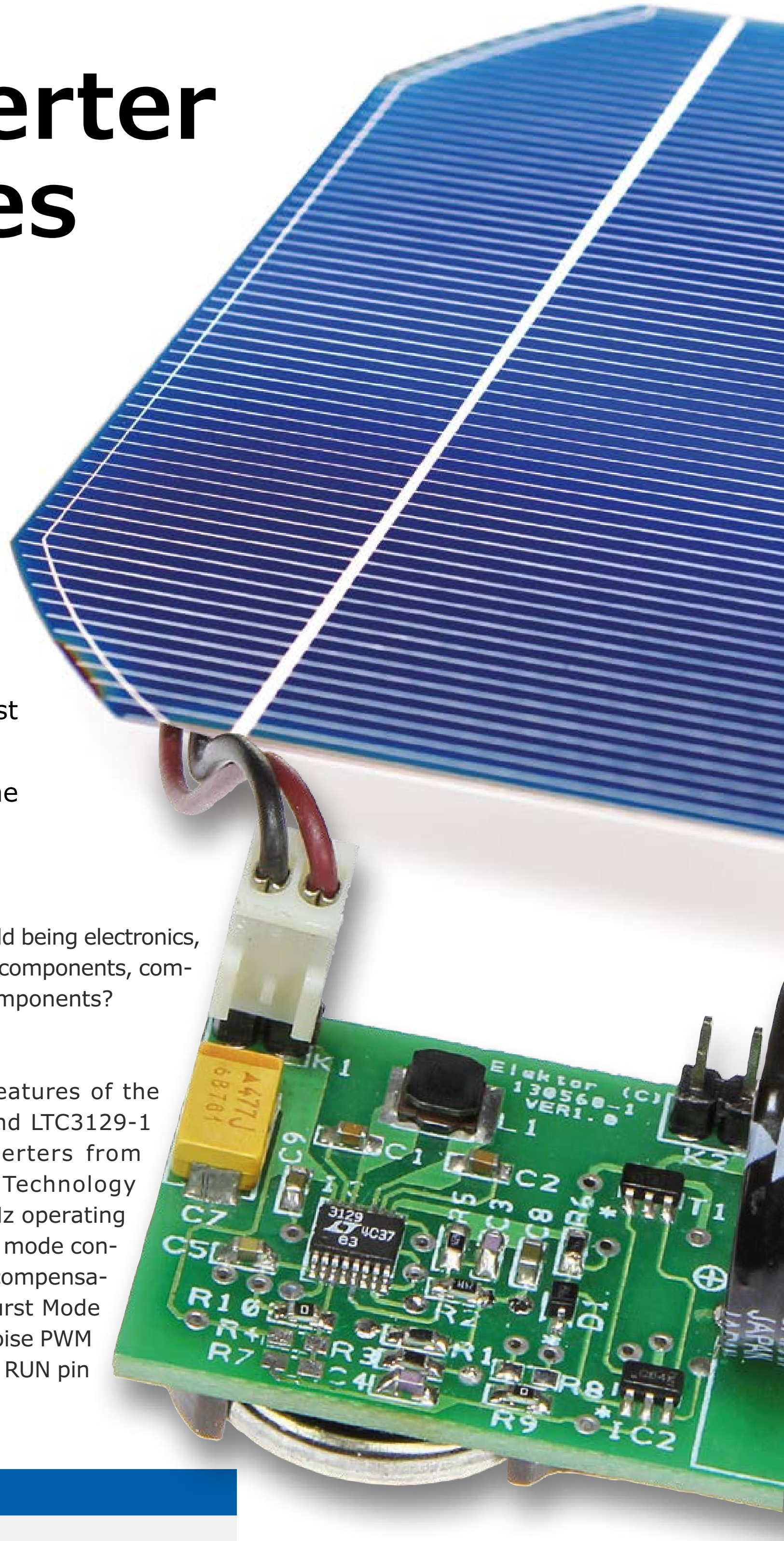
Figure 1. A simple signal amplifier with adjustable offset and amplitude control.

Solar Panel Voltage Converter for IoT Devices

Yes we CAN exploit indoor lighting

By **Sunil Malekar** (Elektor India labs)

The goal of this microcontroller-free project is to design a compact supply to power small indoor IoT devices from a solar panel, indoors (!). A key aspect of the project is its ability to operate from an input source as weak as 7.5 µW so that a low cost mini solar panel can be used. Not forgetting battery backup and extremely compact size, all thanks to the LTC3129 IC.



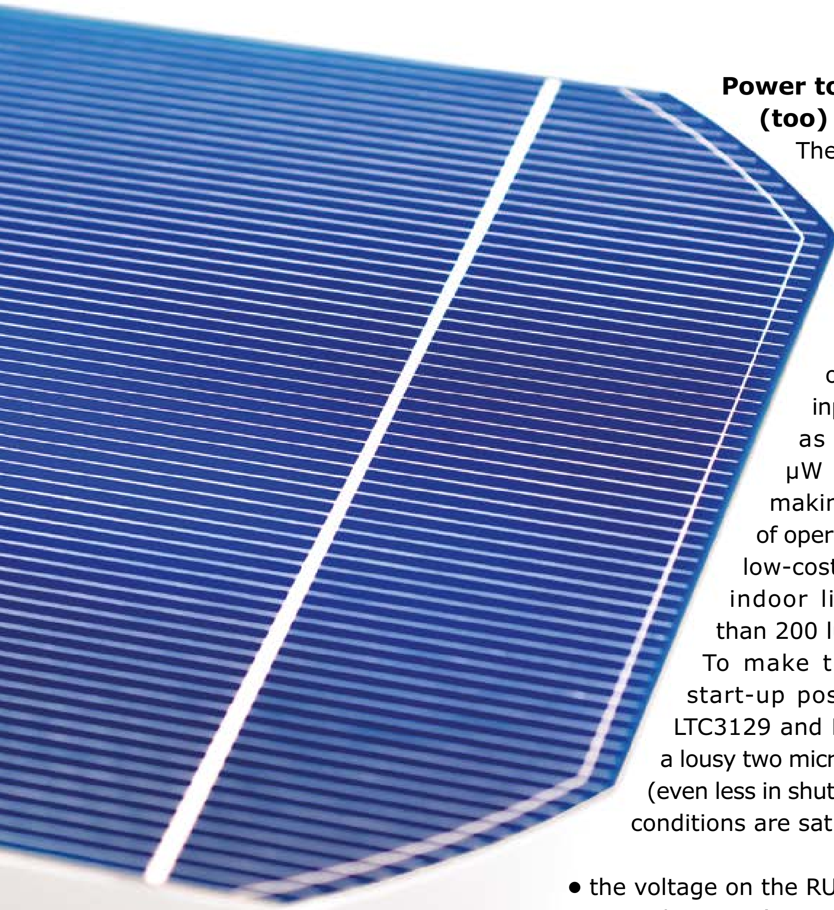
The Internet of Things (IoT) is said to define a network of physical objects embedded with electronics, software, sensors and connectivity to provide services by exchanging data with the connected devices. It's also a globally interconnected *continuum* of devices and objects and things that emerged with the rise of cheap, license free RFID technology. Alternatively some consider the IoT as a scenario in which objects, animals or people are provided with unique identifiers and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction. Eloquent definitions all, but Elektor's field being electronics, we're interested in components, components… what components?

Starring…

Among the key features of the Types LTC3129 and LTC3129-1 buck/boost converters from good old Linear Technology are a fixed 1.2-MHz operating frequency, current mode control, internal loop compensation, automatic Burst Mode operation or low noise PWM mode, an accurate RUN pin threshold to allow the UV_{LO} threshold to be programmed, a power-good output and an MPPC (maximum power point control) function for optimizing power transfer when operating from photovoltaic cells. The full story is at [1] and [2]. Let's see what these devices can do if it comes to powering IoT devices in an eco-friendly way.

Main Features

- Stores energy from indoor lighting
- Solar panel V_{out} 5 V typ., 42 µA
- Input power down to 7.5 µW usable
- 3.2 V typical out
- Choice of LTC3129 or LTC3129-1 converter IC, board configurable for either
- Easily configurable for many output voltages
- Optional backup battery
- Optional super-charge capacitor
- Ready-assembled unit with LTC3129-1 fitted, 3V3, MPPC mode.



Power to the IoT (too)

The circuit shown in **Figure 1** exploits the unique ability of the LTC3129 and LTC3129-1 to start up and operate from an input power source as “weak” as 7.5 µW (microwatts) — making them capable of operating from small, low-cost solar cells with indoor light levels less than 200 lux.

To make the low current start-up possible, both the LTC3129 and LTC3129-1 draw a lousy two microamps of current (even less in shutdown) until three conditions are satisfied:

- the voltage on the RUN pin must exceed 1.22 V (typical);
- the voltage on the V_{IN} pin must exceed 1.9V (typical);
- V_{CC} (which is internally generated from V_{IN} but can also be supplied externally) must exceed 2.25 V (typical).

Until all three of these conditions are satisfied, the part remains in a ‘soft-shutdown’ or standby state, drawing just 2 µA. This allows a weak input source to charge the input storage capacitor until the voltage is high enough to satisfy all three conditions, at which point the LTC3129/LTC3129-1begins switching, and V_{OUT} rises to regulation, provided the input capacitor has sufficient stored energy.

The circuit features battery backup circuitry around BAT1 (sorry about the missing T). A CR2032 backup battery provides power when solar power is insufficient. The LTC3129 is used in this case, allowing V_{OUT} to be programmed for 3.2 V to better match the voltage of the coin cell. With 5 V input from the solar panel on connector K1 you can expect an output

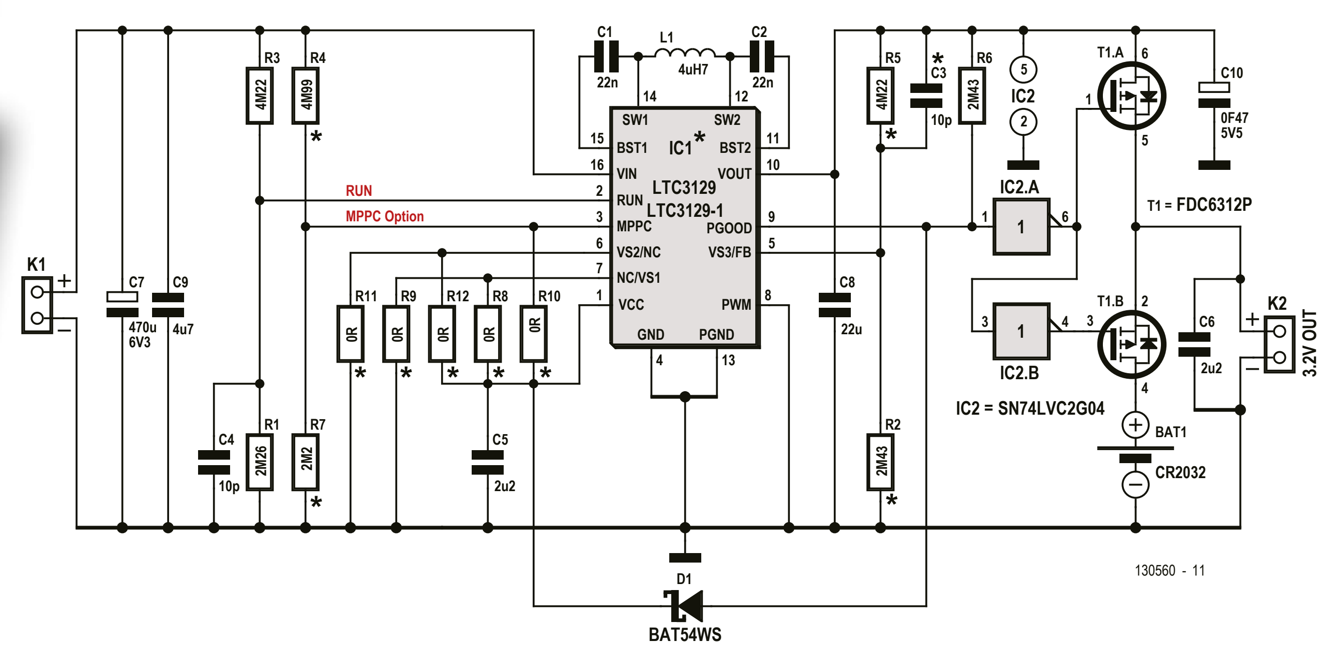


Figure 1. At the heart of the converter is either an LTC3129 or an LTC3129-1 IC, depending on your choice. A number of components need to be configured as a function of the IC you decide to use. Hardly a microwatt of solar power is wasted in this circuit.

Component List

Resistors
R1 = 2.26MΩ 1%, 0.063W, 0603 *
R2,R6 = 2.43MΩ 1%, 0603 (R2*)
R3,R5 = 4.22MΩ 1%, 0603 (R5*)
R4 = 4.99MΩ 1%, 100mW, *
R7 = 2.2MΩ 1%, 0603 *
R8-R12 = 0Ω, 0603 *

Capacitors
C1,C2 = 22nF, 25V, 0603
C3,C4 = 10pF, 25V, 0603
C5,C6 = 2.2µF, 25V, 0603
C7 = 470µF, 6.3V, case D
C8 = 22µF, 10V, 0603
C9 = 4.7µF, 25V, 0603
C10 = 0.47F, 5.5V, Super Capacitor, radial

Semiconductors
IC1 = LTC3129EMSE#PBF or LTC3129-1 *
IC2 = SN74LVC2G04DBVR
T1= FDC6312P (Newark/Farnell # 1700713)
D1 = BAT54WS-E3-08

Inductor
L1 = 4.7µH 20%, SMD

Miscellaneous
BAT1 = Lithium Battery, CR2032, coin cell, 3V, 20mm, with PCB mount holder
K1,K2 = 2-pin pinheader
Solar panel, AM-1815CA, 58.1x 48.6mm (Panasonic)
PCB # 130560-1 v. 1.0 from Elektor Store
Ready assembled unit, # 130560-91 from Elektor Store. Version: LTC3129-1, 3.3V out, MPPC, battery excluded.

* Component, value and/or use subject to user configuration; see text.

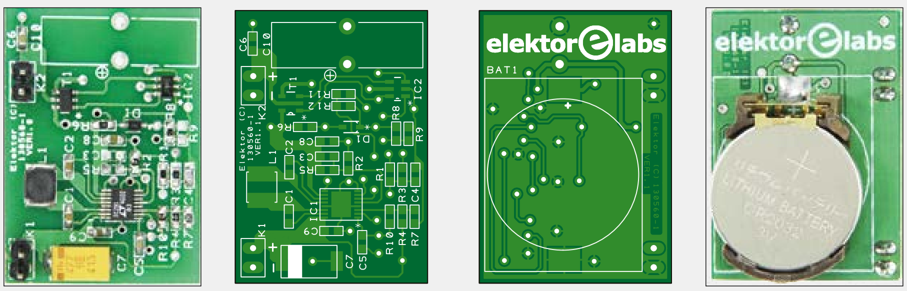


Figure 2. The very compact printed circuit board designed for the Solar Panel converter employs SMDs for the most part. The board is available not only unpopulated (# 130560-1) but ready assembled also (# 130560-91, see text and component list).

of 3.2 V on K2. The output voltage can be adapted to requirements by configuring the feedback resistor values in the case of LTC3129, or by setting the three programmable pins in case of LTC 3129-1. Provisions are made in the circuit to maintain the stability of the output voltage. The circuit can also operate without the coin cell battery.

Since the circuit is designed for indoor use an additional super-charge capacitor C10 is introduced in the circuit to store the energy captured from daylight. When the super charge capacitor is being charged the circuit will not provide the rated output voltage. T1, a Type FDC6312P *Dual P-Channel 1.8 V Powertrench® Specified MOSFET* from good old Fairchild Semiconductor [3] is used to switch between the convertor output (V_{OUT}) and the battery output. The selection is done with the help of two inverter gates in IC2 (74LVC2G04) under control of the PGOOD signal supplied by the convertor IC when the input and output voltages are at their rated values. If the input voltage is too low then the PGOOD signal is not generated thus forcing the output voltage to emanate from the backup battery.

The LTC3129 and LTC3129-1 have different configurations and requirements for their RUN pins. This pin is an input to the RUN comparator, and the voltage on it should be above 1.1 V to enable the V_{CC} regulator, and above 1.22 V to enable the converter proper. Connecting this pin to a resistor divider from V_{IN} to ground allows programming a V_{IN} start threshold higher than the 1.8 V (typical) threshold. In our case, the typical V_{IN} turn-on threshold is calculated from

$$V_{IN} = 1.22 \times [1 + (R3 / R1)]$$

Since the input source current is of the order of microamps, a high value resistor is required. Assuming R3 is selected as 4.22 MΩ and V_{IN} taken as 3.5 V:

$$1.22 \times [1 + (4.22 \times 10^6 / R1)] = 3.5$$

Hence R1 = 2.26 MΩ here.

More configuration options, calculations and component parameters for the LTC3129 and LTC3129-1 are shown in the **Configure It!** inset.

Board using LTC3129

When a solar panel is connected to the input connector K1 whose voltage and current is 5 V, 42 µA, capacitor C7 starts to charge. Since the charging current is too small, it takes 20-30 seconds to reach a voltage of 5 V. When the input supply voltage reaches 3.5 V, the voltage on the RUN pin due to voltage divider R3/R1 equals to 1.22 V which enables the converter output. At the same time the PGOOD signal is generated and IC2.A causes dual transistor T1 to pass the output voltage from converter IC1 to connector K2. The feedback from V_{OUT} is sent to the feedback pin of IC1 via voltage divider built around R5 and R2 which determines the output voltage available at connector K2 (set to 3 to 3.2 V). The feed-forward capacitor C3 on the feedback divider is used to reduce burst mode ripple on the output voltage.

Assuming BAT1 is connected (a 3-V coin cell), in case of no solar panel or low light conditions then IC2 switches on transistor T1.B to pass output current to the load on K2.

When there is no PGOOD signal from the converter IC, the battery power can be used as an alternative source until the solar panel gets sufficient light.

If super capacitor C10 is used when the solar panel is connected then it starts to charge. However, due to the very low output current which is in microamps range, C10 takes a long time to reach a rated output voltage of 3 to 3.2 V, in fact this may take 8 to 12 hours. The process does however store energy in the super capacitor for use when required.

Board using LTC3129-1

Both the ICs have the same functionality but their differences are in the configuration in the circuit. While the **LTC3129** uses a **voltage divider** on the feedback pin to set the output voltage, the **LTC3129-1** has its **VS1, VS2, VS3 pins** used for the same purpose.
A 3.3-V output voltage is obtained with VS1 (pin 7) of the LTC3129-1 connected to the V_{CC} pin through 0-ohm resistor R8;

VS2 (pin 6) connected directly to ground; and VS3 (pin 5) also connected to ground but through resistor R2 using another 0-ohm resistor.

The MPPC pin is taken to V_{CC} through 0-ohm resistor R10 as our functionality requires an input source stronger than 10 mA. In case of other configuration and input source this function can be used and set by using voltage divider resistors R4 and R7 as discussed. Other functions like battery backup and super-charge capacitor C10 are similar to the board with the LTC3129.

Building and testing

Provided you have professional (SMD) production equipment, or access to it, the printed circuit board with its overlay pictured in **Figure 2** can be built using either the LTC3129 or the LTC3129-1 with their required components. That's why a Component List is published here. Fully respecting all 100% DIY readers out there we kindly advise however that the board is also available ready-assembled through the Elektor Store as item # **130560-91**, it's the LTC3129-1 version, MPPC mode, 10 mA min. in, 3.3 V, backup battery not included.

Web Links

[1] LTC3129: www.linear.com/docs/42736

[2] LTC3129-1: www.linear.com/docs/42735

[3] FDC6312P: www.fairchildsemi.com/pf/FD/FDC6312P.html

The components marked * in the schematic are optional and/or need to be selected depending on the IC used. The Feedback, RUN, and MPPC voltage divider resistor values can vary depending on your choice as well as on the input and output supply.
In the case of the LTC3129-1, the output can be configured up to 5 V just by changing the resistor configuration on VS1 and VS2 pins of the IC. Be sure to fit either R11 or R12, not both.
The use of a backup battery and the super-charge capacitor depends on requirements — the board can work without them.

Waste Not Want Not

To power the board, a solar panel with an output voltage rating up 5 V is connected to K1 and the output load, to K2. By connecting a Sanyo AM-1815 solar panel, the board can operate from indoor lighting, and if super capacitor C10 is used a useful charge gets built.
Let's consider charging at 35 µA "stolen" from a light source. If maintained for 24 hours then it will give a cumulative charge of almost 700 µAh, equal to 7 mA for 6 minutes or is almost 42 mA for 1 minute.

Thus the power supply board is most suitable in applications where the power requirement of the devices is within the above range, which should include many IoT devices that need to wake up, respond briefly and go to cybersleep again. Tell us what you've in mind to power with this circuit — IP address optional. ◄

(130560)

Configure It!

MPPC on LPC3129 and LPC3129-1

An MPPC (maximum power point control) programming pin is common to both LTC3129 variants. To enable the MPPC functionality this pin is connected to a resistor divider from V_{IN} to ground. If the load on V_{OUT} exceeds the capacity of the power source, MPPC action will reduce the inductor current to regulate V_{IN} to a voltage calculated as:

$$V_{IN} = 1.175 \times [1 + (R4 / R7)]$$

Assuming R4 = 4.99 MΩ:

$$1.175 \times [1 + (4.99 \times 10^6 / R7)] = 3.2\ V$$

$$[1 + (4.99 \times 10^6 / R7)] = 2.9787\ V$$
$$R7 = 2.13\ M\Omega \approx 2.2\ M\Omega$$

By setting the V_{IN} regulation voltage appropriately, maximum power transfer from the limited source is assured. Note this pin is noise sensitive; therefore minimize PCB trace length and stray capacitance.
In our example the supply is less than 10 mA and hence MPPC is not used. The pin is connected to V_{CC} through R10 which is a 0-ohm device. If you want MPPC though, remove R10 and configure potential divider R4/R7.

Feedback signal on LTC3129

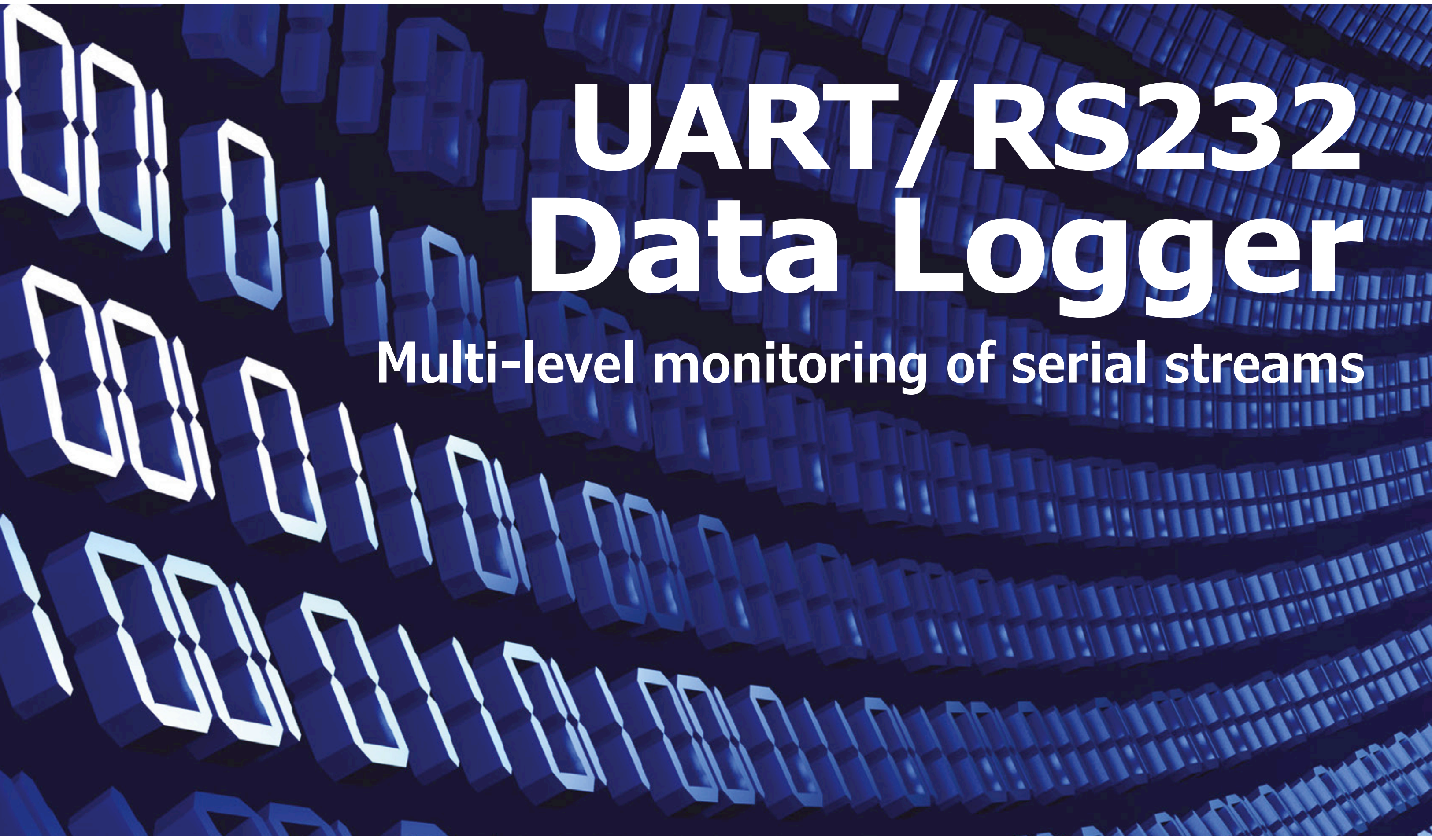
The feedback pin is a feedback Input to the Error Amplifier. This pin is connected to a resistor divider from V_{OUT} to ground. To get an output voltage of 3.2 V from our converter, assuming R5 = 4.22 MΩ we calculate:

$$V_{OUT} = 1.175 \times [1 + (R5 / R2)]$$
$$R2 = 2.44\ M\Omega \approx 2.43\ M\Omega$$

Output voltage configurations on LTC3129-1

VS1, VS2 and VS3 are the output voltage select pins that need to be connected either to the ground pin or to V_{CC} for programming the output voltage. These pins should not float or go below ground. The configuration of these pins for the desired voltage is given in the table below.

VS3	VS2	VS1	V_{OUT}
0	0	0	2.5 V
0	0	VCC	3.3 V
0	VCC	0	4.1 V
0	VCC	VCC	5 V



UART/RS232 Data Logger

Multi-level monitoring of serial streams

By Thomas Schlott, Francisco Ramirez and Dr. Thomas Scherer

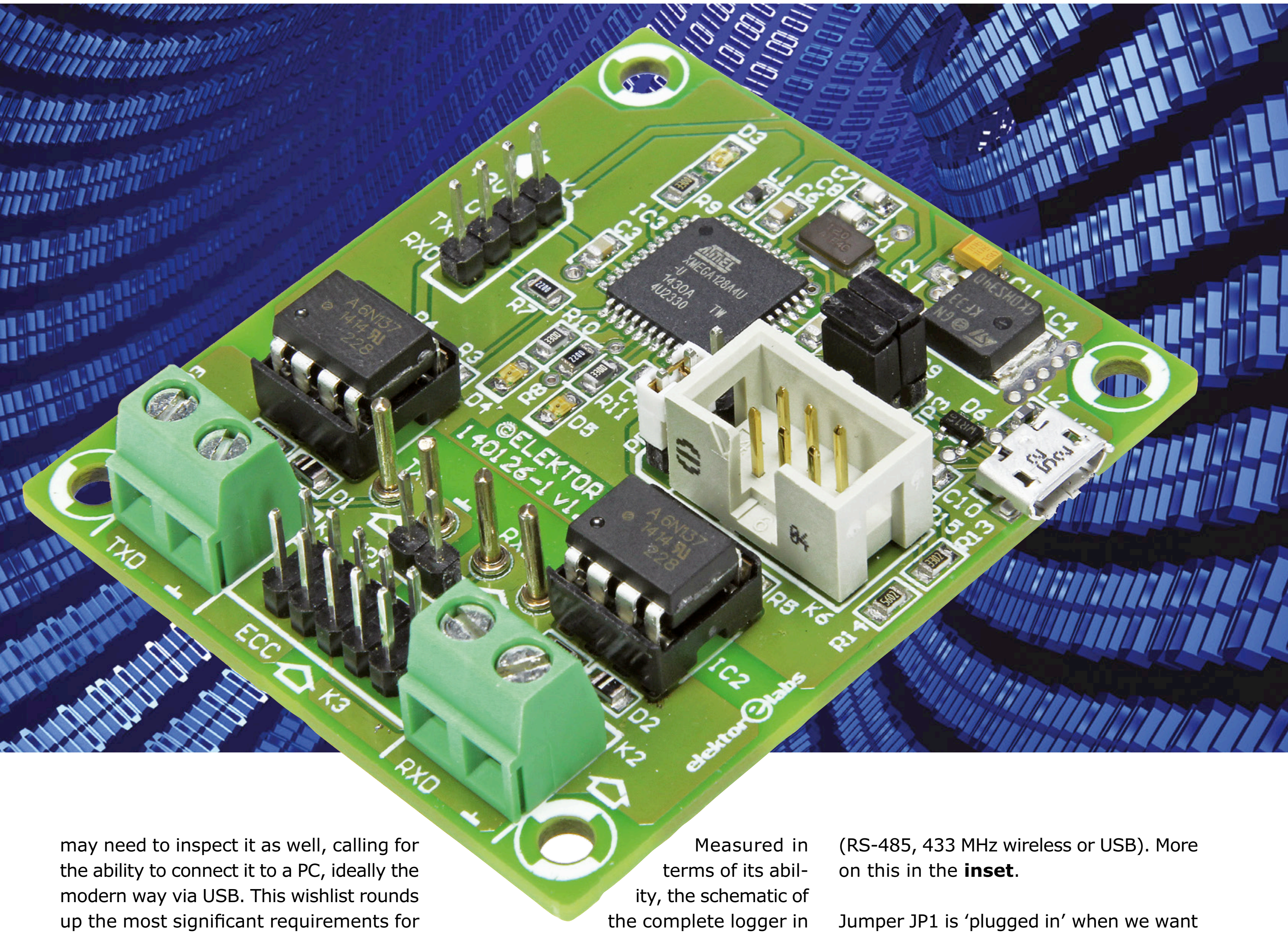
The universal asynchronous receiver/transmitter (UART) remains the favored means of transferring data between hardware devices. The interface is very easy to use, with a wide range of converter chips from which to choose. But when devices refuse to communicate correctly in test and development setups, tracing the cause becomes a tricky business. Our UART data logger makes the task a breeze — it registers bytes in both directions with millisecond accuracy. And its flexible connection options and electrical isolation enable it to be hooked up without difficulty into serial data connections employing TTL or RS-232 levels.

Tracking down failure modes in electronic systems can be a pig of a task when the symptoms appear only occasionally or cannot be reproduced a second time. And when things go wrong, the 'dodgy' data has long since vanished into the proverbial 'bit bucket' or digital nirvana. After the event, the only way of discovering what on earth happened is to capture whatever data is still available and provide it with a timestamp (if this is even feasible).

That's not the end of it either. If two devices are connected together by serial interfaces, bytes will pass in both directions. This means a serial data logger will, in practice, require two data channels simultaneously in order to monitor a bidirectional serial connection of this kind (full duplex) properly. And simply recording the data will not suffice on its own, as we

Technical Specification

- Two serial inputs for bidirectional connections
- Inputs can have separate grounds
- Data transmission to PC via USB
- Operating power derived via USB
- User interface via commands from Terminal Program
- Baud rates up to 230 KBd
- Stores up to 900 data sets
- Data logging for up to 2:20 (h:mm)
- Temporal resolution 1 ms



may need to inspect it as well, calling for the ability to connect it to a PC, ideally the modern way via USB. This wishlist rounds up the most significant requirements for a serial data logger. All we need do now is turn this specification into solid hardware and animate some firmware to produce a cost-effective and uncommonly useful little tool for your test bench.

Hardware and resources

Without doubt the functions listed cry out for a microcontroller that can read in data through two serial inputs, flag the data with a timestamp, file it internally in a buffer and finally output it to a PC. The demands in the hardware are not very taxing; you just need two U(S)ARTs, a timer, USB, an accurate source of timing and another couple of GPIOs. A modern AVR controller with built-in USB is well-nigh purpose-made for this task — all the better if it also has sufficient internal memory on board. The choice therefore fell unerringly on the type ATxmega128a4u [1], as this can be had in an SMD package with 44 pins that happens to be easy to solder manually.

Measured in terms of its ability, the schematic of the complete logger in **Figure 1** is quite modest. To avoid any problems arising from differing ground potentials, the two serial inputs are isolated electrically from the electronics of the logger and connected PC, using particularly high-speed 'digital' opto-couplers of the type 6N137. In tests these opto-couplers have performed stably at Baud rates up to 230 KBd. They are no match, however, for the elevated data rate of an FTDI cable of 460 or even 920 KBd. The two FETs T1 and T2, wired as current sources, permit input levels of up to 30 V at a current of around 3 mA. The RXD and TXD input signals can be taken either from the data transmission under investigation using flying leads or by taking the interface under test to the screw terminals K1 and K2. K3 is used when examining a UART connection passing via an Embedded Communication Connector (ECC). An example might be between the Elektor Extension Shield and one of the converters already described in Elektor (RS-485, 433 MHz wireless or USB). More on this in the **inset**.

Jumper JP1 is 'plugged in' when we want to link the ground connections of both inputs together. If bi-directionality is not an issue and you wish instead to monitor two differing unidirectional serial interfaces, JP1 should be unplugged (removed). At other times JP1 should be in place. The serial data can be extracted at K4 free of any set-up potential and in correct wave shape, for example using a 'scope probe.

The serial signals are received by the controller IC3 via its pins 12 and 16. IC3 is provided with sufficient pins to drive three LEDs (D3, D4, D5) simultaneously to display its operational status. When serial data is being logged, crystal X1 is indispensable.

On the right-hand side of Figure 1 we can see the six-pole programming connector K6, which can be toggled between ISP and PDI modes using jumper JP4. Serial signals from the USB connector K5 are

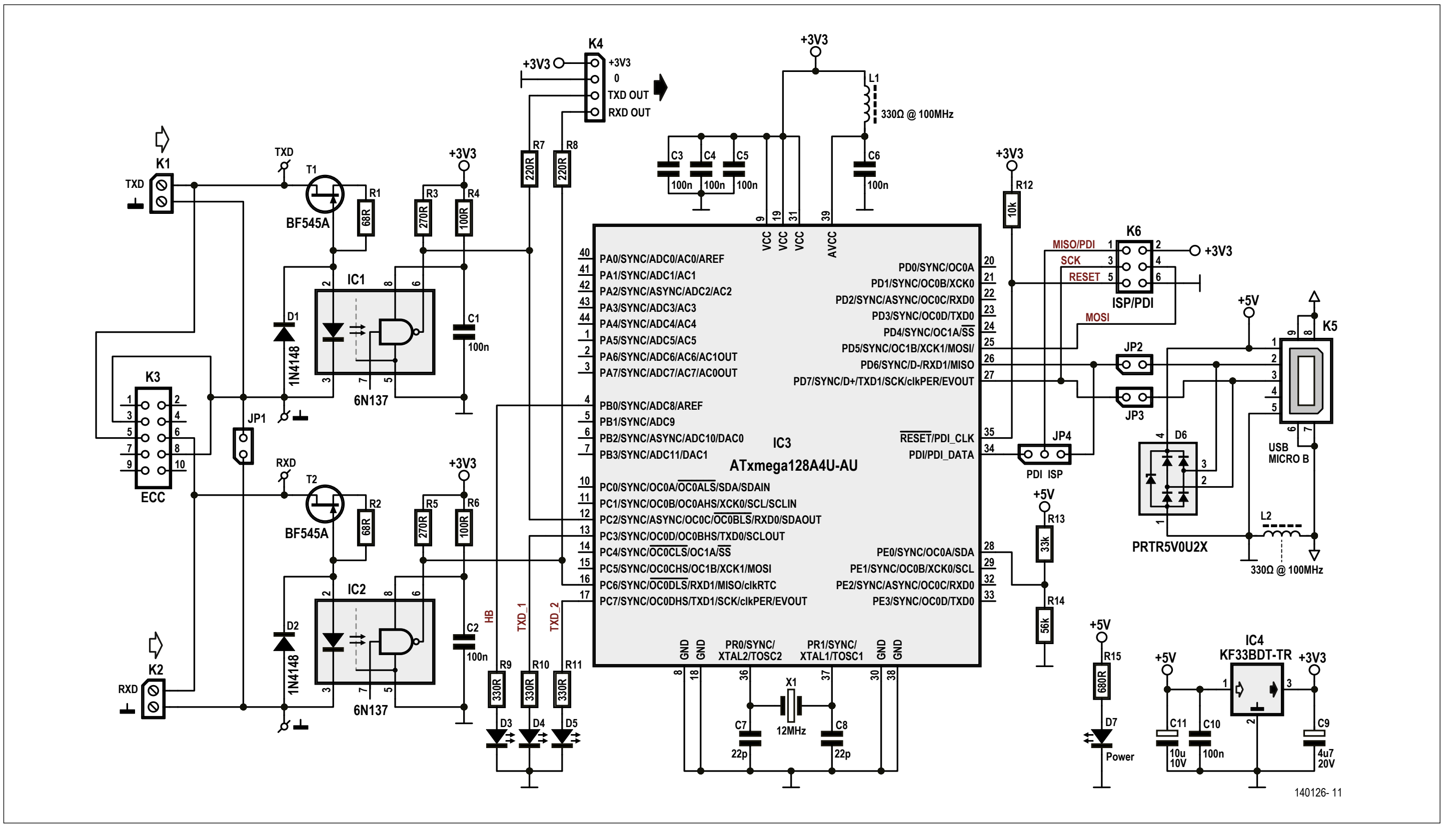


Figure 1. Schematic of the UART/RS-232 data logger.

fed directly to pins 26 and 27 of IC3. The diode matrix D2 protects the electronics from excessive or negative-going voltages. The two jumpers JP2 and JP3 must be removed categorically when IC3 is being programmed. Don't forget to replace them afterwards!

Timestamp

The timestamp occupies 23 bits internally. This provides 1-millisecond resolution over a time-span of 2 hours and 20 minutes. The timestamp format is 'a:bb:cc:ddd', in which:

a:	hours, 0 to 2
bb:	minutes, 00 to 59
cc:	seconds, 00 to 59
ddd:	milliseconds, 000 to 999

In conjunction with a data byte, a data set consequently occupies four bytes. In the 8 KB of SRAM in the controller, besides the variables and other program data, this corresponds to at least 900 complete data sets.

The Xmega controllers represent a further development of the well-known ATmega series by Atmel. They are significantly more capable and also faster, but cannot tolerate a 5 V supply voltage. To supply the data logger directly from a USB source we need to convert this to 3.3 V, which we carry out using IC4. LED D7 is lit when the logger is connected to a (switched-on) PC.

The main 5 V power supply is taken, via a voltage divider formed by R13 and R14, to the analog input of IC3 (pin 28). The data logger can also monitor whether the 5 V supply of the PC is playing tricks or otherwise disturbed, although this feature has not been implemented in the current version of the firmware.

Firmware and functions

To make something useful from microcontroller circuitry we need software to turn the functions into something tangible. This application software was developed in Atmel Studio 6.2 initially by Elektor reader Thomas Schlott, who also came up with the original idea. Our collaborator-at-large Francisco Ramirez further optimized the software, implementing among other things the USB-CDC hookup (see below). In USB-CDC communication it appears to the PC operating system as if the microcontroller is connected via a classic serial interface (virtual COM port). This enables us to use a normal terminal program to send and receive characters by USB. USB connectivity in 'CDC' mode works for Windows Vista and upwards without the need for manual driver installation.

As always, the software (both source and Hex code) is available to download free from the Elektor webpage relating to this project [3]. The functions are provided in commented and hence easy-to-comprehend code files (*.c) and their definitions in corresponding header files (*.h). The specific tasks of the firmware are:

- definitions in corresponding header files (*.h). The specific tasks of the firmware are:
- Interrupt-controlled writing of serial incoming data into buffer memory.
- Interrupt-controlled execution of commands via USB.
- The main function of the firmware is in two sections:

1. Initialization and preparation of the memory together with Variables and Modules such as GPIO, TIMER, USART, Clock, USB, EEPROM, Flash memory and RAM. The RAM contains the Variables, the Flash memory contains the Code plus the predefined Strings and the latest settings are in the EEPROM.
2. Start of the main loop.

- A so-called heartbeat LED (D3) flashes once per character, signifying the electronics are active.
- LEDs D4 (channel 1) and D5 (channel 2) indicate whether data is passing through the channel in question.
- To display the data on a console, it is read from memory (together with channel info and timestamp) and output via USB.
- The settings are concerned with things such as the output data format. Commands are provided for users to change these modes (see panel entitled 'Commands').

Software subtleties

While upgrading the USB interface, Francisco Ramirez had to refer back to the Atmel Software Framework (ASF) [4], which contains a USB stack for USB-CDC communication. It's probably better not worth attempting to unravel the ASF with the aim of borrowing individual elements. Instead use the ASF as it comes for the basis of your own project. You can start a fresh project ('User Board' template) and allow the ASF Wizard from Atmel Studio to assemble the necessary modules. In this project we used the following:

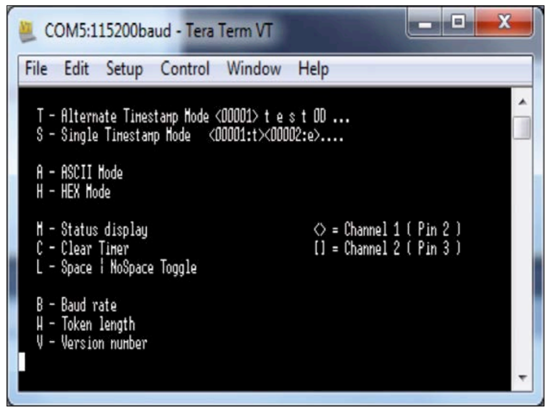
1. Generic Board Support;
2. GPIO — General Purpose Input/Output;
3. IOPORT — Input/Output Port Controller;
4. System Clock Control — XMEGA-A1U/A3U/A4U/B/C implementation;
5. TC – Timer Counter;
6. USB Device CDC.

Even at the outset ASF is not exactly easy to understand, which is rather unfortunate. Admittedly there is plenty of ready-made code and an abundance of documentation, although this is distributed across a fair number of files. Let's mention purely as an example that setting the system clock in ASF works in a different way from the manner you may be familiar with. Here it appears to be necessary to define the clock for each peripheral module of the controller independently. Using the internal 32-MHz oscillator for USB and as a system clock came to nothing, yet the external 12-MHz crystal could have been involved as clock reference without difficulty. Francisco Ramirez describes his experiences with ASF at www.elektor-labs.com [5].

Configuration using simple commands

Commands

You can use a regular terminal program such as HTerm, Tera Term etc. for configuring relevant parameters. These commands are then passed forward to the data logger. The user interface includes commands listed below (see **Figure 4**).



S: Single Timestamp Mode — outputs every character entered on a fresh line with its own timestamp.

T: Alternate Timestamp Mode — outputs a timestamp, followed by the incoming character. A new timestamp (on a fresh line) is generated only once a character is received on the other channel.

A: ASCII Mode — data read in is output as ASCII characters.

H: HEX Mode — data read in is output in Hex format.

E: Execute Line Feed — the <LF> character is passed, unsuppressed, to the terminal program (where it causes, if set, to a new line feed).

M: Show Status — displays the current status of various settings.

C: Clear Timer — resets the timestamp.

L: Space / No Space Toggle — determines whether a space is entered or not between two characters.

B: Baud Rate — selects from a list the Baud rate for the serial interfaces.

W: Token Length — selects the Bit length of an RS-232 token.

I: Inversion — inverts the level. For each channel you can set individually whether activation of the command a second time reverts to the initial state.
While logging an RS-232 connection, both channels must be 'not inverted'; with the TTL UART they must be 'inverted'.

V: Version number — indicates the software version in use.

With Commands that require a parameter suffix, the Command character must be entered first, after which a menu is displayed for selecting the parameter.

Note also that differing brackets are used to distinguish the data in each channel:

<>: Channel 1 — angle brackets around the timestamp and the received data in Channel 1.

[]: Channel 2 — square brackets around the timestamp and the received data in Channel 2.

Construction and operation

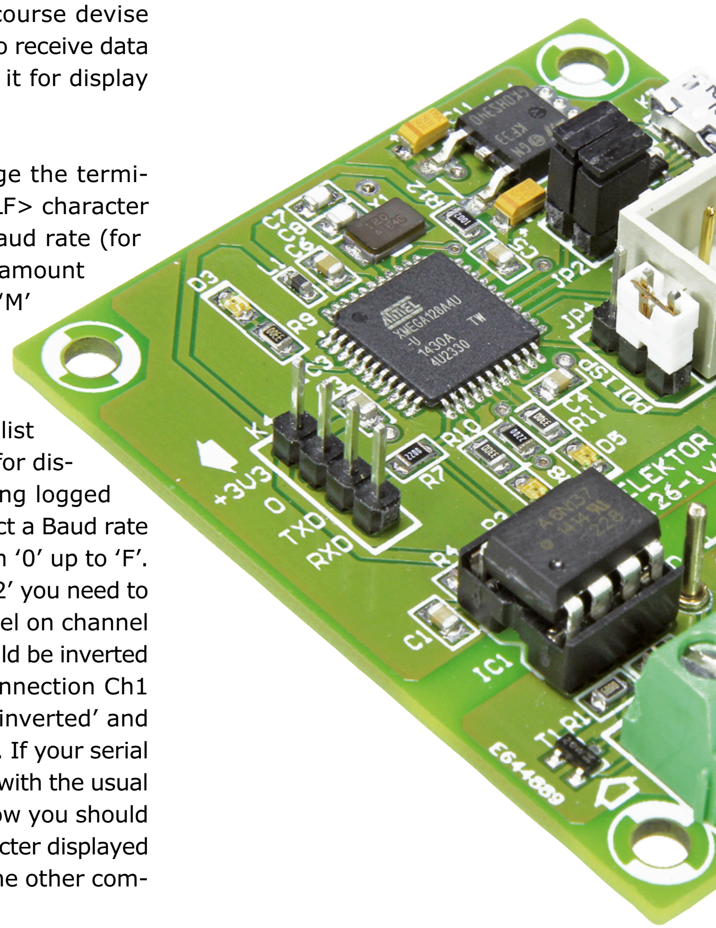
We developed a small double-sided PC board for the RS-232 data logger (see **Figure 2**), also shown complete with components mounted in **Figure 3**. Apart from the opto-coupler, headers, connectors and terminals, all components are SMD devices, meaning constructors need to take care when soldering, fitting IC3 and IC4 first of all, followed by the resistors and capacitors. Since the last-named are almost exclusively of SMD format 0805, you should manage OK without needing a magnifying glass. Polarity checking is necessary only for the diodes, LEDs and the tantalum caps.

For checking correct operation of the input stage with the opto-couplers the best tool is an oscilloscope hooked up to connector K4, while feeding serial signals to the respective inputs RXD and TXD. If you don't have a suitable programmer, you can obtain a pre-programmed microcontroller without difficulty from the Elektor Store [3]. And if you don't enjoy soldering, the same emporium even offers a ready-populated board that can be deployed immediately.

Figure 4 shows how the data readout looks typically in a terminal program. In this example data from channel 2 is displayed in 'single mode', in which each character received complete with individual timestamp is contained within square brackets. With a little experience in PC programming you can of course devise your own software as well to receive data and (for example) process it for display in a spreadsheet.

Ideally you want to arrange the terminal program so that the <LF> character initiates a line feed. The Baud rate (for PC communication!) must amount to 115200. Next you send 'M' (a subsequent <CR> is unnecessary) to display the current status of the settings. A 'B' brings up a list of the Baud rates possible for displaying the connection being logged onscreen. You can now select a Baud rate by sending a character from '0' up to 'F'. Using 'I' followed by '1' or '2' you need to make clear whether the level on channel 1 and/or 2 respectively should be inverted or not. With an RS-232 connection Ch1 and Ch2 must remain 'not inverted' and with TTL-UART as 'inverted'. If your serial communication is executed with the usual eight data bits (8N1), by now you should be viewing the logged character displayed in the terminal program. The other commands are concerned mainly with the display format; a compilation is shown in the panel entitled 'Commands'.

(140126)



Component List

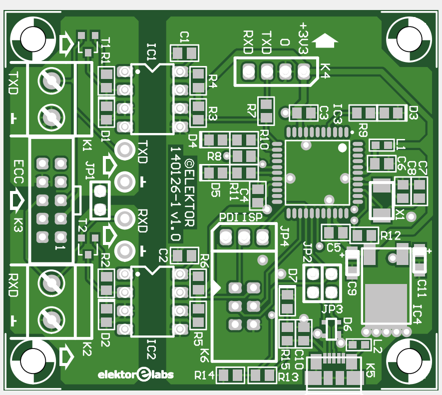


Figure 2. Component plan for the PCB.

Resistors
Default: 5%, .125W, SMD 0805)
R1,R2 = 68Ω 1%
R3,R5 = 270Ω
R4,R6 = 100Ω
R7,R8 = 220Ω
R9,R10,R11 = 330Ω
R12 = 10kΩ
R13 = 33kΩ
R14 = 56kΩ
R15 = 680Ω

Capacitors
Default: 10%, 50V, SMD 0805
C1–C6,C10 = 100nF, X7R
C7,C8 = 22pF, C0G/NP0
C9 = 4.7µF 20V, tantalum, SMD A
C11 = 10µF 10V, tantalum, SMD A

Inductors
L1,L2 = 330Ω @ 100MHz, 0.08Ω, 1.7A, SMD 0603

Semiconductors
D1,D2 = TS4148 RY
D3,D4,D5 = LED, yellow (SMD 0805)
D6 = PRTR5V0U2X
D7 = LED, green (SMD 0805)
T1,T2 = BF545A (SMD SOT23)
IC1,IC2 = 6N137 (DIP8)
IC3 = ATxmega128A4U-AU, programmed, Elektor Store # 140126-41 [3]
IC4 = KF33BDT-TR

Miscellaneous
K1,K2 = 2-way PCB screw terminal block, 0.2" pitch
K3 = 10-pin (2x5) pinheader, 0.1" pitch
K4 = 4-pin pinheader, 0.1" pitch
K5 = Micro USB connector, Type B, SMD
K1 = 6-way (2x3) boxheader, 0.1" pitch
JP1,JP2,JP3 = 2-pin pinheader, 0.1" pitch

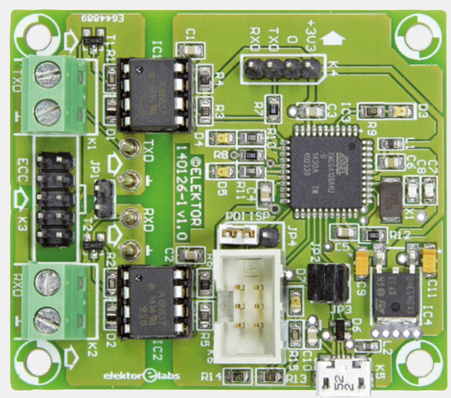
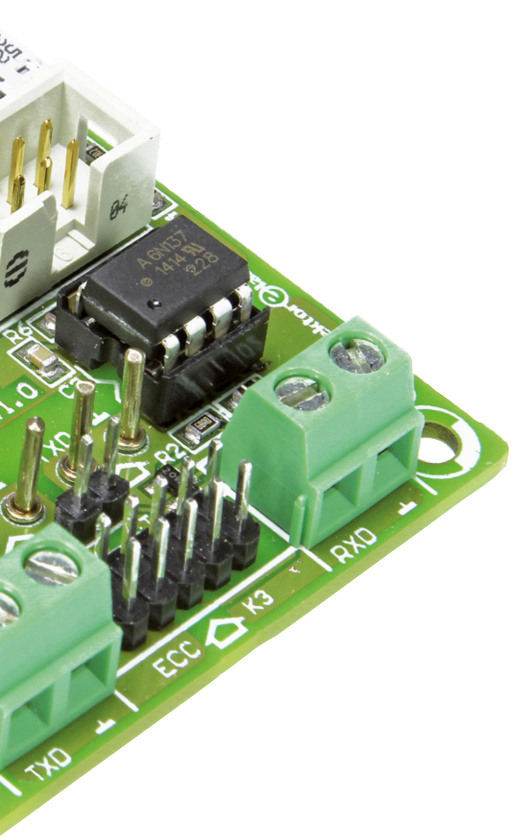


Figure 3. Populated PCB for the UART/RS-232 data logger (lab prototype).

JP4 = 3-pin pinheader, 0.1" pitch
JP1–JP4 = jumper, 0.1" pitch
PC1–PC4 = solder pin 1.3mm
X1 = 12MHz quartz crystal, CL=18pF, SMD, 5x3.2mm, e.g. Abracon ABM3-12.000MHZ-D2Y-T
PCB # 140126-1 v1.0 [3]
Ready assembled module, Elektor Store # 140126-91 [3]



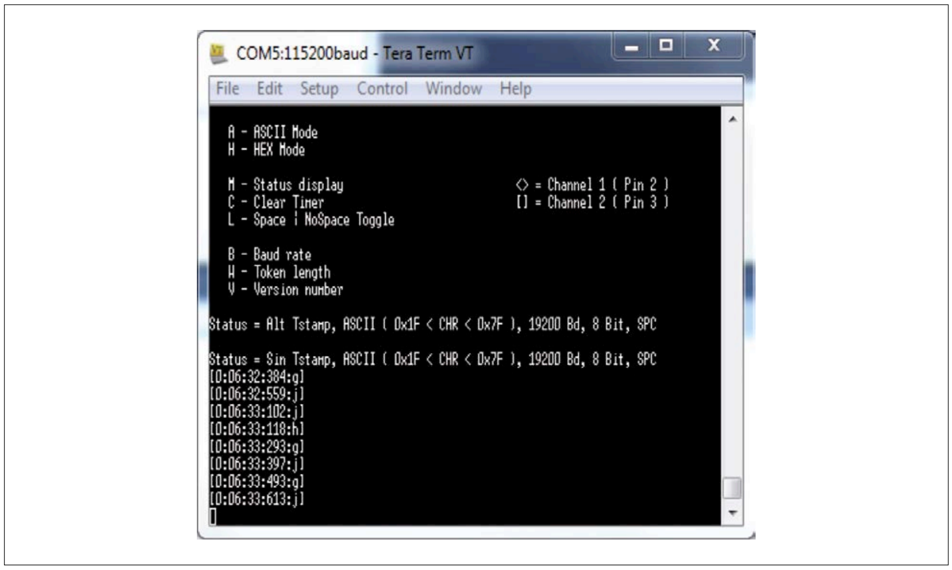


Figure 4. Output display in Tera Term for data on Channel 2.

Web Links

[1] www.atmel.com/devices/ATXMEGA128A4U.aspx

[2] www.elektor-magazine.com/130155

[3] www.elektor-magazine.com/140126

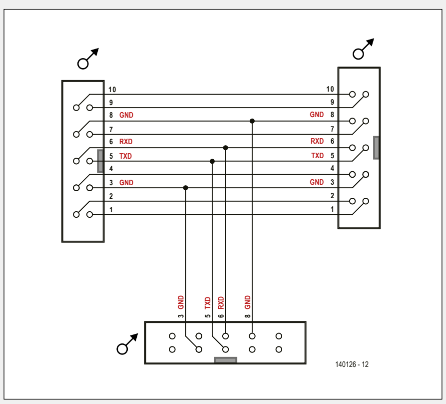
[4] www.atmel.com/tools/avrsoftwareframework.aspx?tab=overview

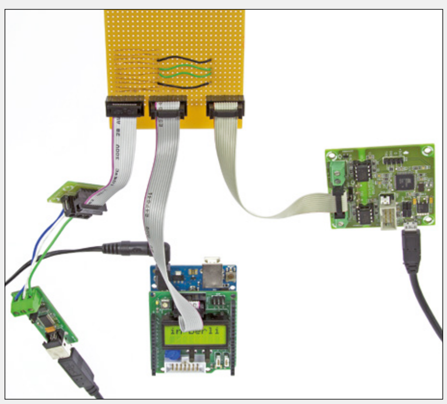
[5] www.elektor-labs.com/contribution/from-the-lab-new-software.14381.html

[6] www.elektor-magazine.com/140009

[7] www.elektor-magazine.com/130023

Data logging with the ECC

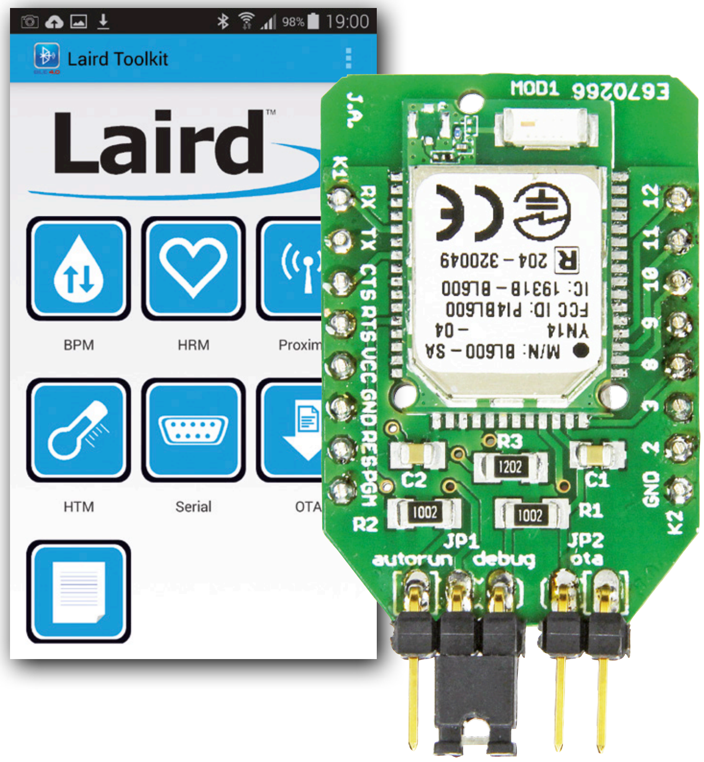




The Embedded Communication Connector (ECC) specified by Elektor transfers TTL UART signals via two pins of a 2x5-pole header connector. The Elektor Extension Shield for the Arduino Uno [6] is already equipped with a header connector of this kind and an adapter for the SAM-D20 Board from the ARM product line will be available shortly. Using a flat cable various communications modules can be plugged into this header, including the RS-485 converter [2] and 433-MHz ISM radio module [7] already described, as well as the UART/USB converter (in this issue). An NFC gateway and further modules will follow.

If you are interested in logging alone, for instance the output from an Arduino Uno, then you can simply hook the Extension Shield direct to the data logger using a flat cable. If you need to monitor bi-directionally, you'll need a Y-splitter for the signals, ideally one equipped with three ECC connectors. A printed circuit board for this has already been designed in our labs. For their first experiments our colleagues simply knocked up the circuit shown here on some perf board. The photo shows them logging data exchanged between the Arduino Uno and a PC (for this see the 'Learn' introductory page in this issue). To do this the Y-splitter and data logger combo were inserted in the hookup between the Shield and the RS-485 converter.

BL600 e-BoB



Part 3

smartBASIC programming for the Bluetooth Low Energy module

By **Jennifer Aubinais** (France) elektor@aubinais.net

The aim of this series around the BL600 e-BoB is to make it easier to implement this remarkable module for wireless communication with devices you design yourself. The fact it can be programmed in smartBASIC is by no means the least of the BL600's qualities. In order to take full advantage of it, you do need get used to handling the events that make smartBASIC so powerful.

Following on from the description of the module's hardware and the tool needed to use it, we're now going to take a look at smartBASIC. This enables you to program the BL600 using what Laird Technologies call "events". I recommend you read their documentation [1]. As an application example, I'm going to be using the coding for our light-chaser from last month [2], and more specifically managing the offset time for turning the LEDs on and off and the chaser movement direction – all using these famous events. So in order to be able to follow, it's best if you've read the previous article. To go a bit further into it, you'll find it best to have it to hand.
Then, as an example of using Bluetooth communication, starting out from the UART program that's already been mentioned, we're going to control a 3-color LED. We'll intercept the characters send by the smartphone to turn the RGB LED on or off. This will give you the opportunity to use our eBOB-BL600 to control a commercial 3-color lamp or string of lights, for example. My `BLE RGB Lite` program is available on Google Play [3].

Handlers in the light-chaser

Our chaser program in the previous article (a simple *for next* loop for the timing, along with, for the LED chase, button position detection using an *if* condition) did not exploit the possibilities of the events in *smartBASIC* [see box]. This time, to do the same thing but more cleverly, we're using handlers, i.e. event managers.
We're going to be seeing two types of events: counting/timing and the changing state of a button. As much of the interest of *smartBASIC* lies in managing such events, it's essential to understand this little program properly before moving on to the next step.
The six LEDs connected to the eBoB-BL600's outputs 3–12 (see circuit and components list in last month's article [2]) turn on and off in succession. In the code in **Listing 1**, we're not going to linger over the black section, described in the previous issue of Elektor, but are going to take a look at what's going on in the red section of the code:

`WAITEVENT`

The command (or statement) `WAITEVENT` makes it possible to run the event manager. It's a sort of wait loop in which the system scans for the presence of events. This waiting stage is usually placed at the end of the main program (*main*).
The events are coupled to the managers (handlers) by `ONEVENT … CALL …` instructions, e.g. `ONEVENT EVTMR0 CALL FuncTimer0`, which means the `FuncTimer0` function is the handler for the event `EVTMR0`. The event names are predefined, but you can choose the names of the handlers.

`FuncTimer0` function
Here, we turn the LEDs on and off alternately at intervals of 200 ms (an arbi-

trary value). To do this, we create an event **EVTMR0** (EVTMR corresponds to a timer event, 0 corresponds to the number of the timer we've chosen) which is going to call the function **FuncTimer0** (this name is arbitrary) thanks to coupling via the instruction ONEVENT EVTMR0 CALL FuncTimer0.
Timer 0 is started by:

```
TIMERSTART(0,10,0)
```

where 0 is the event number, the same as in EVTMR0; 10 is the duration in ms of the timer counter; and lastly 0 for non-iterative; 1 for iterative.
The offset between turning the LEDs on and off is obtained by incrementing a counter (in our example, led) which turns one LED off and the next one on depending on its value. When the counter reaches the number of LEDs — for us, that's 6 — it is reset to zero and the LED sequence starts over.
At the end of FuncTimer0, timer 0 is restarted, this time for 200 ms.

Changing direction, FuncTimer1

To reverse the direction of our chaser, all we have to do is to decrement a counter starting from the number of LEDs — six, here — instead of incrementing it. At each decrement, depending on the counter value, one LED is turned off and the previous one is lit. Once the counter reaches zero, it is reset to 6 for a new LED sequence. That's what we have done here using Timer 1 with its event EVTMR1 and its handler FuncTimer1. We could have achieved this more simply, but the aim here is to demonstrate events.

```
//TIMERSTART(0,10,0)
led = 6
TIMERSTART(1,10,0)
```

Try these lines… When you save your code, remember to delete the old program in the BL600 (don't forget the AT&F 1 command). Compile, transfer, and run. You'll see that the chaser starts in the other direction.

This example shows the simplicity of using timers: we can run a timer for a single (final parameter set to 0) or repeated (final parameter set to 1) count; it produces an event which runs a function [see box].

The "button" event

Before moving on, let's go back to the original code:

Listing 1.

```
Dim led, rc
'//-----------------------------------------------------------------------
FUNCTION FuncTimer0()
  PRINT "WAY + ";led;" \n"
  IF (led == 0) THEN : GpioWrite(12,0) : GpioWrite(3,1) : ENDIF
  IF (led == 1) THEN : GpioWrite(3,0) : GpioWrite(8,1) : ENDIF
  IF (led == 2) THEN : GpioWrite(8,0) : GpioWrite(9,1) : ENDIF
  IF (led == 3) THEN : GpioWrite(9,0) : GpioWrite(10,1) : ENDIF
  IF (led == 4) THEN : GpioWrite(10,0) : GpioWrite(11,1) : ENDIF
  IF (led == 5) THEN : GpioWrite(11,0) : GpioWrite(12,1) : ENDIF
  led = led + 1
  IF ( led >= 6) THEN : led = 0 : ENDIF
  TIMERSTART(0,200,0)
ENDFUNC 1
'//-----------------------------------------------------------------------
FUNCTION FuncTimer1()
  PRINT "WAY - ";led;" \n"
  IF (led == 6) THEN : GpioWrite(3,0) : GpioWrite(12,1) : ENDIF
  IF (led == 5) THEN : GpioWrite(12,0) : GpioWrite(11,1) : ENDIF
  IF (led == 4) THEN : GpioWrite(11,0) : GpioWrite(10,1) : ENDIF
  IF (led == 3) THEN : GpioWrite(10,0) : GpioWrite(9,1) : ENDIF
  IF (led == 2) THEN : GpioWrite(9,0) : GpioWrite(8,1) : ENDIF
  IF (led == 1) THEN : GpioWrite(8,0) : GpioWrite(3,1) : ENDIF
  led = led - 1
  IF ( led <= 0) THEN : led = 6 : ENDIF
  TIMERSTART(1,200,0)
ENDFUNC 1
'//-----------------------------------------------------------------------
FUNCTION Btn0Press()
  PRINT "PRESS DOWN\n"
  rc = GpioBindEvent(1,2,0)
  TIMERCANCEL(0)
  TIMERSTART(1,10,0)
ENDFUNC 1
FUNCTION Btn1Press()
  PRINT "PRESS UP\n"
  rc = GpioBindEvent(0,2,1)
  TIMERCANCEL(1)
  TIMERSTART(0,10,0)
ENDFUNC 1
'//----------------------------------------------------------------------
ONEVENT EVTMR0 CALL FuncTimer0
ONEVENT EVTMR1 CALL FuncTimer1
ONEVENT EVGPIOCHAN0 CALL Btn0Press
ONEVENT EVGPIOCHAN1 CALL Btn1Press
'//-----------------------------------------------------------------------
rc = GpioSetFunc(2,1,2)
rc = GpioBindEvent(0,2,1)
// init all GPIO at value Low
rc = GpioSetFunc(3,2,0)    // pin 3
rc = GpioSetFunc(8,2,0)    // pin 8
rc = GpioSetFunc(9,2,0)    // pin 9
rc = GpioSetFunc(10,2,0)   // pin 10
rc = GpioSetFunc(11,2,0)   // pin 11
rc = GpioSetFunc(12,2,0)   // pin 12
led = 0
TIMERSTART(0,10,0)
//led = 6
//TIMERSTART(1,10,0)
WAITEVENT
```

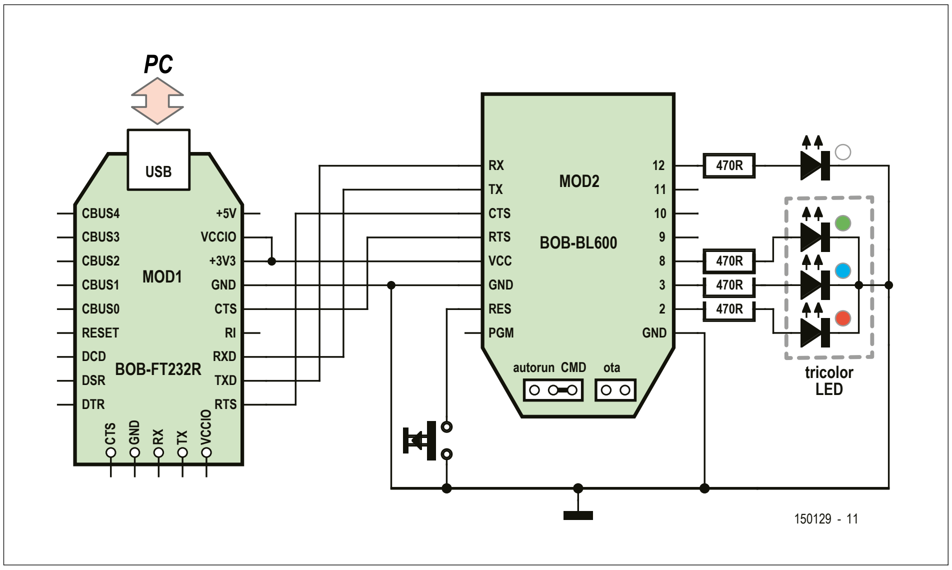


Figure 1. Experimental circuit for wireless control of a 3-color LED. Using the BL600 module, you can turn the LED on and off and choose the color using a smartphone.

Component List

(LED RGB control)

Resistors
R1–R4 = 470Ω

Semiconductors
D1 = LED, 3mm (select color)
D2 = LED, RGB, common cathode

Miscellaneous
K1 = pushbutton
MOD1 = assembled FT232 e-BoB module, # 110553-91 (www.elektor.com)
MOD2 = assembled BL600 e-BoB module, # 140270-91 (www.elektor.com)

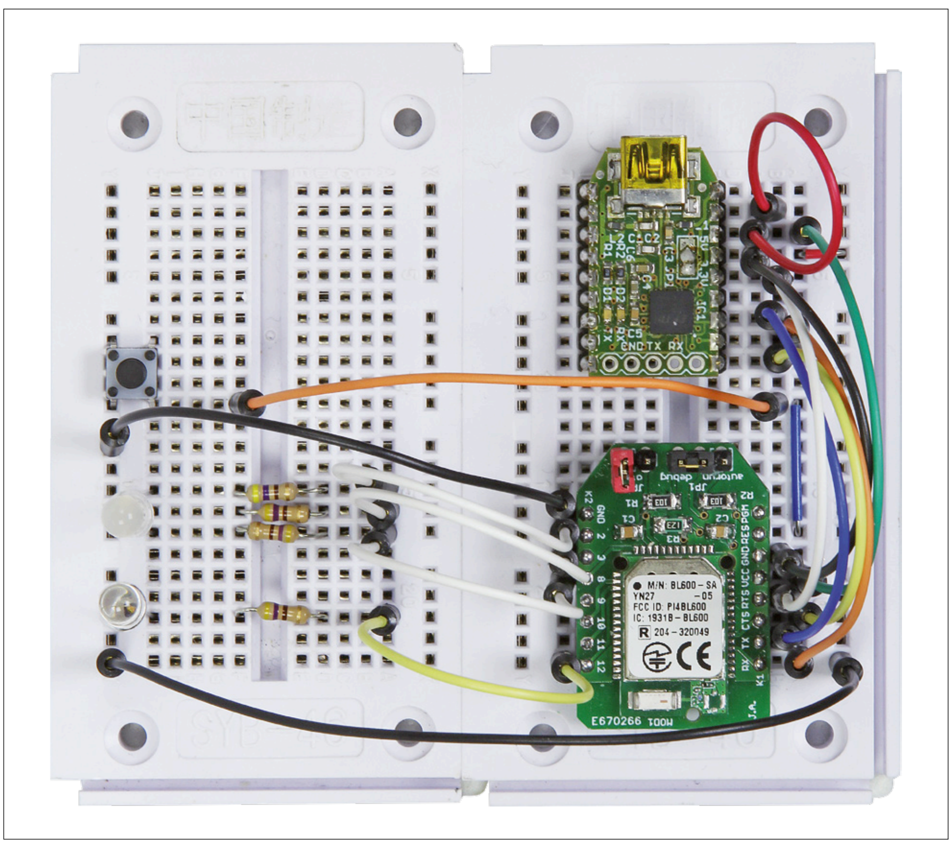


Figure 2. The circuit is easy to build on a solderless prototyping board.

```
TIMERSTART(0,10,0)
//led = 6
//TIMERSTART(1,10,0)
```

and take a look at the code in green in **Listing 1**.

When the button connected to pin 2 is pressed, an event `EVGPIOCHAN0` occurs, where `EVGPIOCHAN` represents "change of state on one of the module inputs", while 0 is the event number (chosen by us). This event is handled in the `Btn0Press` function via the instruction `ONEVENT EVGPIOCHAN1 CALL Btn1Press`. After pin 2 has been declared as an input by `GpioSetFunc(2,1,2)`, `GpioBindEvent(0,2,1)` establishes for this pin a link between the event and a transition (see below).

Declaring pin 2 as an input

`rc = GpioSetFunc(2,1,2)`
`nSigNum = 2:` pin GPIO 2
`nFunction = 1:` port as input
`nSubFunc = 2:` internal pull-up resistor
"rc" is the code returned by the function, which is 0x0000 if everything goes according to plan.

Declaring a link for an event to an input level transition

`rc = GpioBindEvent(0,2,1)`
`nEventNum = 0:` event number: **`EVGPIOCHAN0`** (the zero)
`nSigNum = 2:` pin GPIO 2
`nPolarity = 1:`0 for a Low-to-High transition
1 for a High-to-Low transition
2 for a Low-to-High or High-to-Low transition
"rc" is the code returned by the function, which is 0 if the function has not encountered any problems.

When the button is pressed, the TIMERSTART function (first parameter: **Event 1**) runs the chaser code (in blue) from output 12 to output 3. The reverse happens when the button is released, the TIMERSTART function (first parameter: **Event 0**) runs the chaser code (in mauve) from output 3 to output 12.

Three-color LED

Now you know how the events are handled, it's time to get the BL600 e-BoB to communicate with your phone via Bluetooth. The module is going to receive the phone data, via Bluetooth Low Energy, in order to light up the color(s) of the 3-color LED in the circuit in **Figure 1**. Just like the light-chaser described last

month, we're going to build this new circuit on a prototype board (**Figure 2**).

We're not going to dwell on the hardware, but will describe the basis of the program, the interception of the data, changing the colors of the LED, and the connection status.

The basis of the program

Let's start by preparing a tidy environment for your first program. You'll need to:

Copy the smartBASIC_Sample_Apps directory into your working directory, rename it (e.g. MyProjectBL600), open this directory, delete everything except the `lib` directory, `upass.vsp.sb` (an example used as the basis for our program), `UwTerminal.exe` (UART terminal software to let us compile and transfer to the module), *XComp_BL600r2_8CF9_450E.exe* (compiler specific to the module version). Then you need to rename `upass.vsp.sb` as `pgmRGB.sb` (this will be saved with the name `pgmRGB-step0.sb` in the Elektor file. You'll find the files for all the steps in this article on our website). Then you need to compile, transfer, and run the whole thing on your BL600 e-BoB as described on page 64 in last month's article.

You may recognize this screen from our UART (**Figure 3**). You can do a test again using the `Serial` application from Laird Technologies downloaded from Google Play [3] as described in the article mentioned [2]

Intercepting the data

We have a simple program, let's modify it so as to intercept the data arriving via Bluetooth from the phone. This is going to be much easier than you might fear, as we're using a library to do the work for us. We count the number of characters in order to determine the length of the string that has arrived at our module via Bluetooth and display it using the PRINT command in the UWTerminal application that has been kept open on the PC.

`pgmRGB.sb` file

Not much to it except the declaration of the variables! The program makes use of the `cli.upass.vsp.sblib` library. This version is saved with the name `pgmRGB-step1.sb` in the file that can be downloaded from the Elektor Magazine website [4].

cli.upass.vsp.sblib library

We're not going to study this file in detail, but we are going to take a moment to look at handlers and the HandlerLoop function. The data arriving at the module's UART port or arriving at the module via Bluetooth are handled by the same handler. We suggest copying these four handlers and the associated function into our `pgmRGB.sb` program.

To avoid duplicates that would cause a compilation error, let's rename our function **My**HandlerLoop. You don't need to execute this version — all you need do is verify your code by compiling it (Xcompile option).

```
function MyHandlerLoop()
  BleVspUartBridge()
endfunc 1//all events have the
   same handler
OnEvent  EVVSPRX  call
   MyHandlerLoop //EVVSPRX is
   thrown when VSP is open and
   data has arrived
OnEvent  EVUARTRX call
   MyHandlerLoop //EVUARTRX  =
   data has arrived at the UART
   interface
OnEvent  EVVSPTXEMPTY call
   MyHandlerLoop
OnEvent  EVUARTTXEMPTY call
   MyHandlerLoop
```

`pgmRGB-step2.sb` in download [4]

The `BleVspUartBridge` function sets up a loop: the phone data are sent back to the phone.

Length of received data

In order to read the phone data, we're going to replace the `BleVspUartBridge` function by `BleVspRead`:

`n = BleVspRead(tempo$,20)`

`strMsg` = tempo$: receive buffer

`nMaxRead` = 20: number of data to be read (max. 20)

n = length of receive buffer

```
function MyHandlerLoop()
   DIM n, rc, tempo$
  tempo$ = ""
  n = BleVSpRead(tempo$,20)
  IF (n > 0) THEN
   PRINT n;" data receive\n"
  ENDIF
endfunc 1
```

`pgmRGB-step3.sb` in download [4]

You can use your phone and the `Serial` application to send the data to the module. The `UWTerminal` application displays the number of characters sent (**Figure 4**), plus the end-of-line character (carriage return).

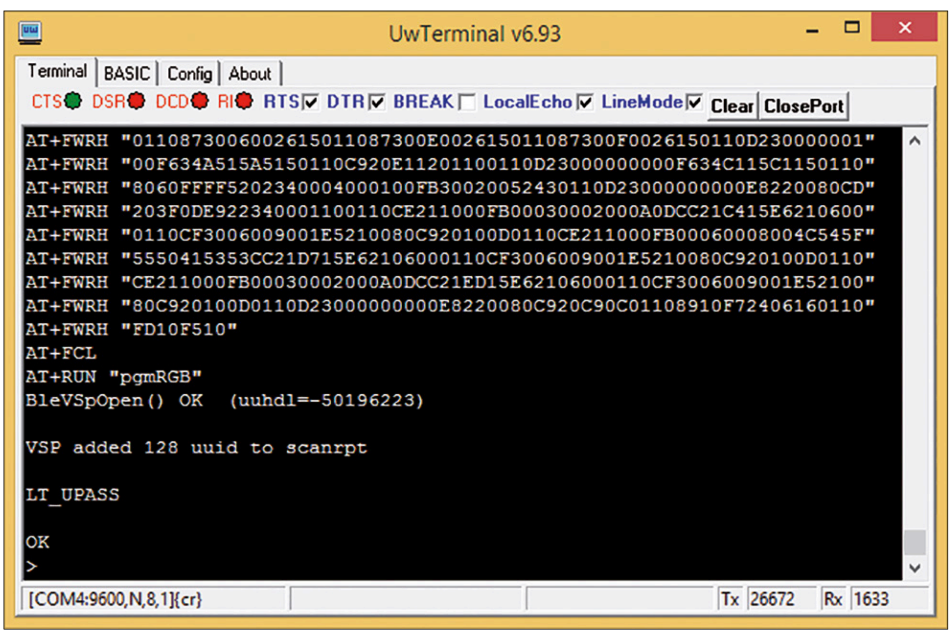


Figure 3. Message from the UART prior to our modifications.

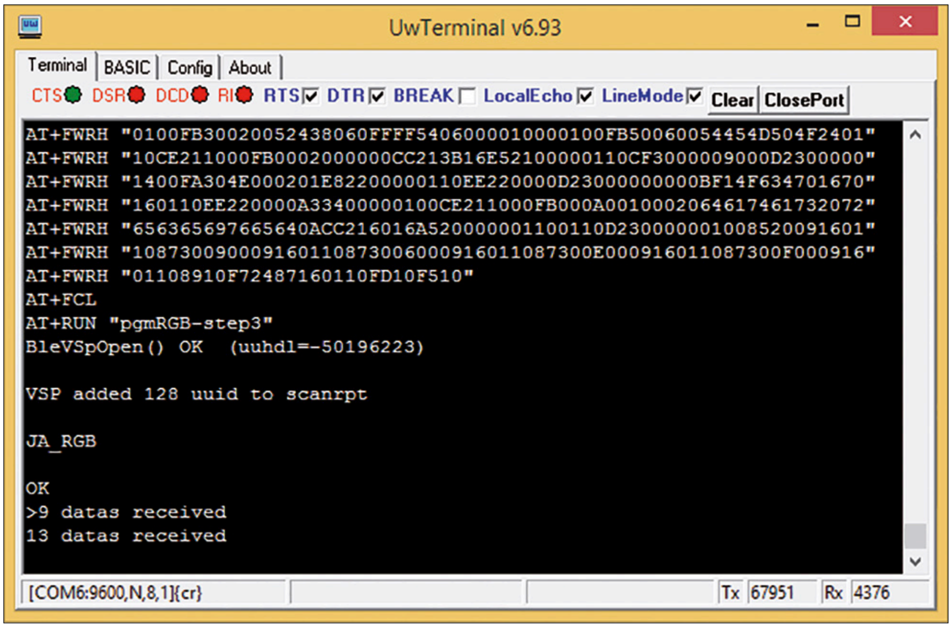


Figure 4. Display of the number of characters sent by the phone.

RGB LED colors

We know how to intercept the data received from the phone; now let's process this information in order to turn our 3-color LED on or off.

Output ports:
in the `main` section, using the `GpioSetFunc` function described in the previous article, we configure ports 2, 3 and 8 as active-low outputs.

Processing the received data: if the character R is received, the color will be red; if it's G, the color will be green; and if it's B, the color will be blue. The character string has no order, position, or length. Here's what happens in `MyHandlerLoop` e.g. for processing the color green.

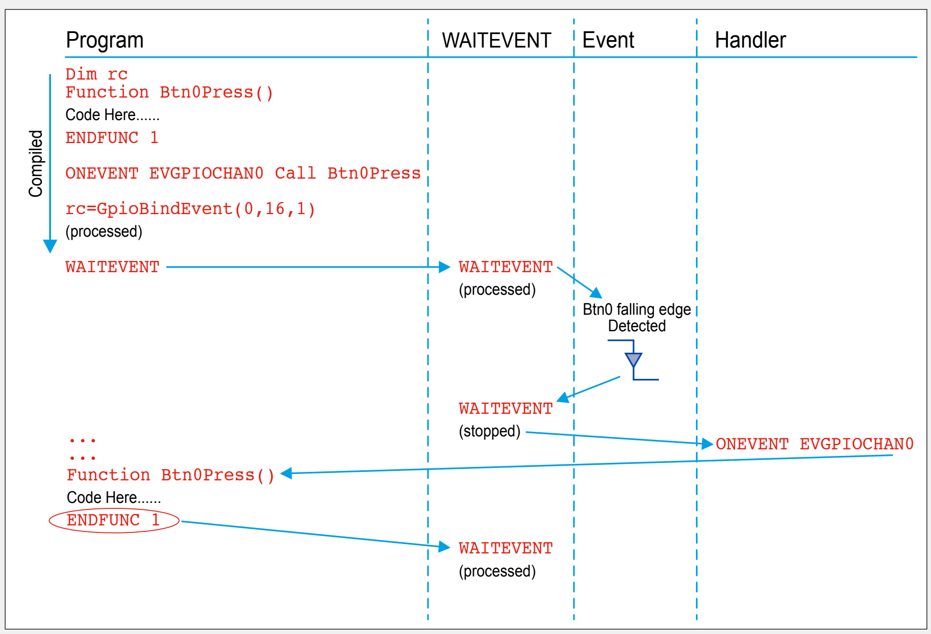
```
tx$ = "G"
pos = STRPOS(text$,tx$,0)
DbgMsgVal("G :",pos)
IF ( pos >=0 ) THEN
GpioWrite(8,1)
ENDIF
```

To avoid the Bluetooth (advertising) loop timing out, we add into our program (the `MyBlrAdvTimOut` handler) the lines – see end of the article.
In the main program:
`rc = bleadvertstart(0,Adr$,25,0,0)`

And in the list of handlers:
`OnEvent EVBLE_ADV_TIMEOUT call MyBlrAdvTimOut // TimeOut`
Watch out, you'll need to rename the handler (e.g. My…)

events and handlers in smartBASIC

smartBASIC revolves around sequences of events that are handled in turn. The `WAITEVENT` function makes it possible to wait for events to arrive. If an event is detected during `WAITEVENT`, the runtime engine checks if there is a specific handler for this event. If an event is detected during `WAITEVENT`, the runtime engine checks if there is a specific handler for this event. If yes, the runtime engine calls the function associated with this event handler. At the end of handling the function, a code is returned. If it is 1, `WAITEVENT` starts again waiting for a new event.



For example, in this program, the event `EVGPIOCHAN0` is triggered by the falling edge produced by the button `Btn0`, and associated with the `Btn0Press` function or handler with the help of the instruction `ONEVENT … CALL ….` The `Btn0Press` function is called *IF and only IF* `WAITEVENT` is running. As soon as the falling edge is detected, `WAITEVENT` proper stops, while the handler manager starts working. When the `Btn0Press` function has ended correctly (`ENDFUNC 1`), `WAITEVENT` starts up again.

In the functions:

```
//============================
// This handler is called when
  there is an advert timeout
//============================
function MyBlrAdvTimOut() as
  integer
if AdvMngrOnAdvTimeOut() == 0
  then
  DbgMsg( "\nAdvert stopped via
  timeout" )
  dim Adr$
        Adr$=""
  rc =
  bleadvertstart(0,Adr$,25,0,0)
   endif
endfunc 1
```

`pgmRGB-step4.sb` in download [4]

Using the `Serial` application from Laird Technologies, you can send orders like: R--, RGB, ---, GB-, and so on.

You can download my BLE RGB Lite program on Google Play [3]. The source code for this program (**Figure 5**) will be available on the Elektor site.

Connection status

A little bonus: we're going to light an LED on output 12 of our module when it is connected; this will be turned off when the module is disconnected. Don't forget the function for initializing port 12 as an output in the main program – you know how to do that now.

We're going to copy the Bluetooth message handler from the `cli.manager.sblib` library and create our own handler, like this:

In the list of global variables:

```
'//********************************
'// Global Variable Declarations
'//********************************
dim hConnLast
```

In the list of handlers:
(Watch out, you'll need to rename the handler, e.g. My...)

```
OnEvent  EVBLEMSG           call
MyHandlerBleMsg
```

We'll add the MyHandlerBleMsg function. When the message concerns a connection, we turn our LED on and when it involves a disconnection, we turn our LED off (code in red). Nothing very complicated:

```
function MyHandlerBleMsg(BYVAL
nMsgId AS INTEGER, BYVAL nCtx
AS INTEGER) as integer
  …… code here …..
  select nMsgId
    case BLE_EVBLEMSGID_CONNECT
      DbgMsgVal(" --- Connect :
",nCtx)
      GpioWrite(12,1)
      hConnLast = nCtx
      ShowConnParms(nCtx)
    case
BLE_EVBLEMSGID_DISCONNECT
      DbgMsgVal(" --- Disconnect
: ",nCtx)
      GpioWrite(12,0)
…… code here …..
```

`pgmRGB.sb` in download [5]

MyBlrAdvTimOut

The purpose of this handler is to re-launch the possibility for connecting to our module in Bluetooth following a timeout. To do this, we're going to copy the default handler from the `cli.manager.sblib` library and create our own `MyHandlerBlrAdvTimOut` handler. We've designed it to re-launch the advertising, i.e. the Bluetooth, via the following code:

`rc = bleadvertstart(0,Adr$,25,0,0)`

Acknowledgements:
Jennifer Gibbs (Laird Technologies); Philippe

(150129)

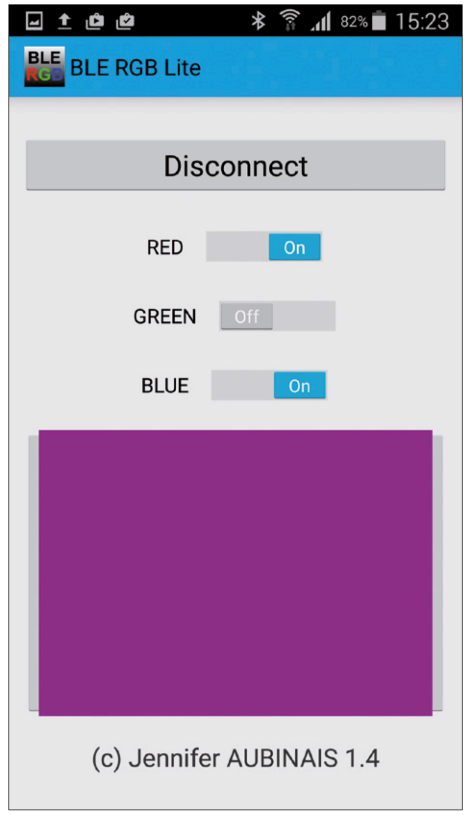


Figure 5. Screen from the BLE RGB application available from Google Play.

Selection of topics

to be covered in future episodes of this series on the BL600 e-Bob:

- Low Energy, 5 μA
- the I²C | SPI ports
- Bluetooth communication
- explanation of the remote wireless thermometer program
- writing a program for Android
- writing a program for iOS

Weblinks:

[1] https://laird-ews-support.desk.com/?b_id=1945

[2] e-BoB BL600 | Elektor no. 442, March 2015, p. 64
www.elektor.com/150014

[3] https://play.google.com/

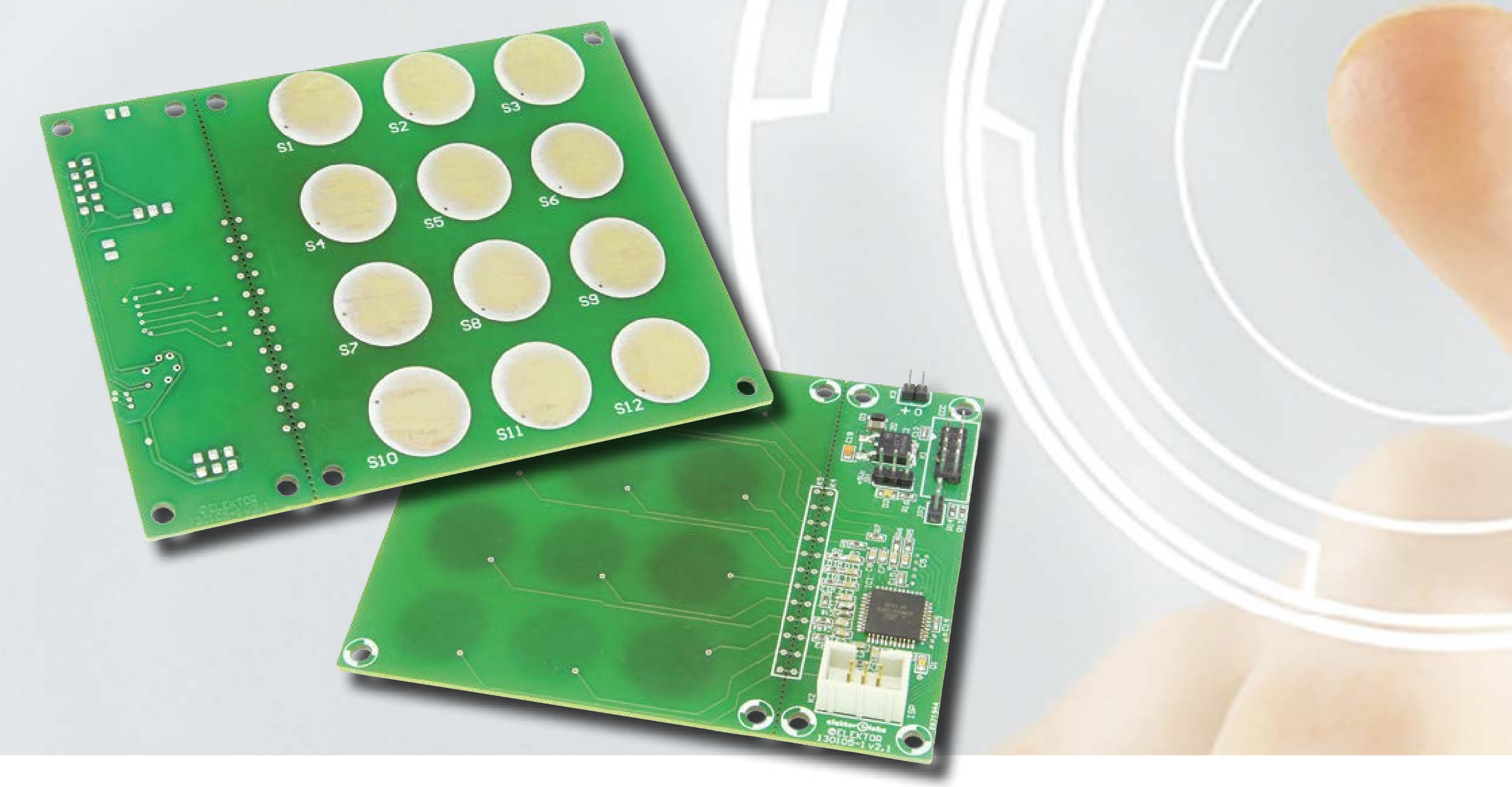
[4] www.elektor-magazine.com/150129

[5] e-BoB BL600 | Elektor no. 441, March 2015, p. 34
www.elektor-magazine.com/140270

[6] Bluetooth LE Wireless Thermometer
Elektor nos. 439–440, Jan. & Feb. 2015, p. 72
www.elektor-magazine.com/140190

Multi-Purpose 12-Key Capacitive Keypad

Vast improvement over flaky 1970's touch controls



Gloating language in a 1975 high-end A/V/TV catalog: "Now featuring Touch Control, the end of clunky switches. Instant, silent response at your fingertips! Just touch the softly illuminated surface." Back to 2015. Says Clemens: "in my student days, that #!*&% old color TV with touch control I had managed to rescue from the garbage truck changed channels spontaneously when the weather was humid, and even worse, right at the peak of excitement when my favorite club was two inches from scoring a goal."

Happy as we are those static-prone touch controls on TVs, amps and turntables have fallen into oblivion, the concept of touch keys seems to have resurfaced. Cypress and Atmel have been busy in this area for at least twenty years now and quite likely Apple's iPod with its control wheel is at the origin of the current touch sensor hype. Compared to 40 years ago, reliability has risen dramatically thanks to research, microcontrollers, and clever software.

Principles of operation

There are several types of touch sensitive sensor (a key is a sensor) based on principles including optical, magnetic, inductive and capacitive. Today however the most popular clearly is the capacitive touch sensor. Although several different ways of 'doing' capacitive sensing got developed over the past years, all measure a change in time constant of some sort of (*RC*) circuit due to a variable capacitor whose value is affected by a nearby object (like a fingertip). The result may be a change in frequency (absolute or relative) of an oscillator, or a change in the charge time of a reference capacitor. The main difference with the old-school touch keys (often based on the detection of noise or mains hum induced on a human body) is that modern touch sensors are **not for touching**; they should be **approached**. Actually we speak of touchless sensing. Because of this property they can be mounted under glass (cooking stoves, great for cleaning) or hidden to improve the aesthetics of a device. 40 years on, ergonomics strikes again.

Basically, a capacitive sensor is just a small surface of conductive material — copper in the case of a sensor on a PCB — but two-electrode sensors are possible too. The single-electrode or self-capacitance sensor is good for keys or buttons, whereas the two-electrode or mutual-capacitance sensor can also be used for position detection. Although we said earlier that capacitive sensors should not be touched directly, this is actually only true for mutual-capacitance sensors. The principle of operation is almost identical for the two configurations (**Figure 1**) but mutual-capacitance sensors offer higher precision. Depending on the system being grounded or not, the

By **Ton Giesberts & Clemens Valens (Elektor Labs)**
Derived from a project proposal by **Simon Tewes**

Introduced in the mid-seventies as the latest in ergonomic control for deluxe audio/video equipment, the touch sensitive switch (or 'key') went down the hill quickly owing to static and poor reliability. In this article we rebirth the touch key, but with 2015 technology meaning an AVR micro, clever software and a advanced board design. Time to throw in AVR micro power!

sensor capacitance change due to a nearby finger(tip) is negative or positive.

In self-capacitance sensor systems the sensor of unknown capacitance is charged to a known potential, and the (unknown) charge that results from this gets collected in a fixed-value sampling capacitor. This process is repeated several times until the voltage across the sampling capacitor reaches a preset level (**Figure 2**). The number of charge cycles needed is a measure of the sensor capacitor's value. A finger in proximity to the sensor will increase the required number of charge cycles. Mutual-capacitance sensors work likewise except that in such a system the sensor capacitor is better defined which allows for more control over the sensor.

Some restrictions

Touchless sensor design offers lots of freedom, and all kinds of shapes are possible. Also, sensors can be grouped to form a slider, a wheel or a pad where their remote sensing capacitance is used to calculate the position of an object nearby with impressive precision. Lots of freedom does not mean that you can do whatever you like though, and some restrictions apply.

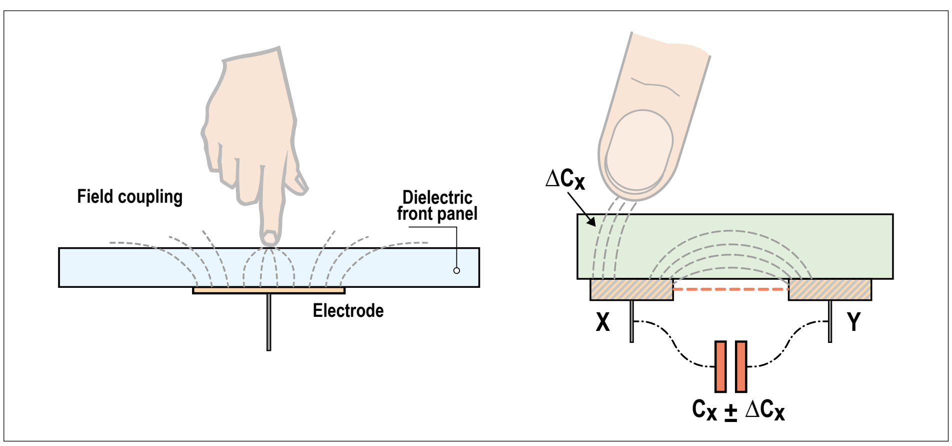


Figure 1. Principle of operation of a capacitive sensor, left shows self-capacitance, mutual-capacitance on the right. In a grounded system the change in capacitance is negative, in a groundless system, positive.

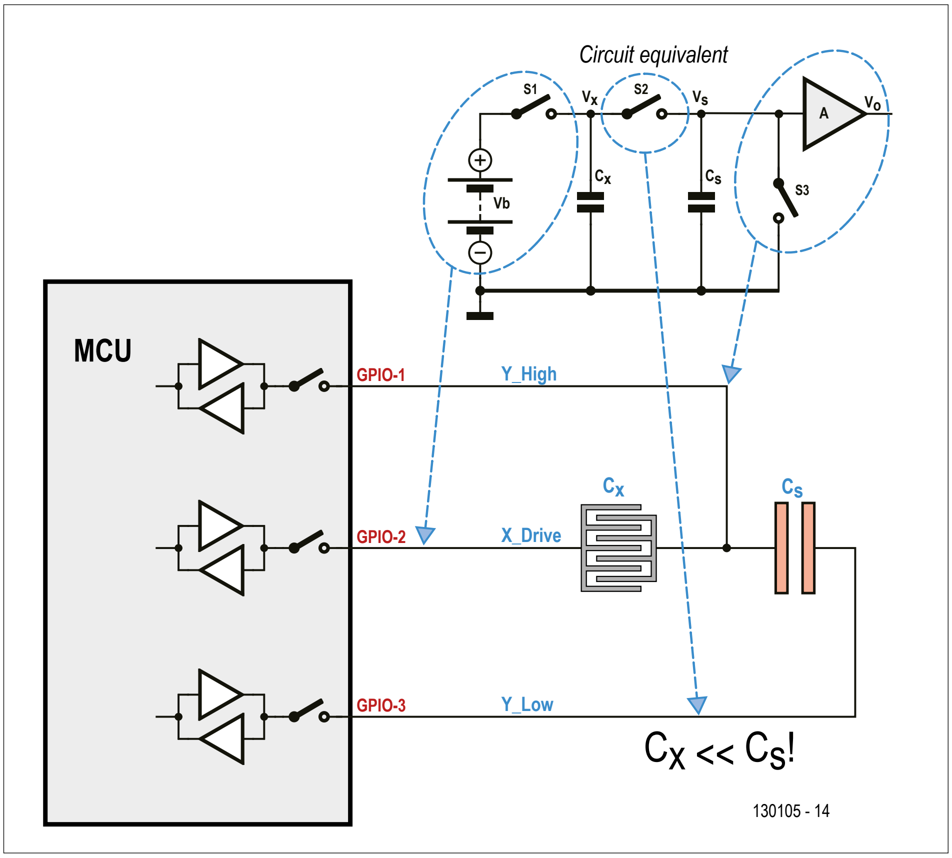


Figure 2. Reset the circuit by closing S2 and S3, then open all switches. Pulse S1 to charge C_x, then pulse S2 to transfer charge to C_s. Repeat the S1-S2 pulse cycle sequence until the charge on C_s reaches the reference level. The number of charge transfer cycles needed is determined by a finger in close proximity to sensor capacitor C_x.

First of all, the material of the panel above the sensor is especially important when using mutual-capacitance sensors as it is part-and-parcel of the sensing capacitor.

In such a system air gaps and bubbles between the panel and the sensors must be avoided. Self-capacitance sensors are not so picky.

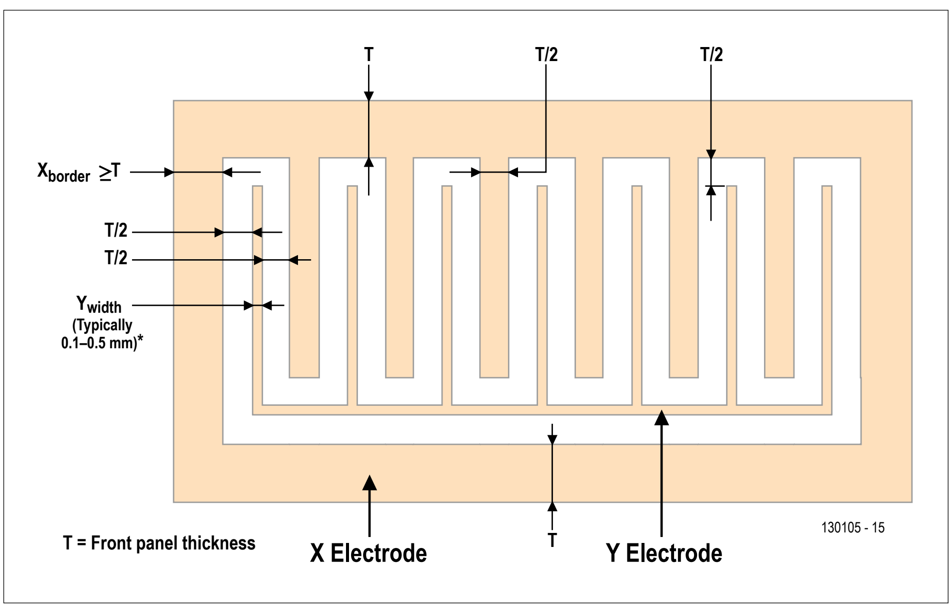


Figure 3. Mutual-capacitance sensors have more design restrictions than self-capacitance sensors.

The sensitivity of capacitive sensors is affected by nearby ground planes and traces (around, under, etc.) so care must be taken when designing a printed circuit board (PCB). This has positive aspects too, like ground traces being used to limit sensitivity in certain areas or improve noise immunity.

Mutual-capacitance sensors consist of two electrodes, a drive or *X*-electrode, and a receive or *Y*-electrode. The electrode 'fingers' are generally intertwined to maximize the coupling length. The more fingers the better the signal-to-noise ratio (SNR) of the sensor. Usually the *X*-electrode surrounds the *Y*-electrode. The *Y*-electrode must be as thin as possible without introducing too much resistance to avoid influencing the sensor time constant; the width of the *X*-electrode is mainly determined by the thickness of the overlying panel. This also holds for the distance between the *X*- and *Y*-electrodes (**Figure 3**).

Self-capacitance sensors can have any shape, but this is not usually desirable. The shape affects the sensitivity of the sensor and there is actually no real reason to decline circular sensors the size of a fingertip (back to the 70s!). Sensors do not have to be shaped as icons — other techniques may have the edge in achieving aesthetic effects.

For the exact calculations and theory of capacitive touch sensors, please refer to the application notes published by all semiconductor manufacturers proposing capacitive touch solutions.

Do it yourself

Armed with the basic knowledge on capacitive touch sensors reproduced above, let's design a capacitive keypad that can be used as an experimental platform or simply as a keypad in some equipment of your own devising. Although it's possible to implement the theory and DIY the software to make it work, we preferred to profit as much as possible from the work done by others. Atmel's QTouch technology felt like a good choice because it is supported by many AVR microcontrollers and there is a lot of documentation available. Strangely though, there do not seem to be many QTouch projects on the Internet so we felt a little solitary out there.

QTouch can handle both self-capacitance and mutual-capacitance sensors. We opted for self-capacitance sensors

because they are easy to design and use without complicated mechanical restrictions. Also, we only needed buttons and no fancy things like sliders and stuff.

When you decide to use a third-party library it is always a good idea to first read the implementation requirements. We did, and discovered that the QTouch Library imposes some restrictions on how to wire up the port pins. First of all, you need two pins per sensor (called a channel) and secondly, you cannot wire them any way you want even though every MCU pin may be QTouch compatible.

A keypad with 12 keys seemed like a good size so 24 MCU QTouch-compatible pins were needed. This corresponds to three 8-bit ports on an AVR. We also needed a communication port for sending the key presses to the host system and maybe some other I/O, so an AVR with a minimum of four 8-bit ports was needed. Since we were not too sure about how the circuit would affect the sensors we decided to make things as small as possible and went for a 44-pin SMD device. In the end we picked the ATmega324PA-AU because the library selection guide knew about it (there are also 'A' and 'P' variants, but nobody really knows what the difference is — must be one of Atmel's best kept secrets).

Atmel supports QTouch with a tool called *QTouch Studio* that can be used to assign port pins to sensors, and help by testing. Unfortunately the QTouch Studio we downloaded only worked on Windows XP (there may be a newer version as you read this). Although the configuration code it produced wasn't flawless it helped us with the hardware design. As you can see from **Figure 4** Port A is employed for buttons S9–S12, all the other buttons have one wire connected to Port C and the other to Port D. This is a compromise that renders the MCU's UART unusable (only available on Port D), but it leaves the programming port on Port B free. For lack of experience we preferred to keep the program/debug port away from the sensors. Serial communication is implemented easily enough in software anywayz.

Each sensor S1–S12 has a 1-kΩ series resistor (value not critical) and a 22-nF sampling capacitor. Note that you need good quality, stable capacitors here, X7R, X5R minimum. Do not use Y5R types. We used 0603 packages in order to keep things compact but workable.

Respecting Atmel conventions, the signal on PA1 (and similar) is called SNSK (SeNSe Key); the signal on PA0 (and similar) is the SNS signal (SeNSe).

K1 is available for connecting the keypad to a host system. This is what we call an ECC connector and it is compatible with ECC connectors found on other Elektor boards like our Arduino Extension Shield from *Elektor* July & August 2014. K2 is the program/debug connector. Thanks to voltage regulator IC2, the keypad can be powered from an external power supply from +6 to +12 V through K3 (short JP1 pins 1 and 2 with a jumper) however it is also possible to power the board via K1 (short JP1 pins 2 and 3).

K4 and K5 are not real connectors but footprints that can be used in case you decide to separate the MCU part from the keypad, probably due to mechanical restrictions imposed by the host system or the enclosure.

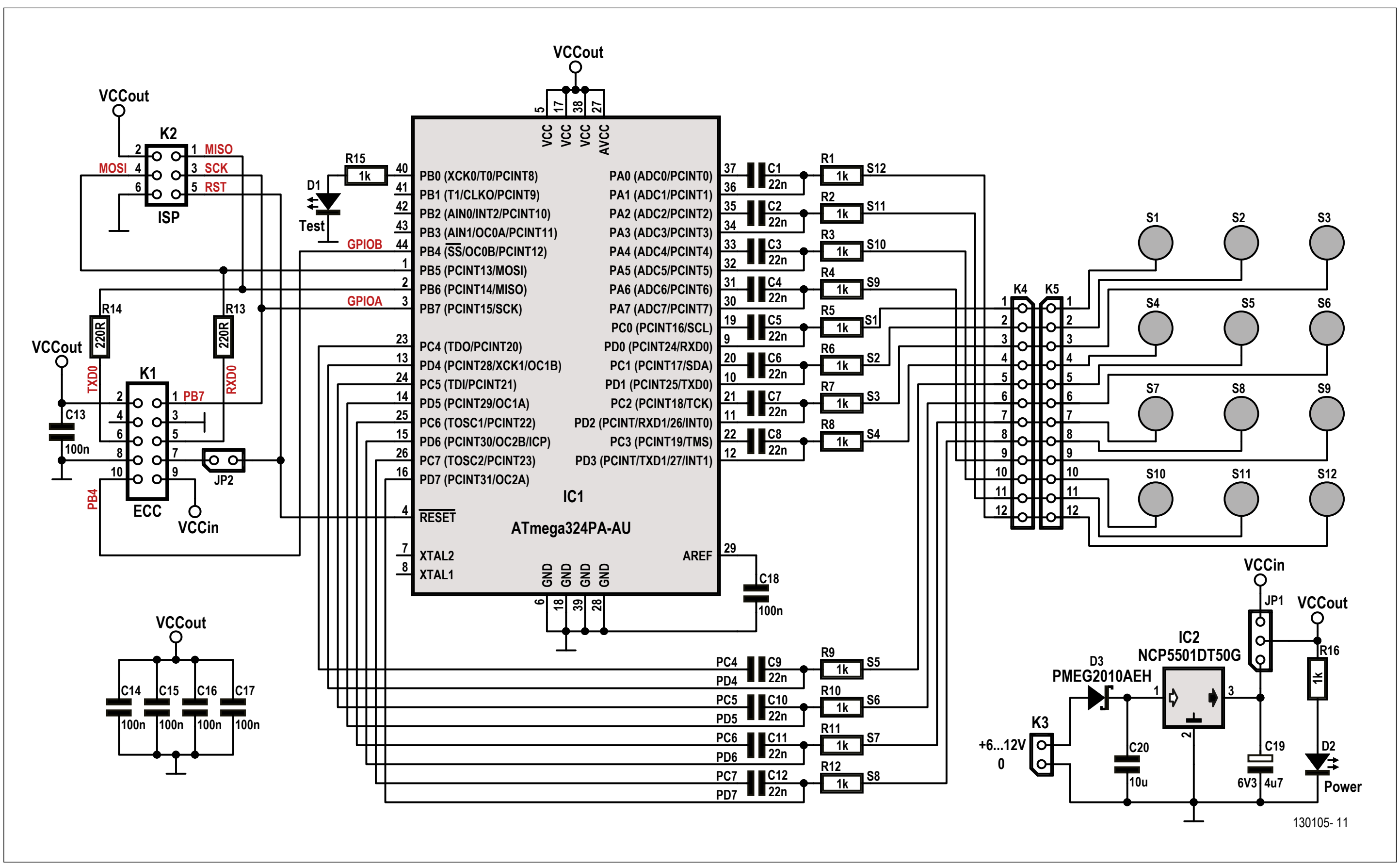


Figure 4. Schematic of our 3 x 4 (12-key) capacitive keypad with control section. Not a 10-meg resistor in sight!

LED D1 is available for debugging or signaling purposes. If LED D2 is on, the board is likely powered.
JP2 can be shorted if an external Reset signal is available on K1.
The MCU runs from its internal oscillator because timing precision is not very important — this saved us a quartz crystal.
The PCB (**Figure 5**) was designed for the sensors to be on one side and the components on the other, allowing easy mounting of the board in an enclosure. The traces from the sensors to the series resistors are as thin as possible (within reason) and placed as far away as possible from other traces and sensors. These traces are part of the sensors and consequently, sensitive to touch. The number of vias in these traces has been kept to a minimum.

Setting up the software

Now we're getting to the hard part, meaning the QTouch documentation albeit rather abundant is confusing at the same time. Also, Atmel's website gives the impression that QTouch is old hat whereas Atmel Studio proposes QTouch updates almost every week. We have QTouch for Atmel Studio installed, but have not been able to figure out how to use it. Although this probably says more about our patience than about the product, the fact remains that we had to get an old Windows XP laptop out enabling us to check with QTouch Studio that our sensor configuration was correct. So, in order to save you from pulling your hair out, here is the QTouch setup procedure in a condensed and hopefully clear form.

1. Download the QTouch library package from the Atmel website [1].
2. Extract and open the Excel sheet "Library_Selection_Guide.xls".
3. Select the second sheet QTouch (we don't do QMatrix and we don't use an ATtiny)
4. Select the MCU (ATmega324PA for us).
5. Select "Max Num Channels" (12 in our case, one channel per sensor).
6. Select "Max Num Rotors/Sliders" (0, we don't have any).
7. Select Toolchain (GCC because we use Atmel Studio).

Now only one library remains left

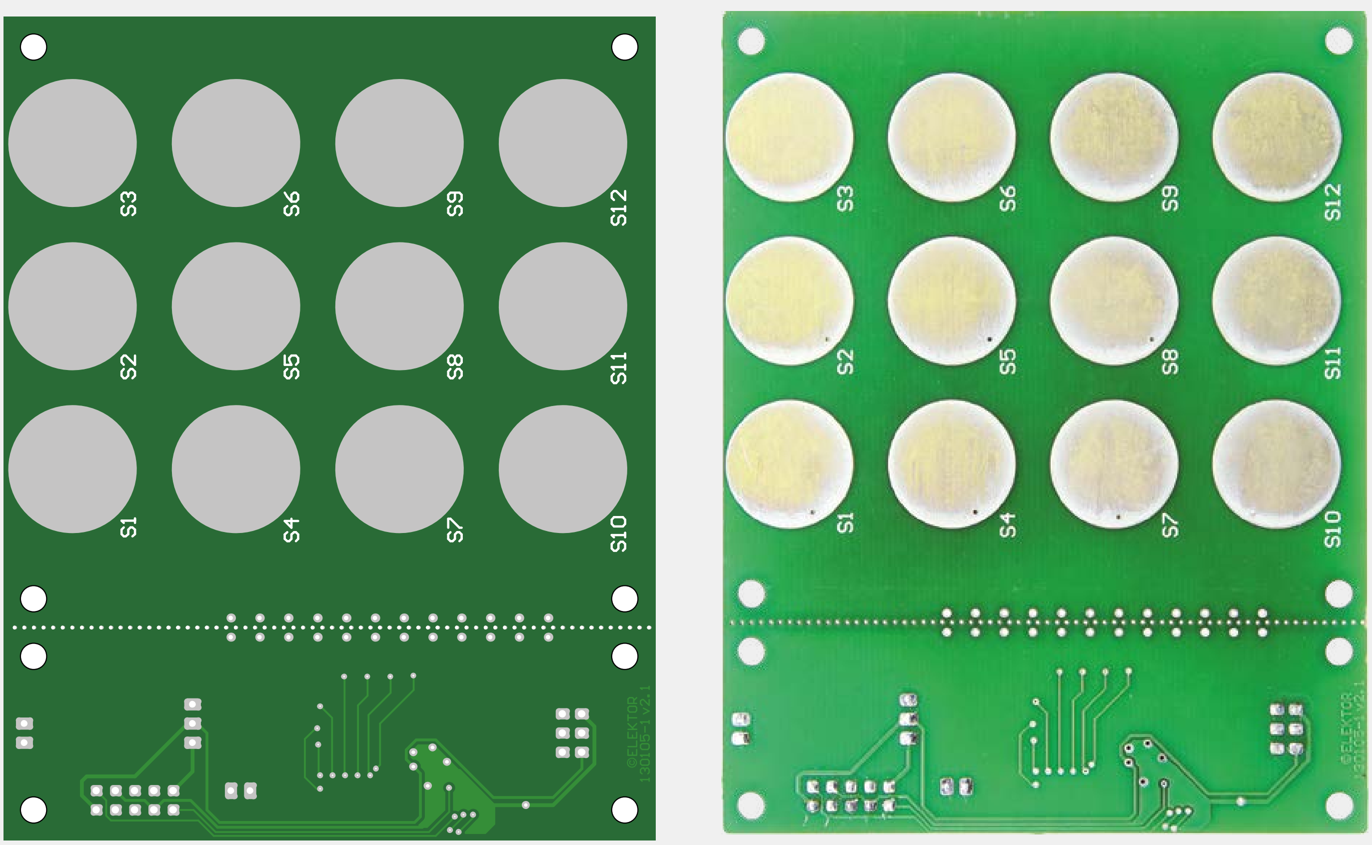
Figure 5. Double-sided printed circuit board, designed with due consideration given to all parameters and requirements for 2015-style capacitive sensing with the help of a microcontroller.

Component List

Resistors
Default: 5%, 0.1W, SMD 0603
R1-R12,R15,R16 = 1kΩ
R13,R14 = 220Ω

Capacitors
C1-C12 = 22nF 10% 50V, X7R, SMD 0603
C13-C18 = 100nF 5%, 16V, X7R, SMD 0603
C19 = 4.7µF 10%, 6.3V, SMD Case R (0805), tantalum
C20 = 10µF 10% 25V, X5R, SMD 1206

Semiconductors
D1,D2 = LED, SMD 0805
D3 = PMEG2010AEH, SMD SOD-123F
IC1 = ATmega324PA-AU, SMD TQFP-44, programmed, Elektor Store # 130105-41
IC2 = NCP5501DT50G, SMD DPAK 3



(*libavr5g1-12qt-k-0rs.a* in our case). Extract it from the download and copy it into your project workspace. You will also need some other files included in the QTouch package:

- `touch_config.h;`
- `touch_api.h;`
- `qt_asm_tiny_mega.S;`
- `qt_asm_avr.h.`

I/O port selection is the next step. We can refer to our schematic, but if you have other requirements you may have to go through this process.
Every QTouch channel (button) requires two GPIO pins for the SNS and SNSK signals. Every 8-bit MCU port can handle four 2-pin channels, but only one port is allowed to be used this way. The remaining channels should be distributed over two other ports in such a way that every channel uses one pin of each port. Within a port, pins may be freely distributed as long as you respect the preceding rules. In the simplest approach, use consecutive pins to avoid the hassle with bit masks in the software. We used port A as a 4-channel port (S9-S12) and port C & D together to handle the eight remaining channels (S1-S8).
QTouch Studio can help you find the masks and produce a tad of C source code for your project, but unfortunately it is a bit buggy and the code requires editing. It can also guide you to the library to use. Once you know how the channels are connected to the port pins you should edit the file `touch_config.h` to reflect this. Find the right section in the file (0 rotors, 0 sliders in our case) and edit (the values given correspond to our schematic):

- `QT_NUM_CHANNELS → 12`
- `NUMBER_OF_PORTS → 2`
- `SNS1 → A`
- `SNSK1 → A`
- `SNS2 → C`
- `SNSK2 → D`

Since SNS1 and SNSK1 both use port A, we should define `_SNS1_SNSK1_SAME_PORT_`. All other parameters, notably the masks because we only use consecutive pins, keep their default value.
We have bundled the microcontroller software for the project in archive file # 130105-11.zip which can be downloaded free of charge at [2].

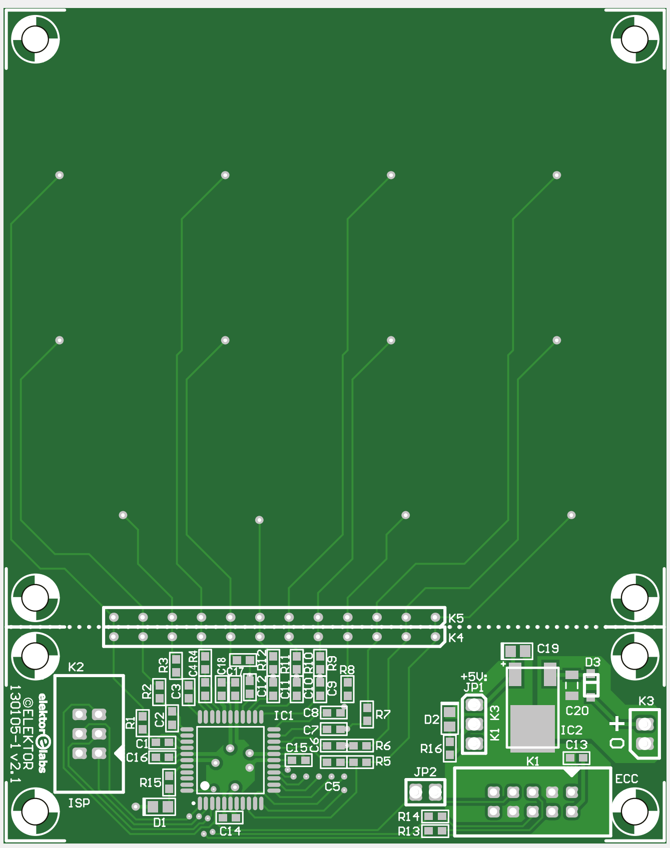
Use that library

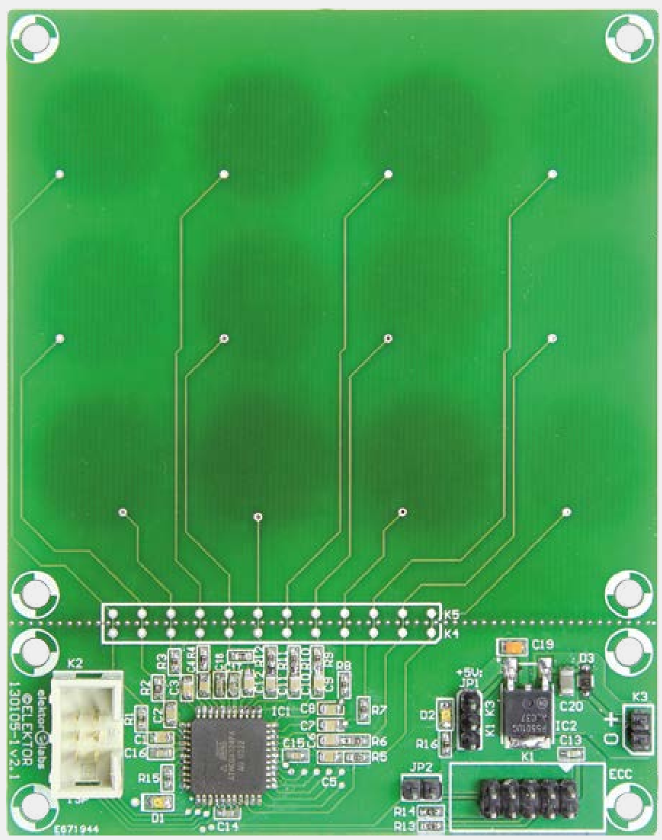
Before continuing, make sure that you have set up your Atmel Studio project properly and that the QTouch library and files can be found by the tool chain.
The QTouch documentation is not very

Miscellaneous
K1 = 10-pin (2x5) pinheader, 0.1" pitch
K2 = 6-pin (2x3) pinheader, straight, 0.1" pitch
K3, JP2 = 2-way pinheader, 0.1" pitch
K4, K5 = not mounted, leave open
JP1 = 3-pin pinheader, 0.1" pitch
Single shunt jumper, 0.1" pitch, for JP1 and JP2

Ready assembled board, ref. 130105-91 from Elektor Store

Alternatively, bare PCB only, ref 130105-1 v2.1 from Elektor Store





albeit rather abundant the QTouch documentation is confusing at the same time

clear about the clock speed of the MCU. The examples seem to be intended for 4 MHz, but the code is not consistent. Furthermore it is not clear if the clock speed is of any importance. To avoid problems we decided to run the MCU on 4 MHz by modifying the clock prescale register `CLKPR`.

The library must be initialized globally as well as for every button/channel:

- Fill in the structure `qt_config_data` (default values worked fine for us);
- For every channel call `qt_enable_key` (example values worked fine for us);
- Call `qt_init_sensing`.

Now you're ready to start sensing. Make sure to regularly call `qt_measure_sensors`. A timer firing every 25 ms is fine, we used Timer1. Inspect the returned value. If the flag `QTLIB_BURST_AGAIN` is set, you must call `qt_measure_sensors` again.

When the flags `QTLIB_NO_ACTIVITY` and `QTLIB_BURST_AGAIN` are cleared you can check the library for active buttons. The best way to do this is by inspecting the array `qt_measure_data.qt_touch_status.sensor_states`.

It is possible to detect multiple key presses at once, but our firmware defaults to one key at a time. The active key is flagged on the serial port with an ASCII string "Sxx" where "xx" is from "00" to "12". Key Up events are not being sent.

Because port D is used for QTouch channels the MCU's hardware serial port is not available. For this reason the software uses a software serial port running at 9600 baud (no parity, 8 data bits, 1 stop bit).

Experiments, hints & kinks

When you play with different materials for the panel overlying the keypad (glass, wood, acrylic plastic, etc.) remember to restart the software every time you have changed something, otherwise the system will not work properly.

Instead of using `qt_measure_data.qt_touch_status.sensor_states` to discover button states you can also call `qt_get_sensor_delta`. This function gives more detailed information, but it requires better knowledge of your hardware. Changing something in the hardware will change the delta values. These values can be very high (no overhead panel) or very low (thick overhead panel) so make sure you know the range of these values for your specific configuration.

A callback `qt_filter_callback` can be registered to filter channel measurements before they are processed. We have added a simple 4-sample averaging filter here.

Changing the default values of structure `qt_config_data` did not seem to have a lot of effect. Only the detect integration limit has a noticeable influence as it slows the system down when the limit is increased. The following commands (terminated with <Enter>) can be sent to the keypad to play with these values:

- **[i|I]** detect integration (DI) limit (default = 4)
- **[n|N]** negative drift rate (default = 20 [x 200 ms])
- **[p|P]** positive drift rate (default = 5 [x 200 ms])
- **[h|H]** drift hold time (default = 20 [x 200 ms])
- **[m|M]** maximum on duration (default = 0 [x 200 ms])
- **[r|R]** recalibration threshold (default = RECAL_50 = 1)
- **[d|D]** Positive recalibration delay DEF_QT_POS_RECAL_DELAY (default = 3)

Refer to the QTouch User Manual [3] for more details about these parameters.

(130105-I)

Web Links

[1] Atmel QTouch Library: www.atmel.com/tools/qtouchlibrary.aspx

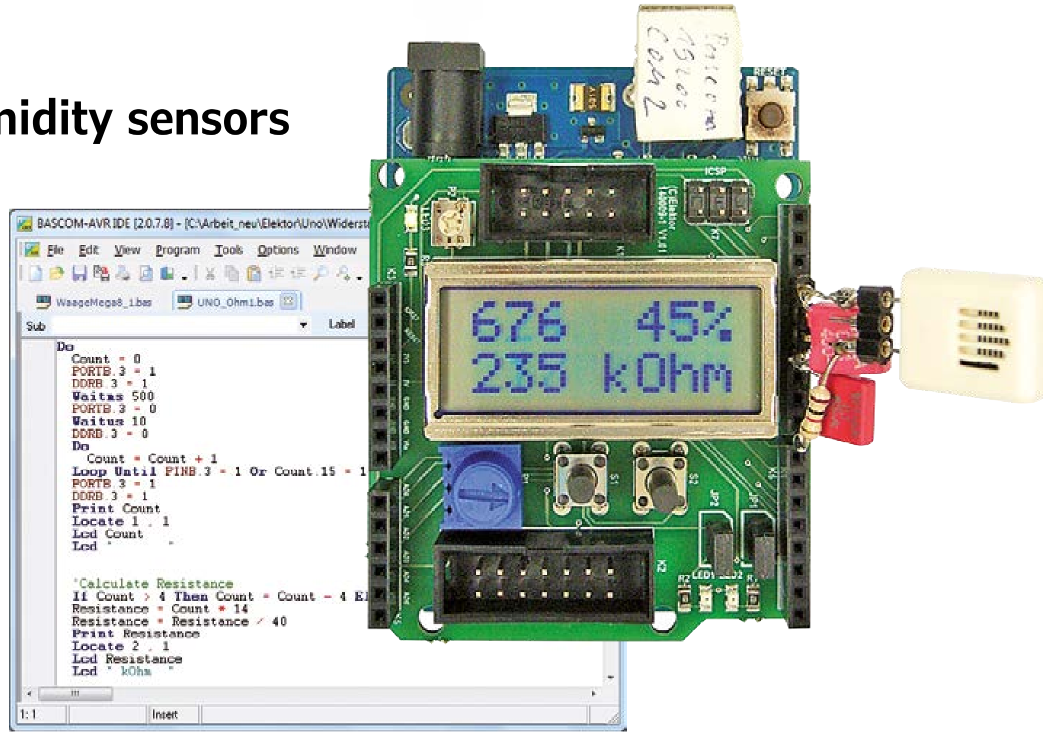
[2] Project Software: www.elektor-magazine.com/130105

[3] Atmel QTouch User manual: www.atmel.com/images/doc8207.pdf

Resistance Measurement with the Arduino

Great for testing humidity sensors

By **Burkhard Kainka** (Germany)



Next to the oscilloscope, the ohmmeter is the most widely used T&M device in the electronics lab. Using this you can measure component characteristics, trace wires, find errors in circuits and evaluate many types of sensor. But a normal ohmmeter or multimeter cannot always fulfill the demands placed upon it, for example when we need to measure alternating current (AC). This is when a microcontroller can help. Sure, another opportunity to use the Arduino Uno, our Extension Shield and Bascom!

The starting point for this project was some newish resistive air humidity sensors, whose resistance varies in the range 1 kΩ to 10 MΩ. The datasheet states expressly that they must be measured using AC. And that's precisely what a regular ohm meter cannot do.

A representative example of these resistive sensors (**Figure 1**) is the HCZ-H8A(N), which you can obtain from Farnell, Conrad, Mantech and other suppliers. The datasheet can be found here [1]. Normally these sensors are driven using an AC voltage of 1 V_{eff}. If you connect them to a signal generator using a voltage divider, you can view the result very clearly on the oscilloscope (**Figure 2**). Put your hand close to the sensor and the humidity increases; you can watch the resistance fall and the signal voltage rise at the input of the oscilloscope.

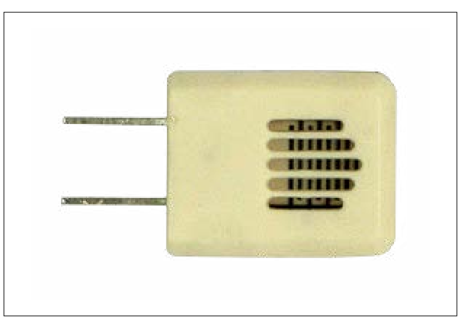


Figure 1. A resistive humidity sensor.

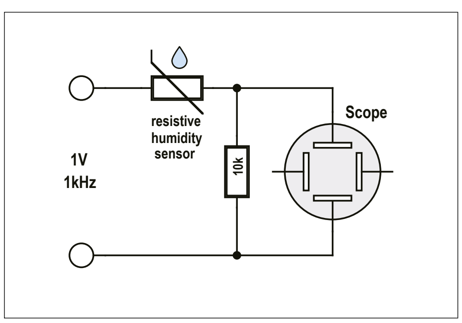


Figure 2. The first test.

Why can't you use direct current (DC) for this? The answer is all to do with polarization. Water molecules, as you probably know, have polar characteristics; in other words they are more positive on one side and more negative on the other. Gradually they will align according to the DC applied and change resistance in the process.

The same effect arises when you measure the conductivity of water; here too we must use only AC. A long time ago I even observed this effect while measuring the conductivity of wood as a function of humidity. The resistance starts off low and then rises slowly. A pair of stainless steel nails pushed into damp wood even behave something like a battery that you can charge up. In those days I was amazed. Since then, however, I found out that this is the same principle you have in dual-layer capacitors, also known as supercapacitors or GoldCaps.

Resistance measurement

How do we get round the fact that microcontrollers prefer DC? Or that handling the huge measurement range involved is no easy task for a 10-bit A-to-D converter? Consequently thoughts turned towards *R-C* elements and time measure-

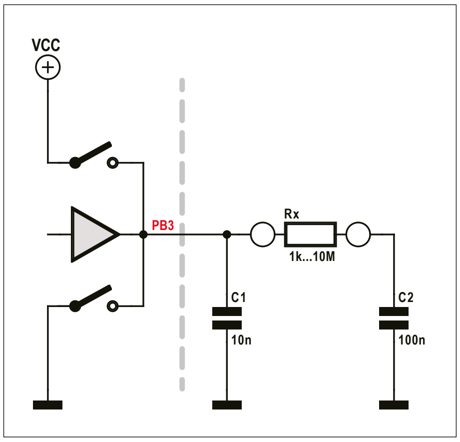


Figure 3. Resistance measurement using only one Port pin.

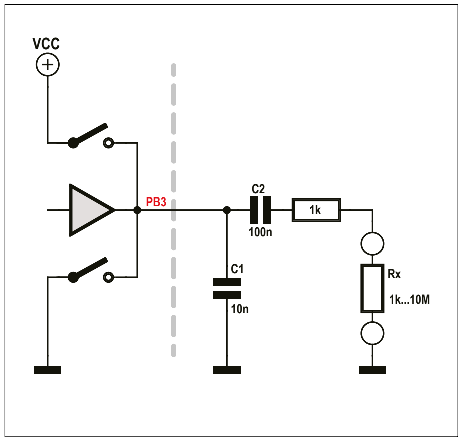


Figure 4. Optimized measurement circuit.

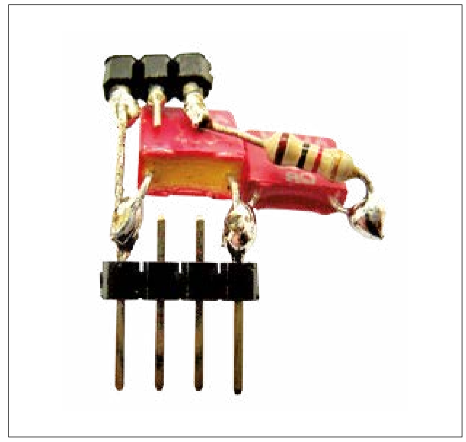


Figure 5. Mini Shield for resistance measurement.

ment. Oh yes, it would be very handy if we could get away with using only one pin of the microcontroller too. The result is the simple measurement circuit using the Port pin PB3 (**Figure 3**).

Rx and C1 form an *R-C* element, whose time constants need to be measured. C2 works in the background like a backup battery that provides the charging current required. All the same, because C2 is also charged via the resistance under measurement, the DC flowing through Rx in the middle is zero. The actual measurement process (**Listing 1**) proceeds in three phases:

1. **Charging.** The Port is connected to V_{CC} via a low resistance, so that C1 charges immediately and C2 more sluggishly.
2. **Discharging.** The Port is connected to GND very briefly, precisely long enough to discharge C1 but short enough to leave C2 retaining almost full voltage.
3. **Measurement.** The Port is configured as a high-impedance input. We then measure the time taken for the input to revert to 1 (High).

The method produces counts that are within broad limits proportional to the resistance. With the input unconnected the test result is limited to 32,768 maximum.

There is still one small problem in that measurement malfunctions with resistances of significantly less than one k-ohm. The reason is evidently that with very small resistances the larger capacitor is discharged immediately during the short discharge pulse, meaning the charging source is now lacking.

Circuit optimization

For this reason it is better to add an extra resistor of 1 kΩ in series, which you can easily subtract later on. Because Rx and C2 are connected in series, you can also change these around (**Figure 4**). This works better because the item under measurement is now connected at one end to ground. The 'no DC' rule still applies, so it's AC measurements only. The same method should be usable for resistive humidity sensors. The small number of components involved can be soldered to a piece of header connector strip (**Figure 5**), for connection to the corresponding Arduino socket strip. This makes our test adapter a kind of Mini Shield. For indicating the value measured we use once more the display on the Elektor Extension Shield [2], on which the Arduino connector strips are duplicated. When you plug the Arduino Uno, the Extension Shield and the test adapter all together, the whole combination looks like our heading photo.

Using linear conversion (**Listing 2**) we can output the resistance in kΩ. The result is not to be sniffed at: between 1 kΩ and 1 MΩ we achieve really good linearity of around 5 %. In the range up to 10 MΩ the variance is a bit larger. In any case, absolute accuracy is also dependant on the tolerances of the capacitors

Listing 1. Measuring the time to charge.

```
Count = 0
Portb.3 = 1
Ddrb.3 = 1          ' Charge
Waitms 500
Portb.3 = 0          ' Discharge
Waitus 10
Ddrb.3 = 0
Do                  'Counter
  Count = Count + 1
Loop Until Pinb.3 = 1 Or
                    Count.15 = 1
Portb.3 = 1
Ddrb.3 = 1
Print Count
Locate 1 , 1
Lcd Count
Lcd "        "
```

Listing 2. Conversion into k-Ohms.

```
'Calculate Resistance
If Count > 4 Then Count = Count - 4 Else Count = 0      ' -1 kOhm
Resistance = Count * 14
Resistance = Resistance / 40
Print Resistance             '...kOhm
Locate 2 , 1
Lcd Resistance
Lcd " kOhm  "
```

and the exact switching threshold of the input. The method is not noted primarily for great accuracy, rather for its broad measurement range and simple circuitry.

Logarithmic measurement

Resistive air humidity sensors possess more or less exponential characteristic curves (**Figure 6**). You need to measure the resistance and then express it logarithmically. For the Arduino this is an easy exercise. The calculation is carried out in several steps (**Listing 3**), in which we produce the natural logarithm in Bascom using the Log function. The following formula delivers the air humidity in percent from the value Count:

$$\text{Air humidity [\%]} = (103 - 8.9 \times \ln(\text{Count}))$$

Errors arise from a certain curvature of the characteristic line in the logarithmic scale. The values in the formula are selected so that the smallest errors occur at 40 % and 80 %. The largest deviation arises from variations among different examples of sensor, however. Calibration is costs money and plenty of simple humidity measurement devices for sale are equally imprecise.

Moreover, temperature dependency is not considered; a room temperature of 20 °C is assumed instead. Nevertheless you can see variations in air humidity very clearly. Unavoidable measurement error is due least of all to any inaccuracy in resistance measurement, since in the logarithmization process these errors merge into virtually nothing.

Listing 3. Conversion into relative air humidity.

```
'Calculate Humidity
F = Count
F = Log(f)
F = F * 8.9
F = 103 - F
Humidity = Round(f)
Locate 1 , 6
Lcd Humidity
Lcd "%        "
```

As these lines are written, it is cold outdoors and warm inside. The air indoors is fairly dry and the sensor (**Figure 7**) is indicating 40 %. That could well be right, according to one of my hygrometers. My flowers urgently need to be watered. Once I do this, the air humidity rises immediately to 41 % and after a while to 42 %. Larger variations arise when you put your hand close to the sensor. With a finger placed either side of the sensor, it shoots up to over 80 % quite rapidly.

By the way, the circuit can of course be used as an ohm meter. All values between 1 kΩ and a few MΩ can be displayed reliably (**Figure 8**).

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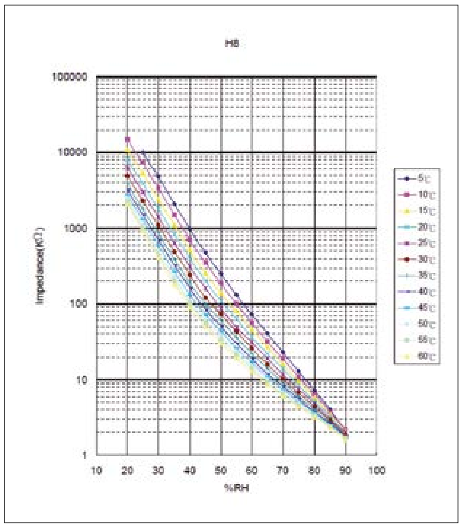


Figure 6. Sensor resistance in relation to humidity and temperature (Source: Datasheet [1]).

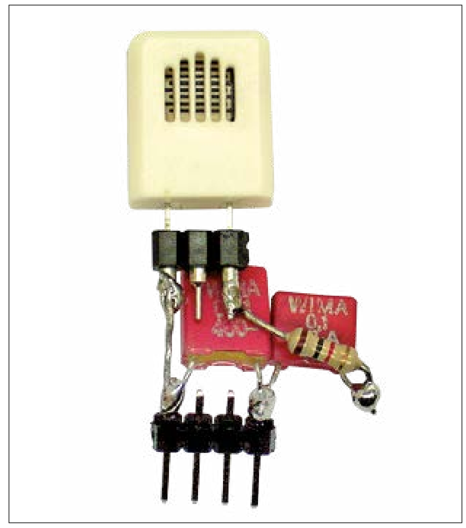


Figure 7. Mini Shield with sensor attached.

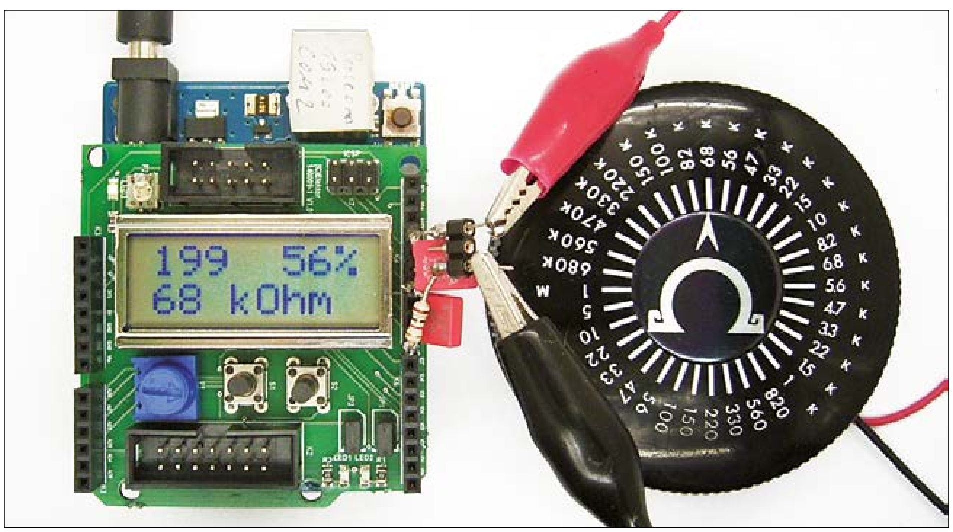


Figure 8. Ohmmeter test.

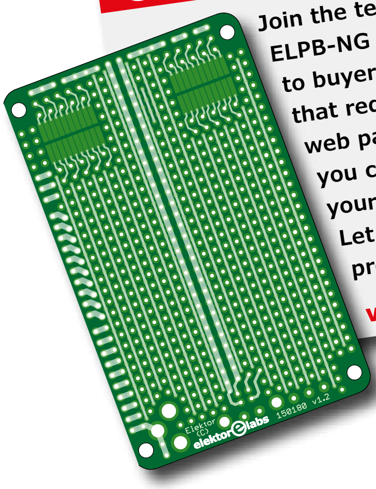
Web Links

[1] www.farnell.com/datasheets/1355478.pdf

[2] www.elektor-magazine.com/140009

ELPB-NG: Prototyping Board Revisited

perfboard is dead — long live perfboard



Get an ELPB-NG for free!

Join the test team. A few hundred ELPB-NG boards will be given away to buyers of Elektor PCBs and kits that require soldering. A special web page has been created where you can leave feedback concerning your experience with the ELPB-NG. Let us know how we can make prototyping boards even better.

www.elektor.com/elpb-ng

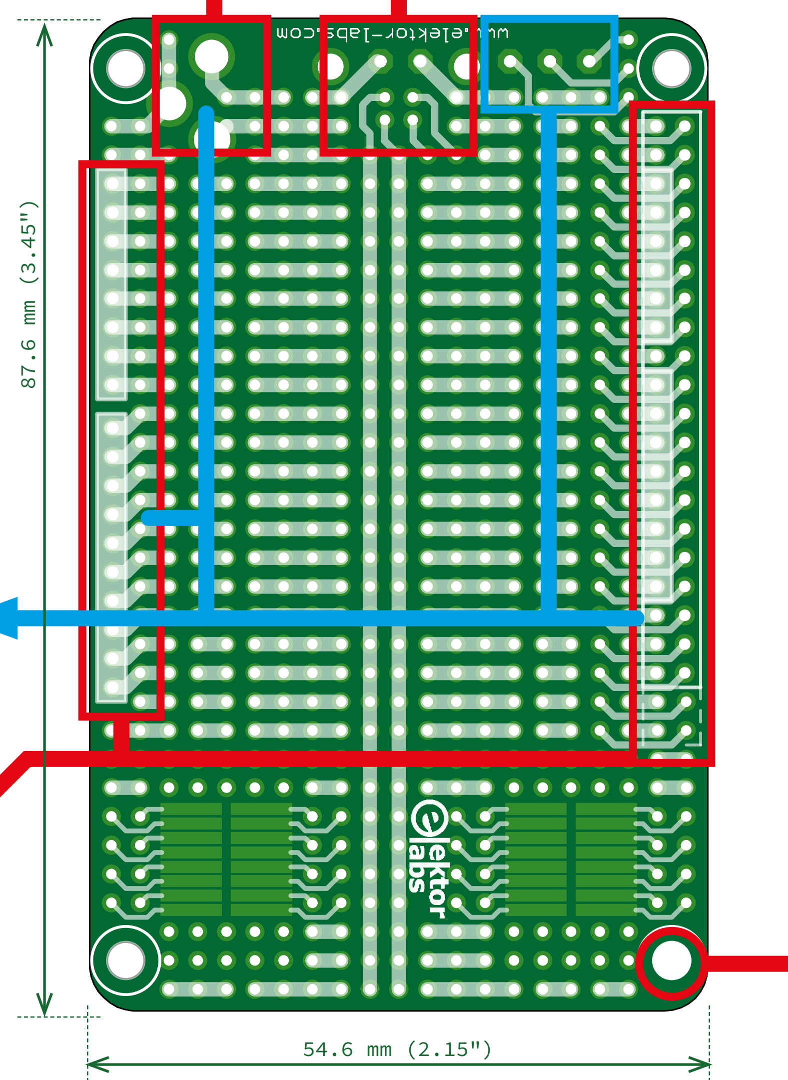
Good power

When prototyping, good connections to the power supply are especially important. That's why the ELPB-NG comes with footprints for USB-B, DC adapter barrel jack and PCB screw terminal blocks. No more croc clips that drop off or create short circuits; just mount the connector that suits you best. The ELPB-NG features two power rails for easy supply voltage distribution.

Dimensions

As Goldilocks taught us, dimensions have to be just right. The ELPB-NG measures 87.6 x 54.6 mm (3.45 x 2.15"), which is about the size of a cigarette pack, i.e. perfect for a 40-pin DIP package. Too small? No problem, boards can be stacked. Pile up as many as you need.

(Boards shown here at 150% of their true dimensions)



Connectivity

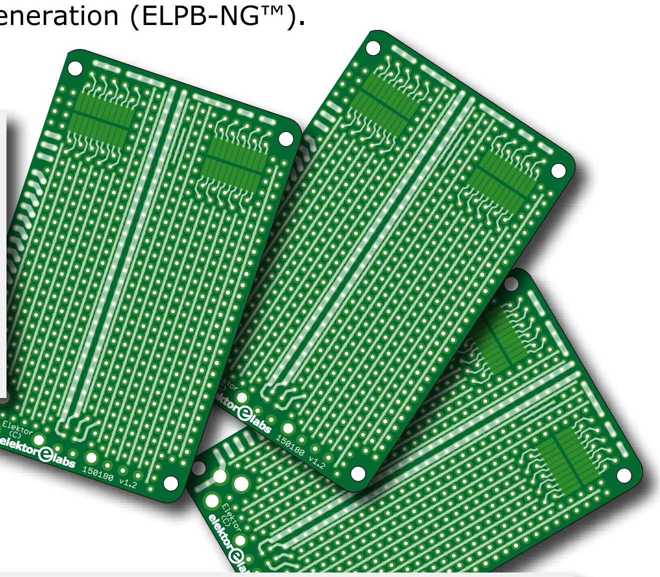
The ELPB-NG was designed with connectivity in mind. USB, Arduino, Raspberry Pi, microcontroller programmers — all are easily connected to the ELPB-NG thanks to special connector footprints with pins brought out.

Arduino & Raspberry-Pi compatible

There is no point in denying it; today's e-experimenting in many cases revolves around an Arduino or Raspberry Pi board. Therefore it is only logical that the ELPB-NG is Arduino and Raspberry Pi (2 model B) compatible.

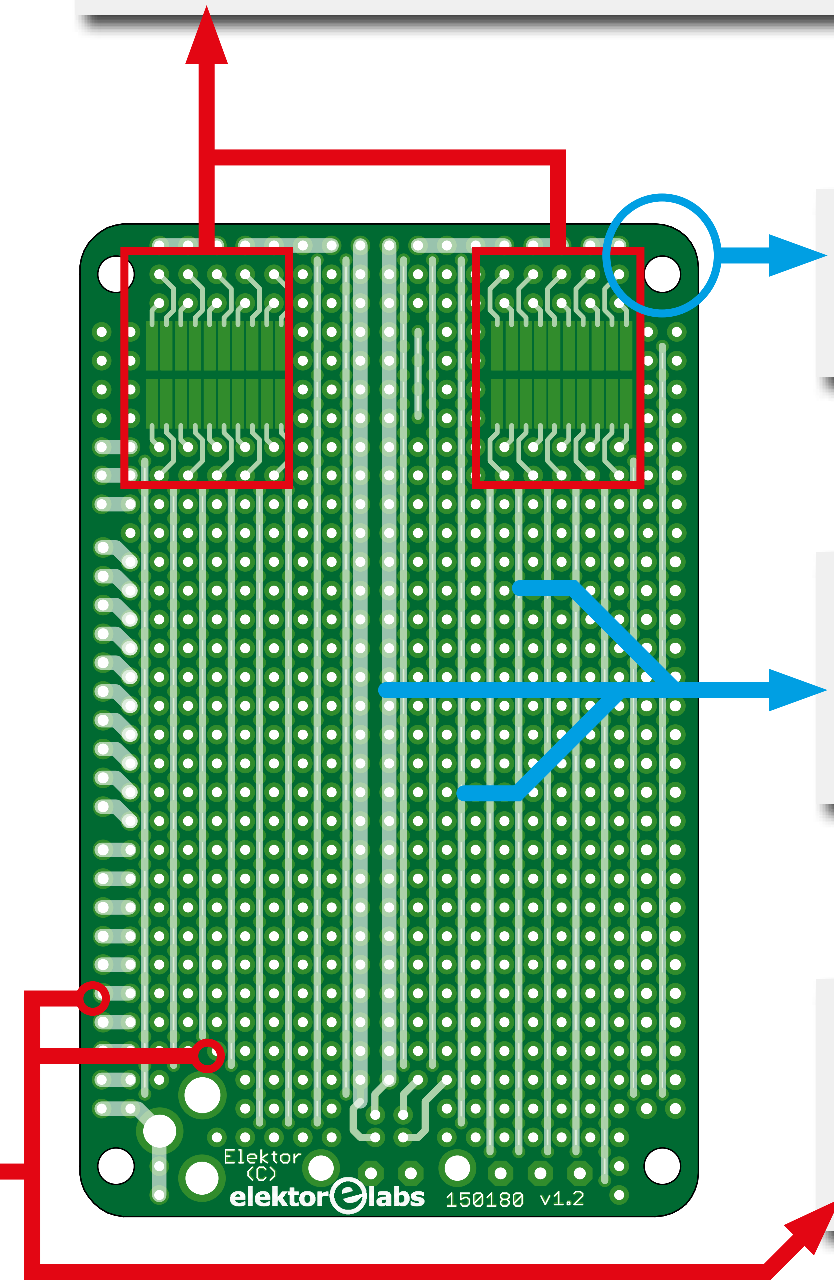
By **Clemens Valens,** Elektor.Labs

All of today's ubiquitous perforated prototyping boards (a.k.a. stripboards; veroboards) have one thing in common: they are outdated. TTL has been replaced by microcontrollers, and opamps no longer require symmetrical supply lines. While electronics keeps evolving, "perf" boards remained stuck in the previous century. At Elektor.Labs we felt it was time for a change and so, after many long months of research, we now proudly present the Elektor.Labs Prototyping Board Next Generation (ELPB-NG™).



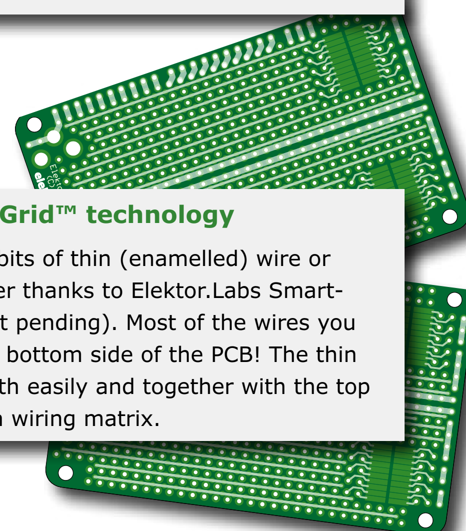
SMT

A problem with SMT footprints is their sheer variety. We combined SOIC and SOT-23 footprints into one and dropped four multi-package SMT prototyping areas on the board, two on each side. Together they allow you to mount up to 20 3-pin SOT-23 parts (or ten 6-pin), or eight SOIC-8s, or four SOIC-14s or -16s and even two SOIC-20s. Two-terminal packages like 0603, 0805 or 1206 fit here too. The SMT areas are on top of each other for creating very compact circuits.



Cutting corners

With safety and ergonomics in mind the ELPB-NG has rounded corners. Every 'corner' has a 3.2-mm (0.126") diameter hole allowing the board to be fixed easily to a supporting surface.



Elektor.Labs Smart-Grid™ technology

No more stripping small bits of thin (enamelled) wire or drawing traces with solder thanks to Elektor.Labs Smart-Grid™ technology (patent pending). Most of the wires you need are available at the bottom side of the PCB! The thin traces can be cut to length easily and together with the top side columns they form a wiring matrix.

Holy holes

A prototyping board without holes is not very practical. This is why each ELPB-NG is carefully perforated 620 times. With 548 0.9-mm (0.0354") holes plus 58 1-mm (0.0394") holes there's great freedom to mount components. The remaining holes of various diameters serve connectors.

Sort-Of Electronic Candle

By **Victor Hugo Pachon** (Colombia)

This simple circuit is a brave effort at simulating a candle flame using an LED. Generated by electronics only and using just two AA or AAA batteries the simulated flame avoids the nuisance of smoke and the dangers of a real flame, particularly if you forget to quench it before you leave the room.

The little project along the schematic in **Figure 1** consists of a small microcontroller type PIC12F675 suitably programmed to generate a PWM (pulse-width modulation) signal which powers a single LED, effectively varying the duty cycle of the signal, resulting in intensity control of the LED. To simulate a softly flickering flame the PWM drive randomly varies its value using a pseudo-random bit sequence (PRBS) values. Each signal change occurs within a period small enough to enable your spell-bound visitors to note the change in LED brightness as if staring into a little flame flickering from a whiff of air (♪ *Like a Candle in the Wind* ♪♪).

A simple little project like this probably does not need a dedicated PCB. The PIC, LED and resistor are easily fitted on a small piece of perfboard for inserting into a short piece of PVC pipe with two acrylic covers. The construction acts as thick sort-of candle which also contains the battery. Don't forget to paint the imitation candle off-white, and add some mystic symbols.

Although a big (5-mm) yellow LED from the Ancient Parts drawer is suggested, nothing should prevent you from using other LEDs with different colors like orange which also simulates a flame rather well.

Now, we start talking software. Because the light intensity and the voltage drop of an LED varies with the model, you must set the minimum and maximum levels of the PWM signal for the LED light to a minimum with the lowest value generated by the PRBS (0), and the maximum, to the highest value generated (255). The PIC

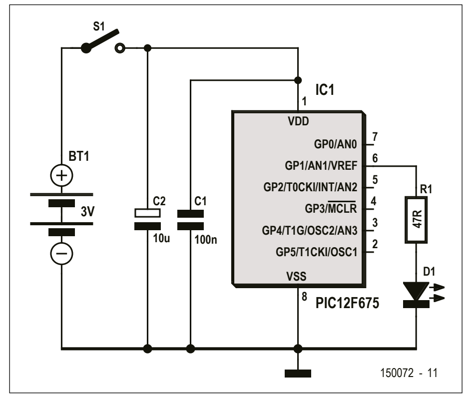


Figure 1. A strong contender for *Simplest PIC Circuit Ever*, this LED controller mimics a flickering candle flame.

firmware you can download at [1] allows the times (i.e. PWM min/max values) to be adjusted to get the proper range. In particular, it's the asm (!) code file listing you need to delve into. Also, if necessary, adapt the value of current limiting resistor R1, to get the light intensity at the desired value.

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Web Link

[1] Project software: www.elektormagazine.com/150072

http://youtu.be/JKh8L83FJV8

Cheap Accurate 12-V Battery Monitor

By **Ramkumar Ramaswamy** (India)

This little idea came about when I was pondering an accurate way of constantly measuring the voltage of each battery in my solar battery bank. A lead-acid battery's voltage remains fairly constant as it discharges. As shown in the **Table**, a no-load voltage of 12.6 volts means 100% charge but 12.2 volts means you're down to 60%. So it's desirable to have a cheap method of adequate accuracy so you can reliably keep a tab on each battery. "Cheap" suggests the many panel displays available on eBay for under \$2, but the accuracy of these is usually not better than 1-2% which sadly is not good enough. Ask for 0.1% accurate panel meters and your spend will increase dramatically.

The circuit shown in **Figure 1** allows you to go cheap **and** accurate. These panel meters typically have three terminals: GND (−); Vcc (+) and a measurement input (T). The LM4040-10 precision volt-

age reference drops exactly 10 volts with better than 0.1% accuracy, and what is left (i.e. anything above 10.00 V) is fed to the measurement terminal of a 0-10 V panel meter which then shows how your battery is doing above 10 V. If the meter reads 2.5 V, your battery is at 12.5 V. Even if a doubtful design, the meter contributes a tolerable error of 2% of 2.5 V or 0.05 V, and the LM4040 "contributes" 0.01 V maximum, so your error is not more than 0.06 V. Good enough for the purpose.
The 47-kΩ resistor ensures that the LM4040-10 is fed with at least 60 microamps required for it to work reliably. ⏮

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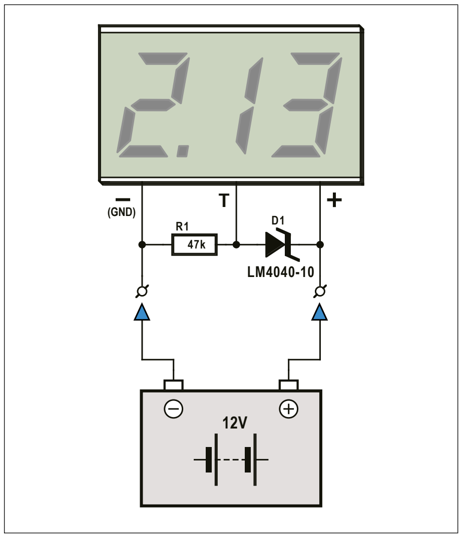

Voltage	State of Charge
12.6+	100%
12.5	90%
12.42	80%
12.32	70%
12.20	60%
12.06	50%
11.9	40%
11.75	30%
11.58	20%
11.31	10%
10.5	0%

Figure 1. Thanks to 10-V precision reference D1, an el-cheapo digital voltmeter unit can be used to monitor a 12-V battery with good accuracy.

Power Failure Audible Alarm

For RVs, motor homes and boats

By **Joachim Schröder** (Germany)

It's often little things that make outdoor living more amenable. This circuit makes it presence felt vociferously when the fixed electricity supply fails or is cut. Any skipper or RV (motor home) driver whose solar or fuel cells do not deliver sufficient mobile energy is often directed towards coin-operated power points, which are provided at many camping sites and marinas for recharging the onboard batteries. These power points are generally consumption-controlled and cut out directly once the amount of power paid for has been extracted.

Often the quantity of electricity bought is unclear and even knowing your own usage is a tough call. It can then happen that the recharging supply shuts off and instead of starting the next day replete with power, your battery needs to feed itself again.
Accordingly I constructed this small circuit, which beeps for a couple of seconds when the AC power supply fails or drops out. For the power supply (PSU) we'll use a small 5 V switch-mode power module (not shown here), which most people will have in their box of bits. All the time that AC power is present, the switch-mode PSU will cheerfully produce its +5 V. In the schematic shown in Figure 1 the chubby 1000 µF capacitor is charged via the diode D1 and the 220 Ω resistor. At the same time the 5 volts are applied via the 1 kΩ resistor to the base of the PNP transistor, so that it does not conduct.
If the AC power is cut, killing the +5 V, the transistor conducts, assisted by the 68 kΩ resistor. The capacitor now discharges through the beeper and the transistor. The beeper makes a noisy account of itself for around 5 s, depending on the capacitor value and type of sounder used (the duration can be extended of course using a larger capacitor).

The complete circuit, as seen above, can be built on a scrap of perf board (for best fit in the case) and made shockproof along with the switch-mode PSU inside a plug-in wall-wart enclosure.
As soon as you have hooked up to a coin-operated power point, you can plug this gadget into a spare receptacle (socket) in the motor home or boat and receive a timely warning when the juice fails. ⏮

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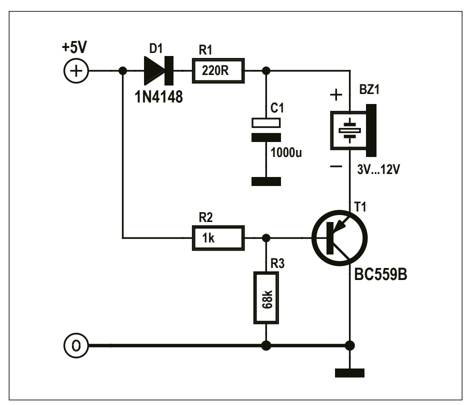


Figure 1. This small circuit is connected to a 5 V switch-mode power supply and raises the alarm when the AC power fails.

MIDI

MIDI In/Out

Once again our kitchen website at www.elektor-labs.com proves a valuable source of inspiration: original poster (OP) ‘midi-rakete’ followed up a project he had had published twenty years ago in Elektor with an updated version, the MIDI Channel Analyzer MkII [1]. In that project a set of sixteen LEDs, one for each channel, was used to indicate when communication was occurring on MIDI channels 1 to 16, for example between a controller keyboard and a synthesizer. (Note that the channels are in fact numbered from 0 to 15 within the MIDI data.) However, the unit does not show what types of MIDI messages are being sent over the wire.

I have personally become interested recently in electronic music production and find it a fascinating hobby, with some similarities to programming. Although I don’t get up on stage to perform and so don’t often have to worry about connecting various pieces of equipment together, it struck me that a small tool that decodes and displays MIDI messages could nevertheless be very handy. As luck would have it, my colleague Clemens Valens had just designed a small MIDI module for his J²B synthesizer [2]. It consists of a microcontroller with a built-in serial interface, configured to receive and transmit MIDI messages.

The MIDI physical layer

No great ‘intelligence’ is required in such a device: the MIDI signals are nothing more than data bytes transmitted serially at a fixed data rate of 31250 baud [3]. Unlike, for example, RS-232, the interface does not use defined voltage thresholds for the low and high levels that correspond to individual data bits and start and stop bits. Instead, the interface is based on a 5 mA current loop between the MIDI Out of one device and the MIDI In of another. A current flow represents a logic zero, while the absence of a current represents a logic one. **Figure 1** shows the implementation in more detail. MIDI In and MIDI Out interfaces each require two pins, and two devices are connected together using a two-wire cable. One of the output pins is permanently pulled to +5 V via a resistance of 220 Ω. In order to send a logic zero, the second output pin is taken to ground, also via 220 Ω. The result is a small current flowing through the pins of the MIDI In connector on the other device.

Analyzer

module for Arduino and friends

By **Jens Nickel**

In this article we extend the familiar pairing of the Arduino and the Elektor Extension Shield into a module offering a MIDI (Musical Instrument Digital Interface) input and output. Its Embedded Communication Connector (ECC) allows it to be connected to other microcontroller boards as well. The demonstration firmware decodes MIDI messages and shows them on a display, but the software modules we use lend themselves to a wide range of other applications.

To send a logic one, the second output pin is taken to +5 V, and then no current flows. The arrangement is therefore, conveniently enough, compatible with UARTs operating at TTL logic levels.

On the MIDI In side there is an optocoupler which includes a phototransistor. When a current flows in the MIDI cable this transistor pulls the output to ground; in the quiescent state the output swings to +5 V. We can therefore connect this signal directly to the RX input of a microcontroller.

The two connections used for input and output are almost invariably taken to pins 4 and 5 of a five-pin DIN socket on the MIDI device. Externally, therefore, MIDI In and Out connectors look identical, but of course separate sockets must be provided on any device that needs both input and output functions.

The hardware

The characteristics described above mean that it is easy to design a circuit to add a MIDI input and output to an existing microcontroller board. It will come as no surprise that I felt that the best choice for connecting the MIDI module to the microcontroller board was to use an Embedded Communication Connector (ECC). So, what we need to do is add an ECC to Clemens' circuit board and then we can, for example, simply connect the MIDI interface board to the proven combination of an Arduino Uno and an Elektor extension shield [4].

The resulting circuit is shown in **Figure 2**. On the left is the MIDI input with a type 6N137 optocoupler. The output of the optocoupler is connected to pin 6 of the ECC (K2), which will in turn be connected to the RX pin on the microcontroller. Pin 5 of the ECC carries the microcontroller's TX signal to the MIDI module, which we use to drive the MIDI output socket (K3)

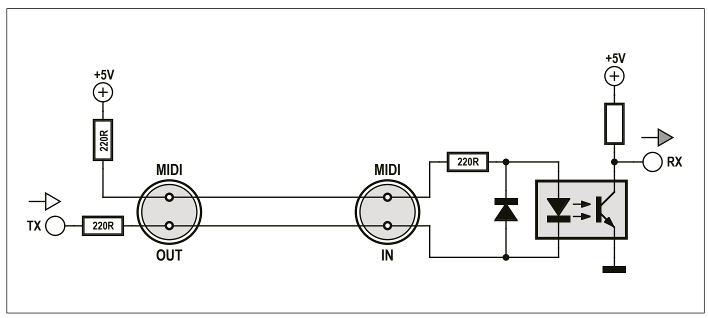


Figure 1. MIDI signals are transmitted using a current loop, where logic zero is represented by a current flowing and a logic one by the absence of a current. RX and TX can be connected directly to a microcontroller with 5 V logic levels.

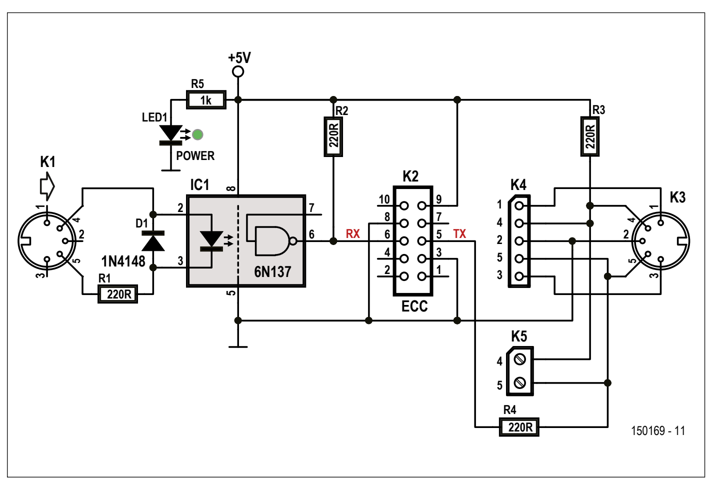


Figure 2. Circuit diagram of the MIDI In/Out module.

Component List

Resistors
R1,R2,R3,R4 = 220Ω
R5 = 1kΩ

Semiconductors
D1 = 1N4148
LED1 = LED, green, 3mm
IC1 = 6N137, DIP8 (incl. socket)

Miscellaneous
K1,K3 = DIN socket, PCB mount, 180°
K2 = 10-way (2x5) boxheader, 0.1” pitch
K4 = 5-way pinheader receptacle, 0.1” pitch
K5 = 2-way screw terminal block, 0.2” pitch
PCB # 150169-1 v1.0

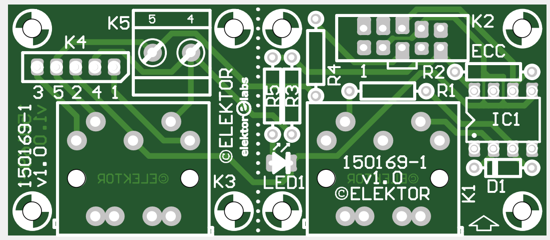


Figure 3. The printed circuit board can easily be cut into two pieces.

directly. The microcontroller board supplies power at +5 V to the circuit via pin 9 of the ECC, and an LED is provided to indicate when power is present.

Ton Giesberts of Elektor Labs has designed a printed circuit board for the module (see **Figure 3**), which is perforated to allow it to be separated easily into two parts [5]. The right-hand part can be used on its own as a simple MIDI input, while the left-hand part can be used as a MIDI output (with MIDI signals supplied at K5) or as a flexible DIN-socket breakout board, with K4 as its input. Our Elektor Labs prototype (**Figure 4**) uses a pinheader for K4, although a header socket would be a better choice to reduce the risk of accidental short-circuits.

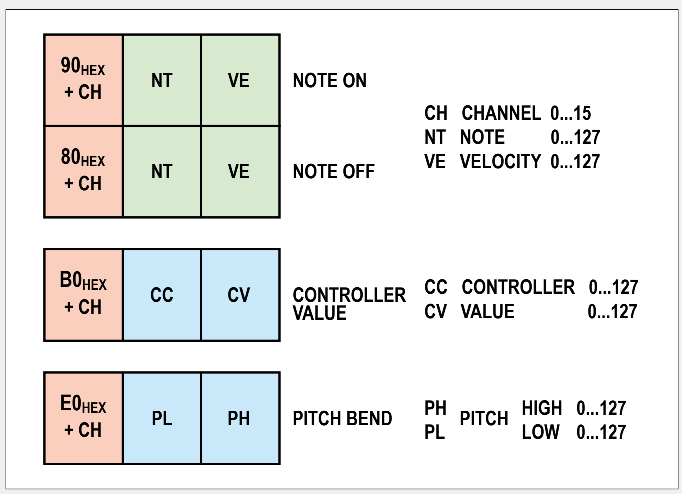
The printed circuit board is available from the Elektor Store [6], and populating it should present no difficulties.

Software

The populated MIDI module is connected to the ECC header on the extension shield using a ten-way ribbon cable, and the extension shield is in turn mounted on the Arduino Uno. The ATmega328P on the Arduino Uno can now receive MIDI bytes using its UART, but of course we need some software [6] to make our MIDI analyzer a reality. Fortunately the MIDI protocol is not too complicated (see text box). The most important MIDI messages almost all comprise three bytes, and it is easy to detect the first byte of a three-byte message. The software

The MIDI Protocol

Despite what many think, the MIDI protocol is in fact rather simple. Most MIDI messages, for example sent from a controller keyboard to a hardware or software synthesizer, consist of three bytes. The first byte comprises a command in the upper four bits and a MIDI channel number from 0 to 15 in the lower four bits. The most significant bit of this byte is always set and the following two bytes always have values in the range 0 to 127 and hence have their most significant bit clear. This makes it easy to detect the beginning of a message in the data stream; a similar very simple mechanism was used in the ElektorBus protocol.



The software for this project [6] recognizes the four most important MIDI commands. Two of these (90 hex and 80 hex) are ‘note off’ and ‘note on’ messages. The second byte encodes the pitch of the note in semitones as an integer from 0 to 127: thus twelve values cover one octave. The third byte, again from 0 to 127, is a velocity value corresponding to how quickly the key on the keyboard was pressed or released.
The command B0 hex begins a ‘control change’ message and is followed by a controller number (from 0 to 127) and a new control value (again from 0 to 127). A controller number is assigned to each of the parameters that affect the sound produced by a synthesizer so that they can be controlled over MIDI, even in real time during a performance. For example, controller number 1 is reserved for the modulation wheel found on almost all controller keyboards. More details on this can be found at [8].
The command E0 hex begins a ‘pitch bend change’ message. Fine resolution is required for this function, and so a range from 0 to 16383 (14 bits) is provided for. The second byte of the message carries the least significant seven bits of the value, and the third byte the most significant seven bits.

carries out the following tasks.

1. Initialize the UART and set the data rate to 31250 baud.
2. Store received bytes in a circular buffer under interrupt control.
3. Periodically check the circular buffer; detect a new MIDI message on the basis of its first byte; decode this byte and the two following bytes; store the decoded elements in a dedicated structure; and then call a specified function to indicate that a new MIDI message has been decoded.
4. Show the elements of the newly-received message on the display. A message will remain on the display until a new message is received (for example when the value for one of the MIDI controllers changes), at which point the display will be updated. This makes it easy, for example, to watch the effect of adjusting a controller.

The ideal situation is that we have a separate software module responsible for each of these tasks, in the interests of improving reusability, portability and ease of maintenance. Dependencies (including time-dependencies) between the modules should be kept to a minimum, and we shall return to this issue later. The Embedded Firmware Library (EFL) [7] is a natural choice for our demonstration software, as it already includes an implementation of the circular buffer and a display library, which in turn are based on board and microcontroller files for the extension shield, the Arduino Uno and the ATmega328P. Essentially all that remains is to write a small MIDI library to handle task 3 above, although as we shall see there is rather a lot hidden in that word 'essentially'.

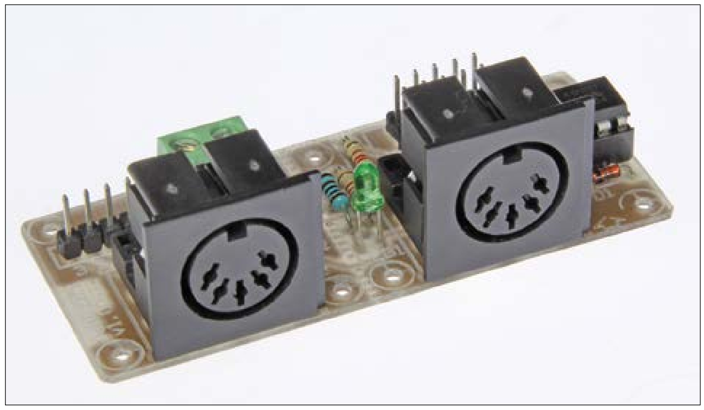


Figure 4. The Elektor Labs prototype fitted with two DIN sockets.

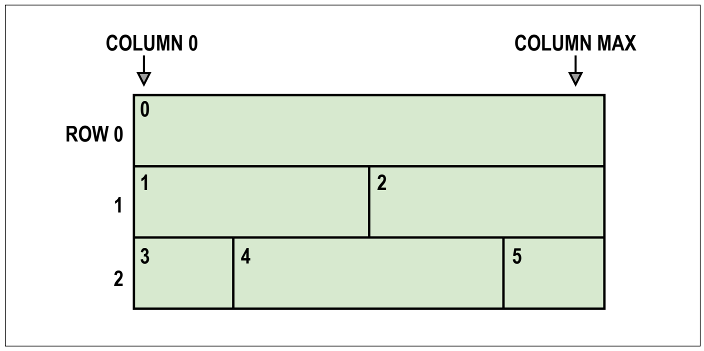


Figure 5. The extended display library allows for the configuration of fields in the display area where text and numbers can be shown. Here a three-line display is shown divided into six fields numbered from 0 to 5.

MIDI decoding

The MIDI messages are decoded in a small library called MidiEFL.h/.c. Like other EFL protocol libraries that we have described in Elektor (such as the ElektorBus library), it is designed so that it can work with a range of different physical communication channels, and so in principle it could even be used to decode MIDI messages received over a TCP/IP connection. All that matters is that the bytes to be decoded arrive in a circular buffer, whose location is communicated to the library when it is initialized as follows:

```
MIDI_LibrarySetup(UARTInterface_Send, 0,
   UARTInterface_GetRingbuffer(0), MIDIIn_Process);
```

The first parameter specifies the function that should be called when a MIDI message is to be sent. The second parameter specifies that UART interface 0 is to be used to transmit and receive bytes. (In fact there is only one UART interface on the Arduino Uno.) The third gives the circular receive data buffer, and the last parameter is a pointer to a callback function that must be implemented in the main part of the code. This function will be called by the MIDI library when a new message has been received and decoded.
The main loop of the program must regularly call the library function `MidiProtocol_Engine()`, which handles the work involved in the third of the tasks listed above.

You've got MIDI

As soon as a message has been decoded it is stored in a structure `ReceivedMidiData` of type `MidiData`. The main part of the code can obtain a pointer to this structure using the function `Midi_GetReceivedMidiData()`, and hence can access the decoded elements. In the callback function mentioned above we now have convenient access to all the elements of the most recently received MIDI message, and we can show them on the display. For example, typical code might be as follows:

```
MidiData* ReceivedMidiData =
   MIDI_GetReceivedMidiData();
Display_WriteNumber(0, 0, ReceivedMidiData->Channel);
```

This code will show the channel number of the received message in the first line of the display.

Unfortunately the EFL display library only includes commands for showing text and numbers on a specified line of the display, always starting from the extreme left of that line. The display on the extension shield has only two lines, and we wish to show four elements on it. To resolve this problem the library was extended so that it is possible instead to specify that text and numbers are shown in any one of up to eight possible fields. The fields are numbered from 0 to 7 (see **Figure 5**), and this number is called the field's 'position'. Positions can also be used to select a particular LED within an LED block or a button within a button block.

The output commands for controlling an LED (ON = 1 or

OFF = 0) within an LED block and the output of text to a specified field of the display therefore look rather similar:

```
SwitchLED             (LEDblocknumber, position,  ON);
Display_WritePosition (displaynumber,  position, “ON”);
```

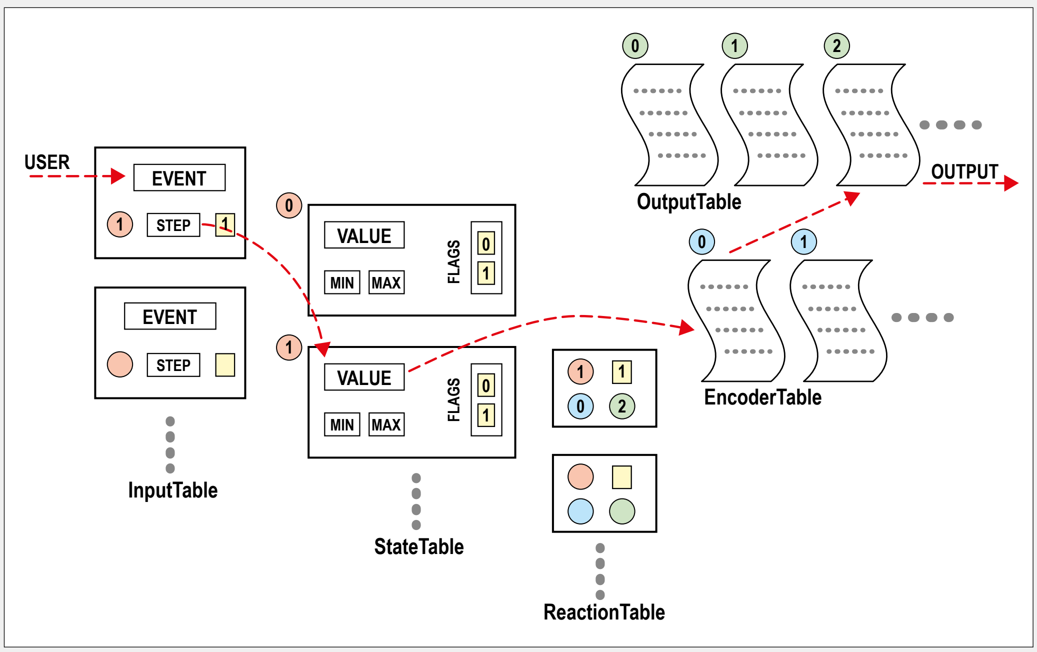
The coordinates and the extents of the fields in terms of character spaces can be specified from the main code using the function `Display_SetPosition(uint8 DisplayPosition, uint8 row, uint8 column, uint8 columnmax)`. To further simplify matters, upon initialization the display library sets up two fields on each row of the display, each occupying half the row. So in our case we have four fields, all the same size, in which we can show the four most important elements of the received message (see **Figure 6**).
To keep storage requirements to a minimum, different displays in a single system cannot be configured differently from one another, and a field is not allowed to occupy more than one row. Of course, the functions can be enhanced to remove these restrictions if required.

Flexible output

If writing to the display is implemented directly inside the function that is called by the MIDI library when it has decoded a new message, we have voluntarily created a close coupling between the two modules, in particular from a timing point of view, and this is not desirable. A better idea is not to update the display immediately. It is possible that further extensions to the software will include tasks that require higher priority: for example we might wish to log incoming MIDI bytes with timestamps, or perhaps at some point we might create a mini-synthesizer to turn incoming note messages into sounds. The solution to this problem involves making an entry in a special table (called ‘StateTable’) for each of the different MIDI

The EFL InOut library

We can illustrate the advantages of the library using a simple example. Imagine that we want to design a power supply, in which there are four application variables, or state values, called U_setpoint, U_actual, I_actual and I_max. There are input controls (such as buttons, rotary encoders or potentiometers) that adjust the values of U_setpoint and I_max, and the values of U_setpoint, U_actual and so on are to be output, for example to a display. We would like first of all to be able to run the software on different boards with a minimum of adaptation. For example one board might offer a potentiometer for setting U_setpoint while another might offer ‘up’ and ‘down’ buttons. Of course some changes will be needed to the code when we port it, but the idea is to make it as simple as possible by isolating the hardware-dependent parts of the program in the `ApplicationSetup()` function.



A second objective is to decouple from one another, both from a software perspective and a temporal perspective, the processes involved in input, changing of state values, and output. If readings of a value are taken at the rate of a thousand per second it does not make sense to update the display with each one as it arrives.
The third objective is that we would like to minimize the programming effort involved. User inputs that involve setting values always need to be validated against upper and lower limits, and the new framework should spare us the drudgery of coding line after line of ‘if’ statements.

The new EFL common library InOutEFL.h/.c maintains several tables which must be initialized at the beginning of the program. The functions `State_Add()`, `Output_Add()`, and so on are used to generate a new entry in the corresponding table; they return the index of the newly-added entry, which can then be used as a parameter when creating a new entry in another table. This approach can be compared to the wiring of a circuit board: adding table entries is like adding wires to create connections between inputs, state changes, and outputs.

At the heart of the architecture is the **StateTable**. Each entry in this table gives the current (16-bit) value of an application variable, its minimum and maximum permitted values, and up to eight flags. The **InputTable** links input events (such as the pressing of a particular button specified

elements to be displayed. Alongside the current value of each element we maintain a flag that indicates whether the value has changed since we last refreshed the display. Inside the function that is called after each MIDI message is decoded we write the new values of the MIDI elements into the StateTable. If the value does not agree with the value previously stored there, the 'STATE_UPDATED' flag is set.

We must now periodically check whether the display needs refreshing with updated values. Note that how often this is done is now independent of the rate of arrival of MIDI messages. Refreshing the display in response to changes in values is done with a call to the function `Reaction_Process()` in the main program code, implemented in a new EFL module called InOutEFL.c. The function inspects the table entries to see which have their flag set, and then for each calls the required output function. The desired output functions are given in a table called

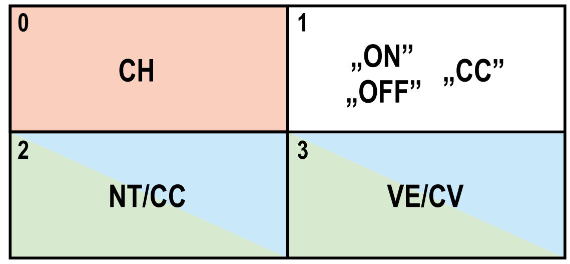


Figure 6. The various elements of a received MIDI message are shown in four fields on the display: CH=channel; NT=note (as a text string); VE=key velocity; CC=controller number; CV=controller value.

by the button block number and its position within the block) with an index in the StateTable. Alongside this is a step size by which the value of the variable is to be adjusted when the event occurs, and the flag that is to be set when the event occurs.
In the InputTable it is therefore possible to specify, for example, that when a particular button is pressed the variable U_setpoint (which might represent a target voltage in millivolts) is to be increased by 100. When the value is increased it is checked to verify that it lies within the preset limit values. If the upper limit is exceeded the value will either be clamped to the upper limit value or reset to the lower limit value, depending on the configuration. The latter alternative allows values to be adjusted in a 'wrap-around' fashion. If the value changes as a result of this process, a specified flag is set: in this case we would choose the STATE_UPDATED flag.
The **OutputTable** is the counterpart to the InputTable. It stores the output functions (which might be implemented for example in the display library) along with the block number and position of the output element. Any function can be used here as long as it has the signature:

```
functionname(uint8 blocknumber, uint8 position, int16
   numericalvalue)
```

or:

```
functionname(uint8 blocknumber, uint8 position, char*
   textstring)
```

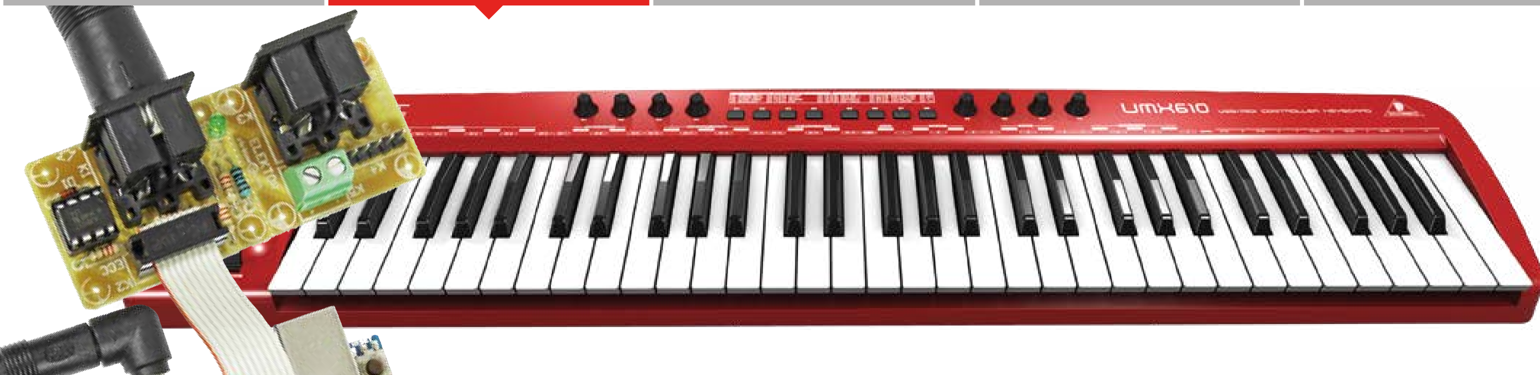
The **EncoderTable** stores encoder functions that convert numerical values into text strings. They can be implemented in any of the various EFL modules, but must have the signature:

```
char* functionname(int16 numericalvalue)
```

An entry in the **ReactionTable** links an index to the StateTable (or equivalently an application variable), a flag, an output function and optionally an encoder, all stored as indices to the respective tables. To ensure that output functions are triggered it is necessary to call the function `Reaction_Process()` regularly. This function inspects the entries in the ReactionTable and for each checks whether the flag specified to trigger the reaction that accompanies the specified application variable in the StateTable is set. If it is, the output function is called. Normally this function will either output the current value of the application variable or the result of passing it through the encoder function. Finally, the flag in the StateTable is cleared.

Continuing with our example, we could define an entry in the OutputTable to output text at position 0 of display 0. Also, we could implement an encoder function to convert a value in millivolts to a text string with the format 'x.yyy V'. This function will be added as a new entry in the EncoderTable.
A new entry in the ReactionTable can now be used to link U_setpoint, the STATE_UPDATED flag, and the indices of the entries we have just generated in the OutputTable and the EncoderTable.
Now, if we press the button and increase U_setpoint by 100 mV, upon the next call to `Reaction_Process()` the encoder function will be called and then the text will be written to the display. Altering the code to use the Continental European-style comma instead of the decimal point is easy: we simply write a slightly modified version of the encoder function, add it to the EncoderTable, and then change the corresponding index in the ReactionTable. This can be done even while the program is running, for example if we wish to allow the user to change the language of the user interface.

There will be more on the EFL InOut library in a future edition of Elektor.



OutputTable that must be set up in advance. A third table, called ReactionTable, links the two others, ensuring that there is an output function associated with each value that might change. It is also possible to provide an index into a fourth table, called EncoderTable. An example will help explain the interrelationships between these tables, and we will now look at how a received MIDI note value is processed.
At the beginning of the program we set up some table entries as follows.

```
S_MidiIn_Note  = State_Add(0, 0, 127,
   STATE_MINMAXMODE_OVERFLOW);
O_Write_Pos2   = Output_Add(Display_WritePosition, 0,
   2);
E_Midi_Note    = Encoder_Add(Midi_NoteEncode);

Reaction_AddOutput(S_MidiIn_Note, STATE_UPDATED, O_
   Write_Pos2, E_Midi_Note);
```

When a new note value (which must be in the range from 0 to 127) is received it must be written to the StateTable and the STATE_UPDATED flag must be set. This is implemented in the callback function as follows.

```
MidiData* ReceivedMidiData =
   Midi_GetReceivedMidiData();
State_Update(S_MidiIn_Note, ReceivedMidiData->Note);
```

The function `Reaction_Process()` is periodically called in the main loop, and the function checks whether the flag is set. If it is, then the encoder function that has been configured to handle the value is called: in this case the encoder function is `Midi_NoteEncode()`, which is implemented in the EFL MIDI library. This function takes the note value from 0 to 127 as a parameter and converts it into a string such as 'C#4'. This string is in turn passed as a parameter to the configured output function `Display_WritePosition()`, which writes the text to position 2 on display 0.
The behaviour of the software can be modified simply by changing table entries, even dynamically while it is running. For example, the user interface language could be changed simply by changing the table entry for the encoder function.

Hardware independence

We have brought the degree of hardware independence and modularity of EFL applications to a new level. At the start of the program in the `ApplicationSetup()` function all we need to do is suitably initialize our tables, and then everything will be taken care of and the various modules are kept decoupled from one another. We can easily port the firmware to another board, where for example we might want to use display 1 rather than display 0 to show the MIDI data, or we might want to change the positions where the various elements are displayed; another possibility might be to output the decoded MIDI elements over a (different) UART instead of showing them on a display; and yet another might be to visualize keyboard velocity information using the brightness of an LED. All these can be implemented with simple modifications to the setup code, leaving the rest of the program unchanged.

In a future article we will expand this project to include user input. The **text box** 'The InOut Library' gives an outline of the idea. Watch this space!

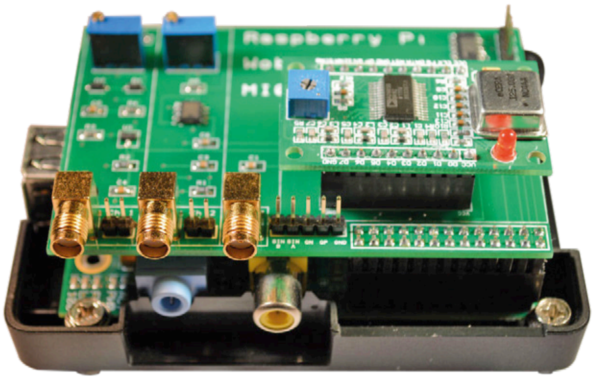
(150169)

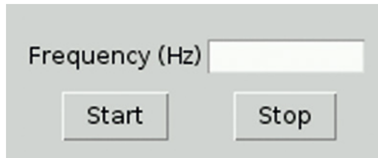
Internet Links

[1] www.elektor-labs.com/project/midi-channel-analyzer-mkii-140065-i.13380.html
[2] www.elektor-magazine.com/140182
[3] http://en.wikipedia.org/wiki/MIDI
[4] www.elektor-magazine.com/140009
[5] www.elektor-labs.com/project/150169-midi-analyzer-light.14481.html
[6] www.elektor-magazine.com/150169
[7] www.elektor-magazine.com/120668
[8] www.midi.org/techspecs/midimessages.php

A Raspberry Pi Wobbulator

With AD9850 DDS and AD8307 Log. Detector





By **Tom Herbison,** MI0IOU (United Kingdom) Twitter: @TomHerbison

The Raspberry Pi computerette harnesses so much connectivity it's just crying out for extension circuits to make it do unusual things. This Reader's Project covers the evolution of an RPi and a purpose designed extension circuit into a DIY RF sweep generator, or 'wobbulator'. The project started out at elektor-labs.com and went through the full Learn, Design, Share cycle.

As you can see in **Figure 1**, a wobbulator (or 'sweep generator') is a piece of test equipment which is used in conjunction with an oscilloscope to measure the frequency response characteristics of an (RF) circuit. It uses a "ramp" or "sawtooth" function generator connected to a voltage controlled oscillator (VCO) to produce an output sweep over a defined frequency range. The response characteristics of the circuit under test — usually a filter or an amplifier — can then be displayed on an oscilloscope. A wobbulator is a useful tool for aligning the intermediate frequency (IF) stages of superheterodyne receivers, but can also be used to measure the frequency response characteristics of RF filters and other circuits.

One of the great things about a wobbulator is its direct presentation of the filter or amplifier response curve, allowing you to see specifications like the 3-dB roll-off points, slope steepness, and in-band ripple, "live" on the screen as you tweak the circuit under test. Multi-stage RF passband and notch filters especially are a joy to 'wobble' into shape with instant visual feedback on their response. It's like drawing the curve in small steps and can keep you busy for hours to get the textbook shape.

The Plan

While in the dim past a wobbulator was a complex, expensive all-analog instrument (even with vacuum tubes), today we have little computers like the RPi to do the job with simpler hardware when it comes to control, and with the luxury of software, which can be changed and optimized for best results.

The Raspberry Pi Wobbulator implements the functionality of a conventional wobbulator by using a Raspberry Pi computer, a Direct Digital Synthesizer (DDS) module and an Analog to Digital Converter (ADC) module. The Raspberry Pi's General Purpose Input Output (GPIO) interface is programmed to control the DDS module to generate the frequency sweep and to communicate with the ADC module to measure the response of the circuit under test. The Graphical User Interface (GUI) allows the user to choose the parameters for the frequency sweep and also displays the results.

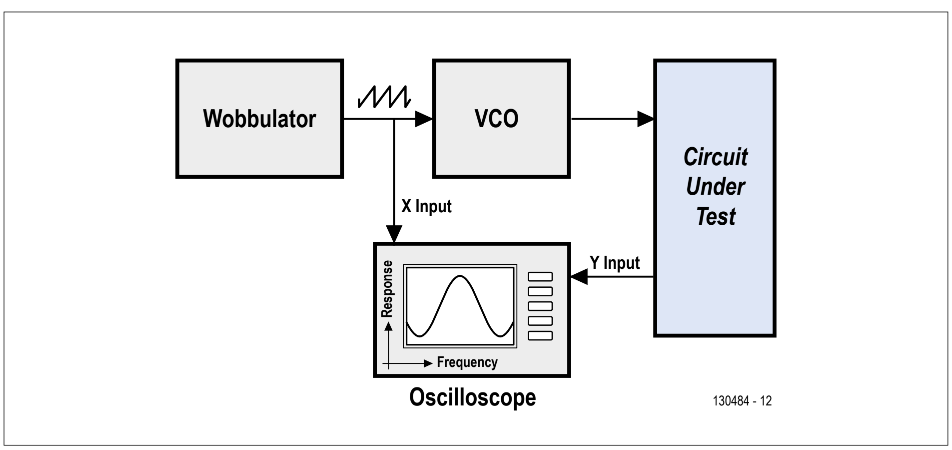


Figure 1. Basic operation of a wobbulator, also known as a sweep frequency generator.

The Circuit

Figure 2 shows the latest version of the RPi hardware extensions that together form the wobbulator.

Initially the wobbulator had a single input amplifier/buffer followed by a rectifier to display the linear response of the circuit under test. As the project evolved this circuit was extended with a logarithmic amplifier for a dBm readout on the Y scale. The LIN amplifier was retained though, here it is seen around FET U1, with diodes D1 and D2 doing the RF rectification.

The LOG amplifier is contained for the most part in integrated circuit IC1, an AD8307ARZ, which was an instant hit among radio amateurs when it appeared on the market a few years ago.

The selection between the LOG and LIN output signals is done with the aid of IC2, a Type MCP3424 four-channel differential-input 18-bit (max.) Sigma-Delta A/D Converter [1] which is essentially an I²C Slave. Via its SDA and SCL pins the 3424 listens to I²C commands and data received from the RPi's GPIO port, which is the I²C Master here. The SDA line also carries the measured 'Y' signal (LOG or LIN) in digital form, so the RPi can do the math and then the displaying on an HDMI TV or monitor, like your CRT 'scope did in the past. CH3 and CH4 on the 3442 are not used here and avaiable for your extensions, they are grouped on a connector.

Early versions of the wobbulator were built on an Adafruit extension board which plugs straight on the RPI. This board took most of the wobbulator parts and the DDS module with its 20-way connector.

The DDS module (**Figure 3**) is based on the AD9850 frequency synthesizer chip and is available from a number of suppliers on eBay. Tom also sells them. Like the MCP3424 the DDS module operates under control of the RPi, which issues all control words necessary for a swept-frequency output signal that appears on the RF OUT connector. This signal is fed to the circuit under test, while the output of the circuit under test goes to the LOG or LIN input, depending on the application.

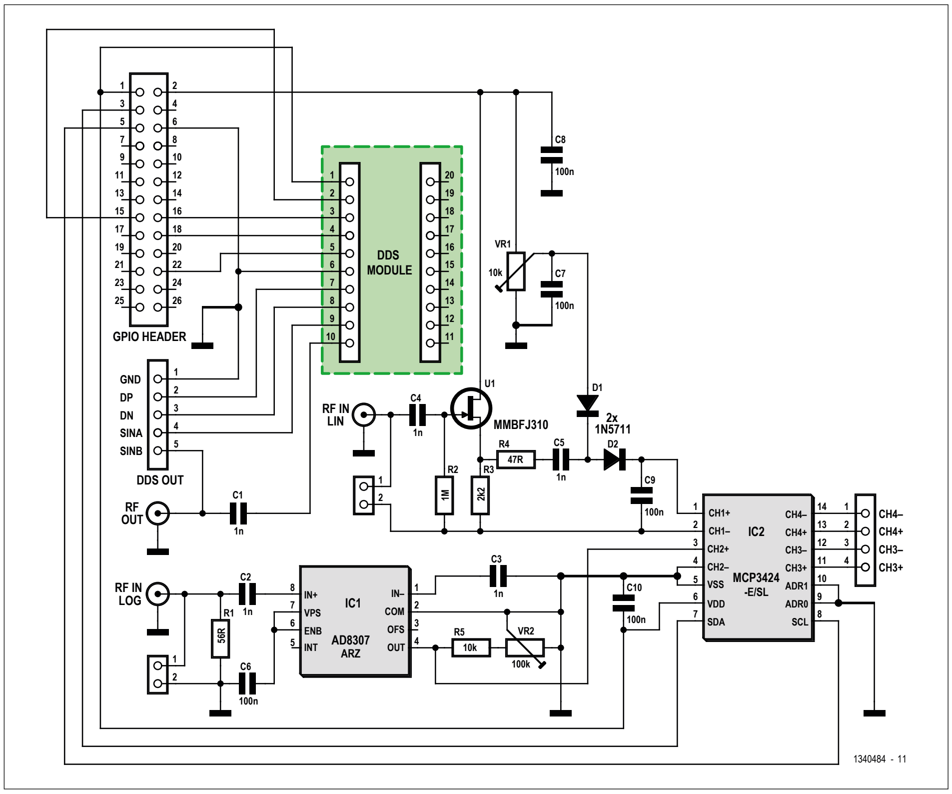


Figure 2. Schematic of the Raspberry Pi controlled Wobbulator. The DDS module is an off the shelf module.

The Software

The Python control software developed for the project may be found at [2]. It is a treat for programmers. Since its kick-off in 2013 the project now has many new features including X and Y scales and a continuous sweep option. The latest version of the software is available on GitHub [2] and has been uploaded to the Yahoo group [3]. For those potential users new to Linux and the Raspberry Pi a highly detailed guide to installing the lot from scratch is found on the author's

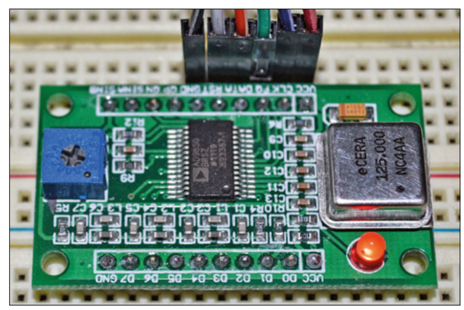


Figure 3. The AD9850-based DDS board can be obtained from various quasi-resident sellers on EBay.

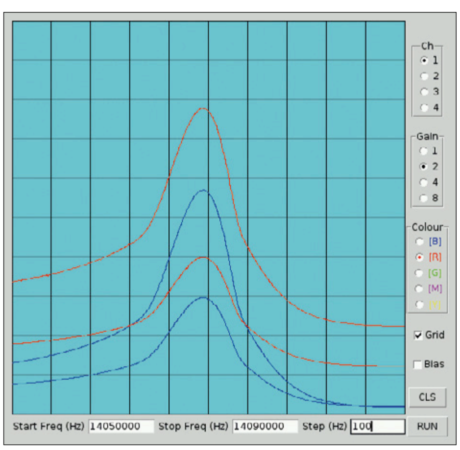


Figure 4a. Demonstrating the effect of the 'bias' option on a 20-m (14-MHz) filter

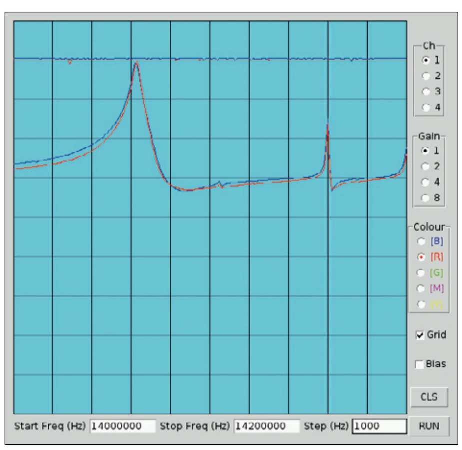


Figure 4b. Frequency response of a quartz crystal.

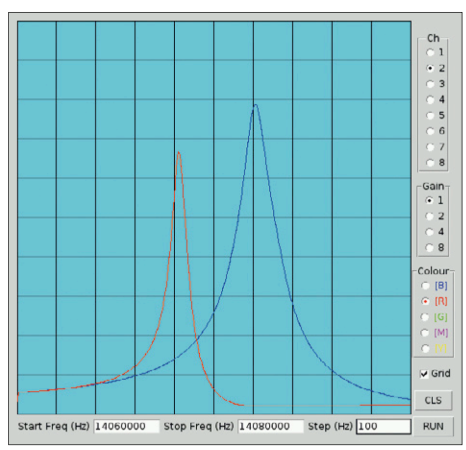


Figure 4c. Resonant frequency of a quartz crystal with (red line) and without (blue line) capacitance in parallel.

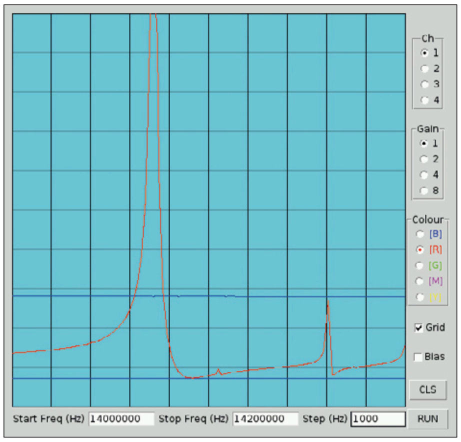


Figure 4d. Response of an RF filter measured on CH1 (LIN).

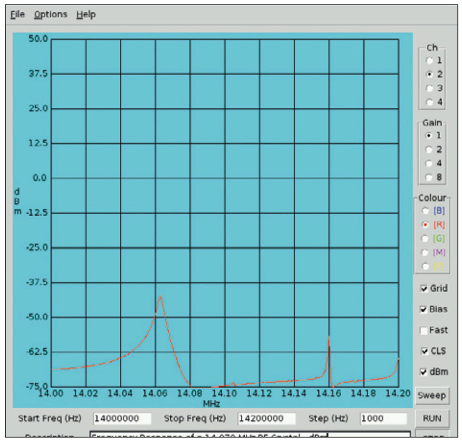


Figure 4e. 14-MHz filter analyzed using the LOG (dBm) Y axis scale.

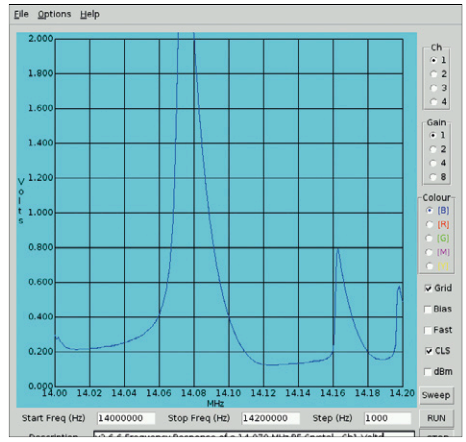


Figure 4f. 14-MHz filter analyzed using the LIN Y axis scale.

blog [4] — look for the April 8, 2014 installment.

Conclusion

To check its operation the RPi Wobbulator was used to 'sweep' a quartz crystal and filters for the 20-m radio band (14 MHz). Some of the results can be seen in the screendumps pictured in **Figure 4**. Finally, this is a Reader's Project publication, meaning the project was not built or tested at Elektor Labs. Rather than describing the RPi Wobbulator in great detail as a DIY project, the purpose of this article is to alert you to the way it got developed interactively by the author using his blog and the Elektor Labs website [5] where it got 5 out of 5 stars. After designing a PCB for the design (**Figure 5**) Tom progressed right up to offering kits for the project, optionally with the DDS generator module included. Talk to him via his blog [4] or Twitter @TomHerbison. ◀

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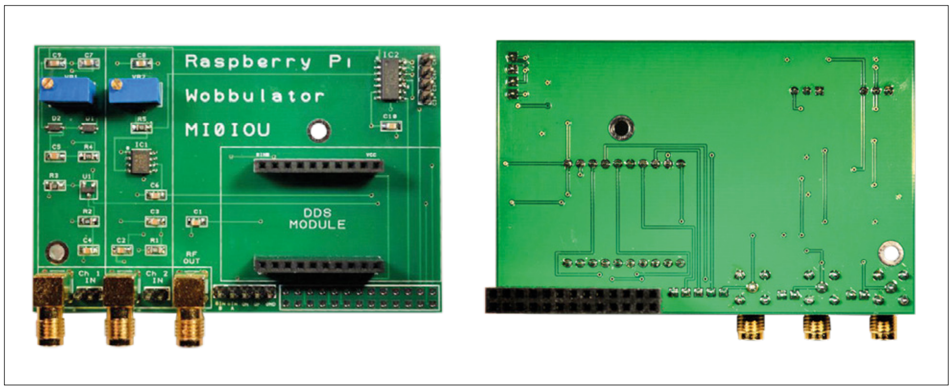


Figure 5. Printed circuit boards for the RPi Wobbulator are available from the author.

Web Links

[1] MCP3424: www.microchip.com/wwwproducts/Devices.aspx?product=MCP3424
[2] RPi Wobbulator Software (Python 3): https://github.com/mi0iou/
[3] Yahoo Group: http://groups.yahoo.com/neo/groups/rpiwobbulator/info
[4] Author's blog: www.asliceofraspberrypi.co.uk
[5] www.elektor-labs.com/project/raspberry-pi-wobbulator-130484-i.13612.html

Pan-Tilt-Zoom

Pelco-D Control for CCTV Cameras

Based on the Elektor Platino

By **Grégory Ester** (France)

Pictures from video surveillance (CCTV) cameras have (alas) become familiar. Their quality is often poor and often the cameras are fixed, in spite of the fact that they can be pointed and adjusted remotely to obtain much better images. Which is exactly what I aim to do using an Elektor Platino board. All that is needed is to be able to talk Pelco-D.

A motorized dome camera can be moved horizontally (pan) and vertically (tilt). The zoom function allows the focal length of the lens to be altered in order to better distinguish or identify the subject. These functions Pan, Tilt and Zoom are usually abbreviated to their acronym P-T-Z. Other parameters that may be changed are the diaphragm or iris, the opening of which determines the quantity of light admitted through the lens, and the focus, for obtaining the sharpest possible image. In this article, we will discuss the P-T-Z camera communication protocol. For this, two programs were written for the Elektor Platino board, and tested with two types of P-T-Z dome cameras (**Table 1**).

Figure 1. PTZ Cameras can be controlled with this keyboard and three-axis joystick.

The Pelco-D Protocol

A PTZ camera is usually driven from a keyboard with a joystick (**Figure 1**) using the Pelco protocol, from the name of the American company *Pelco Corporation*. This is a standard, used in cameras as far afield as Buckingham Palace, the Statue of Liberty, and the Presidential Palace in Beijing.

In the Pelco-D protocol, there is a master and numerous slaves: the master is usually the keyboard/joystick panel, and the cameras are the slaves. A Master can communicate with up to 255 slaves. Each slave has a unique address from 1 to 255. As the master can only address one slave at a time, this is a unicast protocol. Physically, the messages are sent on a serial two wire RS-485 bus. The speed is usually 2400, 4800 or 9600 bauds. A character is sent as eight bits, LSB first,

with a start and stop bit and no parity bit. Whether at Buckingham Palace or Beijing, it is always the master which initiates the communication, slaves may only reply when commanded by the master. They are doomed to a lonely existence, as they are unable to communicate between themselves.
A command in the Pelco-D protocol consists of seven bytes (**Table 2**). The address byte, the command and data bytes are always framed with a SYNC byte which marks the start of the useful bytes, and a CKSUM byte which corresponds to the checksum of bytes 2 to 6. The DATA1 and DATA2 bytes may contain from 8 to 16 bits of data. If a 16-bit word is needed, DATA1 is the most significant byte and DATA2 the least significant byte. For example, if DATA1 = $12 and DATA2 = $34, the sixteen bit word is equal to $1234 (values preceded by a '$' sign are hexadecimal).
The checksum is a modulo-256 sum of bytes 2 to 6. This is calculated by truncating the intermediate and final results to 8 bits.
Here is an example in binary to show what happens if byte 2 = 0000 1010 (10, $0A), byte 3 = 1000 1000 (136, $88), byte 4 = 1001 0000 (144, $90), byte 5 = 0000 0000 (0, $00) and byte 6 = 0010 0000 (32, $20)

```
  0000 1010   (byte 2)
  1000 1000 + (byte 3)
  1001 0010   (= $92), the result
                    is within 8 bits
  1001 0000 + (octet 4)
1 0010 0010   (= $122), this value
                    needs 9 bits.
```

The modulo-256 operation truncates the ninth bit, so we get 0010 0010 (= $22) instead, and we continue our calculation with this value:

```
0010 0010   (= $22)
0000 0000 + (byte 5)
0010 0010   (= $22), the result
                  is within 8 bits
0010 0000 + (byte 6)
0100 0010   (= $42), the result
                  is within 8 bits
```

The checksum CKSUM is thus $42.

Table 1. Specifications of the IP camera and the analog camera used in this article. Both cameras may be configured with the software `platino-pelco_camera_osd_setup`. The IP camera may also be controlled by the software `platino-pelco_2df7274-a_query`.

IP Camera 1.3 Megapixels	
Model number	**2DF7274-A**
Lens focal length	4.3 mm – 86 mm
Optical zoom	86 / 4.3 = 20x
Firmware Version	V5.2.4 build 141009
Analog Camera 650TVL	
Model number	**SD6C23E-H**
Lens Focal length	3.9 mm – 89.7 mm
Optical zoom	89.7 / 3.9 = 23x
Firmware Version	V1.03.8.RHAHDV

Table 2. The Pelco-D protocol uses frames of seven bytes.

Byte	Name	Contents
1	SYNC	255 ($FF in hexadecimal), signals the start of a frame.
2	ADDR	1 to 255, the address of the camera.
3	CMND1	The command over two bytes.
4	CMND2	
5	DATA1	The data over two bytes .
6	DATA2	
7	CKSM	Checksum for bytes 2 to 6.

Table 3. For movement commands, bit 0 of CMND2 is always 0. A function is activated if its bit is set to 1, and deactivated when that bit is reset to 0.

CMND1							
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Sense	0	0	Auto Scan / Manual Scan	Camera On/ Camera Off	Iris Close	Iris Open	Focus Near
CMND2							
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Focus Far	Zoom Wide	Zoom Tele	Down	Up	Left	Right	0

Tableau 4.
Some examples of movement commands sent to camera 12 ($0C).

	SYNC	ADDR	CMND1	CMND2	DATA1	DATA2	CKSUM
Pan Right, Speed $25	$FF	$0C	$00	$02	$25	$00	$33
Motion Stop	$FF	$0C	$00	$00	$00	$00	$33
Tilt Up, Speed $20	$FF	$0C	$00	$08	$00	$20	$34
Motion Stop	$FF	$0C	$00	$00	$00	$00	$33
Zoom Out (Wide)	$FF	$0C	$00	$40	$00	$00	$4C

Zoom to the movement commands

The Pelco-D protocol uses two types of command, movement commands (*Pan*, *Tilt*, *Zoom*, *Iris*, *Focus*), recognized by the value of bit 0 of the CMND2 byte set to 0, and control commands which allow advanced configuration (bit 0 of CMND2 = 1).

The movement commands are shown in **Tables 3** and **4**. A function is activated if its corresponding bit is set to 1, and deactivated if that bit is set to 0.

DATA1 allows the rotation speed of the camera (Pan) to be set from 0 (slow) to 63 ($3F, fast). A value of 64 ($40) corresponds to turbo speed. To stop the rotation, the *Left* and *Right* bits can be set to 0 while keeping, if desired, the contents of DATA1 unchanged. The horizontal rotation speed (pan) usually varies from 0.1°/s to 80°/s (0.1°/s to 160°/s in manual control mode for our two cameras).

DATA2 allows control of the vertical inclination speed (Tilt) from 0 (slow) to 63 ($3F, fast). There is no Turbo setting for the vertical tilt. To stop it, the Down and Up bits must be set to 0, while keeping, if desired, the contents of DATA2 unchanged. The speed of vertical rotation usually varies from 0.1°/s to 40°/s (0.1°/s to 120°/s in manual control mode for our two cameras).

Most Pelco devices are equipped with a

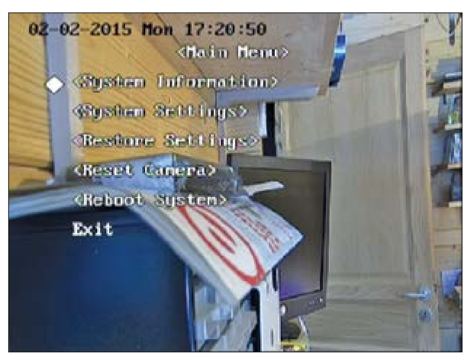


Figure 2. The setup menu of the camera is embedded in the camera picture, also known as an On-Screen Display or OSD menu.

movement (runaway protect): movement commands are stopped automatically after 15 seconds. To obtain continuous movement, the commands must be resent around every 5 seconds. This is the case with our analog camera.

Table 4 gives some examples of movement commands for Pan, Tilt or Zoom of the camera.

Freeze Frame : Presets

A PTZ camera compatible with Pelco-D offers some preset settings accessible from a menu shown within the image (**Figure 2**, On-Screen Display or OSD). This menu is brought up with the control command Preset 95 detailed in **Table 5** (This is a real control command, since bit 0 of CMND2 is set to 1).

Once the main menu is visible on the screen, navigation up or down and to sub-menus, and the incrementing or decrementing of the values, modification of On/Off options, cancelling of options, etc., is done using movement commands, which no longer apply to the camera but to the OSD menu.

The camera talks back

A Pelco-D formatted command may give rise to three types of response:

- General Response (4 bytes);
- Extended Response (7 bytes);
- Query Response (18 bytes).
-

The camera type SD6C23E-H does not give responses but the model 2DF7274-A sends only extended response, so we will not concern ourselves with the General Response and Query Response types.

Table 6 shows the format of the extended response comprising 7 bytes, **Table 7** gives some examples of the control and movement commands to which the camera will respond.

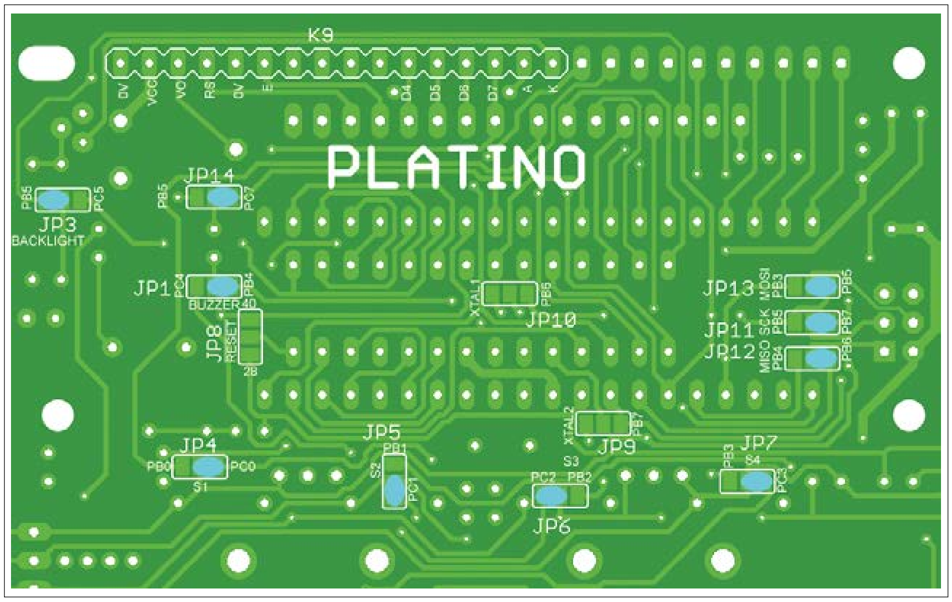


Figure 3. Here is how to place the solder bridges to configure Platino for this application. JP8, JP9 et JP10 are not used for this configuration. Component List downloadable from [1].

Platino in action

To put this protocol into action, we will use Platino with one rotary encoder with push button, and one separate push button. The four possible actions are: rotating the encoder to right or to left; push the button on the rotary encoder (S5C on the Platino); and push the separate push button (S4C on the Platino).

An RGB LED and a liquid Crystal display (LCD) of 4 lines x 20 characters allows the

Table 6. Format of the Extended Response, *coded in seven bytes*.

1	2	3	4	5	6	7
SYNC	ADDR	RESP1	RESP2	DATA1	DATA2	CKSM

Table 5. Call up Preset 95 of a camera, address 12 ($0C), using a control command with bit 0 of CMND2 set to 1. Following this command, the camera will show its OSD setup menu.

	SYNC	ADDR	CMND1	CMND2	DATA1	DATA2	CKSUM
Binary	1111 1111	0000 1100	0000 0000	0000 011***1***	0000 0000	0101 1111	01110010
Hexadecimal	$FF	$0C	$00	$07	$00	$5F	$72
Decimal	255	12	00	07	00	95	114

Table 7. A conversation between the master and camera 12. The master sends commands and requests, the camera sends back replies.

	SYNC	ADDR	CMND1/RESP1	CMND2/RESP2	DATA1	DATA2	CKSM
Command *Pan Right*	$FF	$0C	$00	$02	$25	$00	$33
Command *Motion Stop*	$FF	$0C	$00	$00	$00	$00	$0C
Request *Pan Position*	$FF	$0C	$00	**$51**	$00	$00	$5D
Response received ($7452 = 297.78°)	$FF	$0C	$00	**$59**	$74	$52	$2B
Request Tilt Position	$FF	$0C	$00	**$53**	$00	$00	$5F
Response received ($0868 = 21.52°)	$FF	$0C	$00	**$5B**	$08	$68	$4C

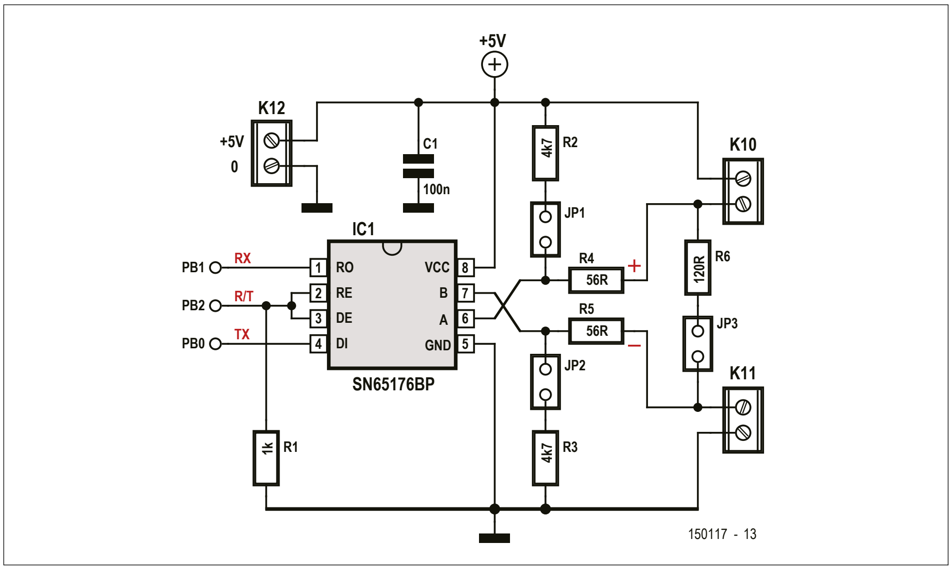


Figure 4. Schematic of the RS-485 interface.

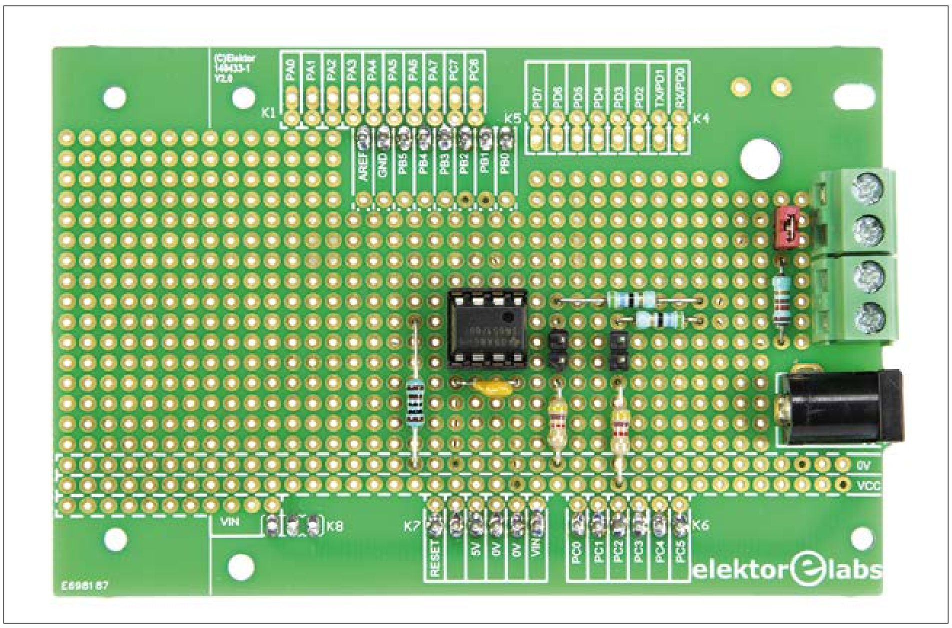


Figure 5. The RS-485 interface constructed on an extension card for Platino.

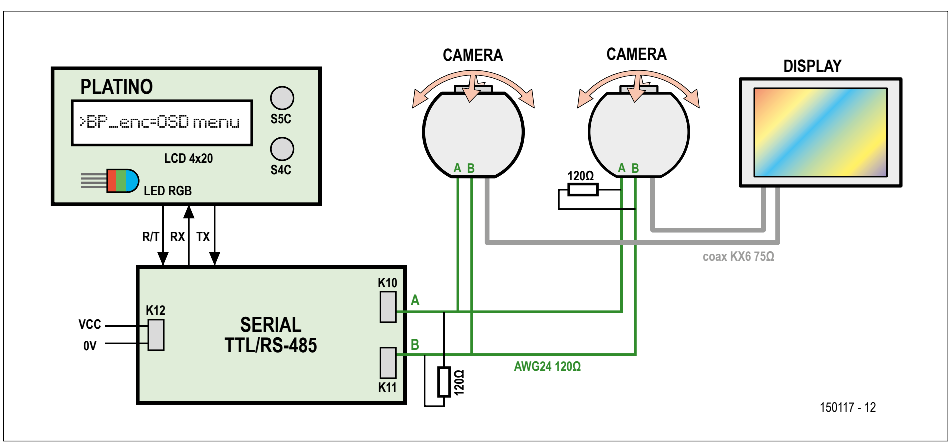


Figure 6. Block diagram for our Platino Pelco-D system. In case of a long connection to the left camera, install a termination resistor as with the right-hand camera.

system to output information to the user. Reading the original Platino article [2] and **Figure 3** will allow you to identify the solder bridges that must be made. The components needed for the Platino board are shown in the Component List [1]. Because of the need for an RS-485 port, Platino cannot interface directly with PTZ cameras. An interface is needed to change the unbalanced TTL serial signal output by Platino into a balanced differential signal to the RS-485 standard. We built the interface on a Platino extension card (**Figures 4 and 5**). The RS-485 compatible signal is available on screw connectors.

Figure 6 shows the cabling diagram of the entire system. At the Platino, setting the R/T line High is followed by transmission of data on the TX line in TTL format. A low level on R/T allows reception of data bytes from a PTZ Camera.
Both the Platino and the RS-485 interface board are powered from the RS-485 interface board.
A twisted pair AWG24 cable carries the RS-485 signals.

Two programs

To let us control our two cameras, two programs were written in BASCOM:

`Platino-pelco_camera_osd_setup.bas` allows access to the OSD setup menu to, for example, set the IP address 192.168.1.112 on the IP camera 2DF7274-A, or set the date and time.

Component List, RS-485 Interface

Resistors
5%, 0.25W, 10mm
R1 = 1kΩ
R2,R3 = 4.7kΩ
R4,R5 = 56Ω
R6 = 120Ω

Capacitors
C1 = 100nF, 0.2” pitch

Semiconductors
IC1 = SN65176BP

Miscellaneous
K5 = 8-pin pinheader, 0.1” pitch
K6,K7 = 6-pin pinheader, 0.1” pitch
K8 = 3-pin socket strip, 0.1”pitch
K10,K11 = 2-way PCB screw terminal block, 0.1” pitch
K12 = DC connector (eg Farnell 1217037)
JP1,JP2,JP3 = 2-pin pinheader, 0.1” pitch
PCB #140433-1 v2 or most recent (Elektor)

Figure 7. Turn the camera to the right (Pan Right).

`Platino-pelco_2df7274-a_query.bas` controls the IP camera and retrieves the response information on the horizontal and vertical rotation positions.

Both programs can be downloaded from [2] by Elektor members

The first program is shown in detail in the sidebar. Here is how the second is used. Obviously we start by loading the program into the Platino, and restarting it. Thereafter, the Pan and Tilt positions should appear on the 4th line of the LCD Display.

With repeated presses of the S4C push-button, you will bring up the Pan, Tilt and Zoom functions of the IP camera. The rotary encoder will then allow you to turn the camera right (Pan Right, **Figure 7**) or left (Pan Left), tilt it higher (Tilt Up) or lower (Tilt Down), or zoom out (Wide) or in (Tele). The RGB LED is red during Pan, Green during Tilt and blue during Zoom operations. Press on the rotary encoder push button to stop the movement (Motion Stop) and the fourth line of the LCD display will show the new horizontal and vertical positions.

Final applause

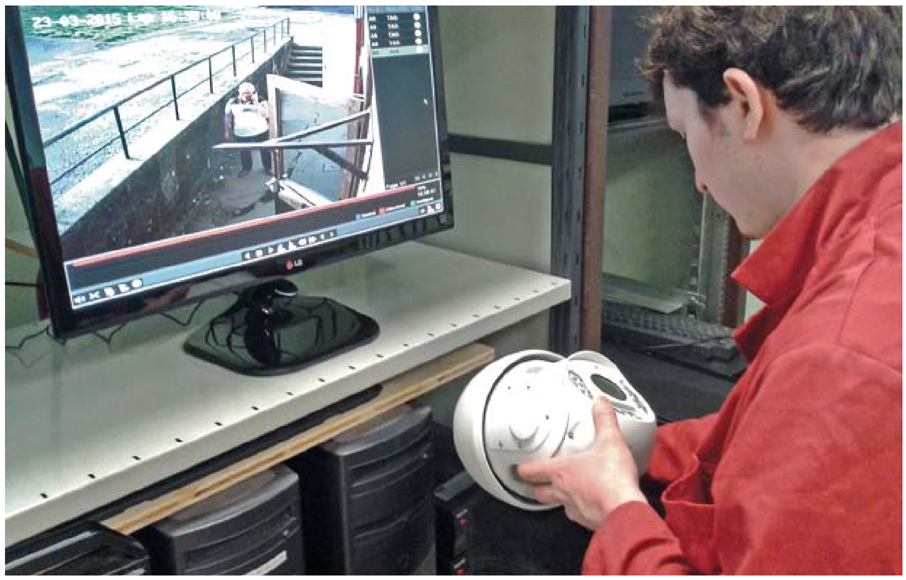
The final paragraphs of this article are essentially informative: understanding the configuration and control of a PTZ camera using the Pelco-D protocol. However, the whole project presented with the source code forms an original remote control system which anyone should be able to change, build up or simplify to any requirements.

Big Brother, it's all yours!

(150117)

CCTV or not CCTV

In France the Pelco-D protocol is taught at the ECA Technical College. To bring theory and practice together we are associated with Videocom 2000, a company specializing in video surveillance. We wanted to find a training facility offering real-life situations. Another technical College in this field, Sainte Famille, trains security guards whose main purpose is to ensure the security of property and persons. This college has a central security control post and an excellent infrastructure for training in CCTV technology. Our student installers can thus meet the needs of other students and users.
Up to 37 cameras monitor the entire site. Before final installations, we use the *JVSG - CCTV Design Software* to best distribute and place the cameras so that their images will cover the entire area to be monitored.



Like everyone, our students smile when they're being filmed but they also smile often as they are happy and valued in their training!

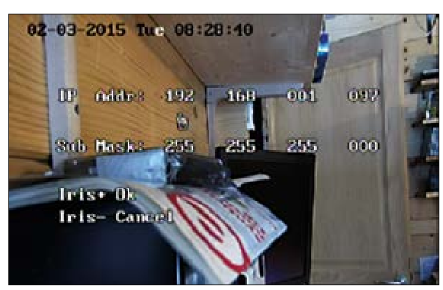
Web Links

[1] This article: www.elektormagazine.com/150117

[2] Platino: www.elektormagazine.com/100892

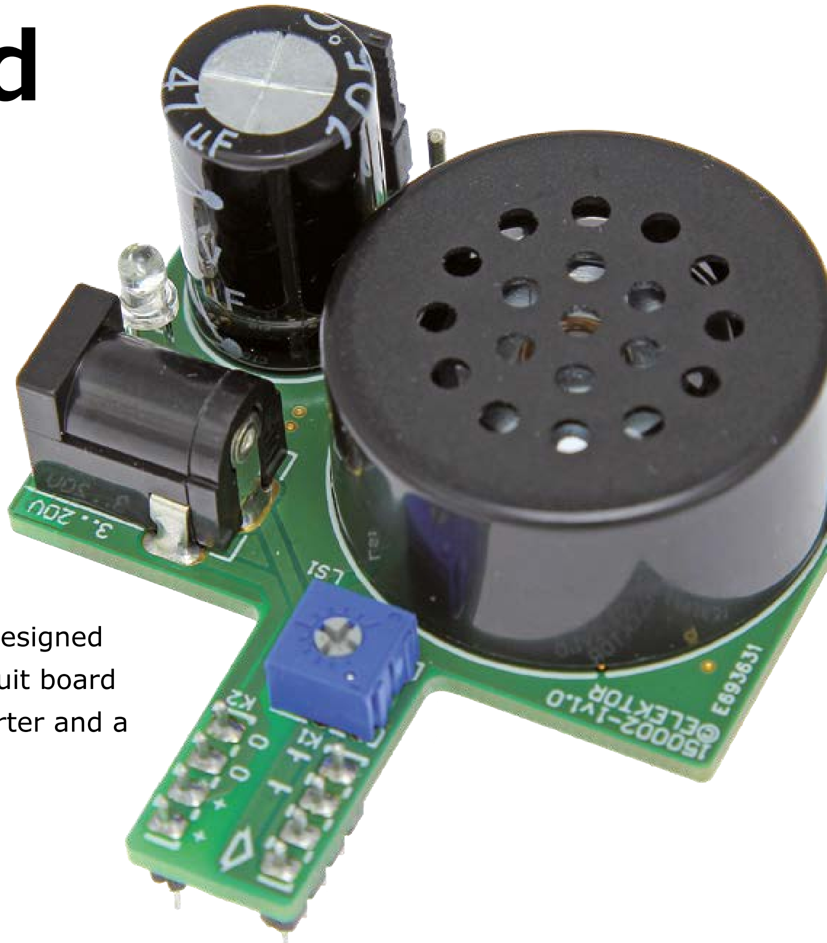
Camera parametrization

`Platino - pelco_camera_osd_setup.bas` provides access to the OSD setting menu. The 4th row of the Platino display shows the current setup of the rotary encoder (scroll by pressing S4C). Here a press on the encoder button will display the OSD menu of the camera with the possibility to navigate. For example, it is possible to set the IP address bytes. The complete procedure is described in a downloadable document [1].



Audio T-Board

With integrated loudspeaker



By Ton Giesberts (Elektor Labs)

When experimenting with analog circuits on a breadboard, a small audio amplifier with corresponding speaker can often be a very handy aid to make signals audible. That is why we have designed a convenient T-board, which on a single, small circuit board accommodates a class-D amplifier, a DC/DC converter and a small loudspeaker.

Technical Characteristics

• Quiescent current:	7.5 mA (4 V)
	2.3 mA (20 V)
• Input sensitivity (P1 max.):	100 mV (1 kHz / 300 mW/8 Ω)
	85 mV (1 kHz / 400 mW/4 Ω)
• Frequency range:	min. 20 – 20,000 Hz (at LS+/LS-)
• Max. distortion:	<1% (at 300 mW / 8 Ω, 400 mW / 4 Ω)
• Power supply voltage:	4 – 20 V (8 Ω)
	4.5 – 20 V (4 Ω)
• Max. current consumption at 8 Ω:	125 mA (4 V), 30 mA (20 V)
at 4 Ω:	225 mA (4 V), 45 mA (20 V)

Until now Elektor's series of T-boards contained only digital versions: the T-board 8, 14, 28 and Wireless. Is there a reason why we should not make an analog version? After all, plenty of analog designs are built and tested on a breadboard. We asked ourselves what could be a useful circuit when experimenting with an analog circuit. Then you will soon arrive at the subject of audio. So, what do you think of a T-board with a small power amplifier and preferably also with a built-in speaker, so that you can make any audio signals audible immediately, without first having to build a separate circuit for this and then connecting some speakers to it. Of course, it does require a power adapter or separate battery to power the amplifier, but that is usually not a problem. That is how the idea came into being of designing a circuit board with a small power amplifier and a corresponding speaker.

In the first instance we were going to use an analog IC, such as the LM386, but there isn't really any space for a large output electrolytic capacitor if we would like to keep the dimensions of the T-board reasonably small. If you want to avoid this and also don't want to use a symmetrical power supply, then you will quickly arrive at a bridge configuration, where the loudspeaker is connected between the outputs of two power amplifiers. The next question is then: Do we choose analog or digital power amplifiers? The latter have a higher efficiency (no heatsinks!) and can also deliver more power at a lower power supply voltage, so the choice is an easy one. Then there is the question of how much output power we would like to have at our disposal. For many small loudspeakers it is usually sufficient to have a power of 0.15 or 0.2 W and this is also still enough to drive a somewhat larger external speaker.

For the amplifier IC a type from Analog Devices was selected, a SSM2305 (IC2 in the schematic of **Figure 1**). The power supply voltage for the IC may be anywhere between 2.5 and 5.5 V. At 2.5 V it can still deliver an undistorted output power of a little more than 0.3 W into an 8-Ω load. This is more than adequate for our purpose. The IC contains a class-D final output stage with push-pull outputs and symmetrical inputs. The design is such that, according to the datasheet, there is no need for LC-filters on the outputs. The total number of external components is minimal.

As already noted, we decided to fit a small loudspeaker directly on the circuit board. This does make the overall dimensions

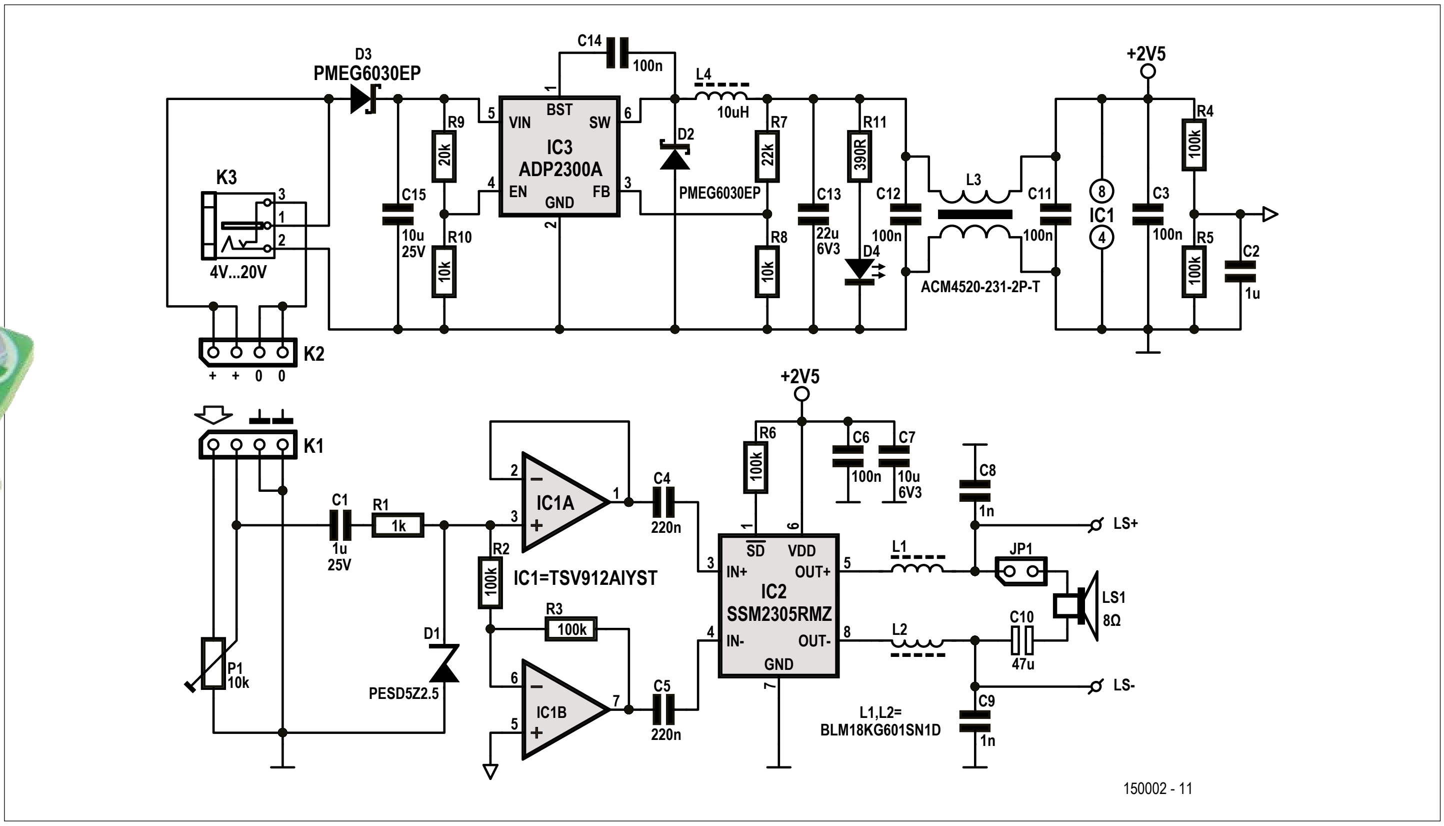


Figure 1. The circuit is built around a class-D amplifier IC and a DC/DC converter.

of the circuit board somewhat larger (the T-board is a little top-heavy), but this certainly makes it much more convenient to use. Via a couple of printed circuit board pins you can always also connect an external loudspeaker.

Amplifier

The input signal, coming from the circuit on the breadboard, enters at connector K1. If you use pin 1 of K1 for this then you can adjust the volume with P1. If you use pin 2 then the signal is passed unattenuated to the power amplifier. The input sensitivity is quite large (100 mV at a load of 8 Ω). The input impedance is, depending on the position of P1, between about 9 and 10 kΩ. The signal goes via C1 and R1 to IC1A/B. ESD protection diode D1 protects the inputs of this IC against input voltages that are too high.

The completely differential input of the SSM2305 will not be that practical for most experiments. For this reason, dual opamp IC1 converts the asymmetrical input signal into a symmetrical version for driving the SSM2305. The design is simple: IC1A serves a buffer for input IN+, while IC1B inverts the signal and presents it to input IN–. For IC1 a TSV912AIYST was selected, a fast (8-MHz) dual rail-to-rail input/output opamp, which is also suitable for power supply voltages in the range of 2.5 to 5.5 V. The values of C4 and C5 are such that the low cut-off frequency is at 20 Hz. External loudspeakers will therefore have the full audio frequency range available to them.

The amplifier IC is provided with a shutdown pin (pin 1), but this is not used here and is permanently connected to the power supply voltage via R6.

To keep the EMI radiation from the switching outputs to a minimum (in particular when connecting an external speaker), small LC-filters are inserted in the outputs, comprising tiny ferrite beads and small capacitors (L1/L2/C8/C9). These are therefore not low-pass filters for the audio signal, such as those that are commonly used with class-D amplifiers (in that case the dimensions of these components would have been considerably larger).

The loudspeaker that is on the circuit board is very small and therefore we must not have too high an expectation when it comes to the reproduction of low frequencies. Such speakers typically start to roll off below 500 Hz. Although it is not absolutely necessary, a small decoupling capacitor (C10) is connected in series with this loudspeaker, so that it will not be subjected very low frequencies that are too large in amplitude and the corresponding excessive deflection of the cone. The loudspeaker on the circuit board can be disabled with jumper JP1.

Power supply

For the power supply a switching version was also chosen, on the one hand because of its high efficiency and on the other hand because of the large input voltage range that is possible. It is the intention that the power amplifier can be connected to most line power adapters, the input voltage range therefore has to be at least up to 12 V.

Here too the choice was made for an IC made by Analog Devices, in this case a step-down regulator ADP2300A (C3). This IC is only available in a 6-pin TSOT (Thin Small Outline Transistor package, also called a UJ-6) and can deliver a maximum output current of 1.2 A. There are a few additional components to complete the circuit. The design around the ADP2300A follows the standard application from AD. Inductor L4 can remain

quite small (10 µH) thanks to the high switching frequency of 700 kHz. This has been dimensioned for a maximum ripple voltage of 30% at the maximum load current and an input voltage of 5 V. It higher input voltages the ripple will be a little larger. The maximum undistorted output voltage of the power amplifier amounts to about 3.6 V peak-to-peak into a 4-Ω load. Under this condition the peak current delivered by the power supply comes to about 0.45 A.

IC3 has an enable input which can be used the set the minimum start-up voltage. With the values for R9 and R10 as indicated the DC/DC converter will start up at 3.8 to 3.9 V at the input (including the voltage drop across the reverse-polarity protection diode D3). The input voltage is allowed to go up to a maximum of 20 V.

> A mini audio amp and accompanying speaker are always handy when experimenting with audio

Voltage divider R7/R8 determines the output voltage of the converter, in this case 2.5 V. LED D4 serves as the power supply indicator. This is followed by a common-mode filter choke which effectively suppresses RF-interference signals. Finally R4 and R5 are used to make a reference voltage that is half of the supply voltage, which is used as a reference for IC1B.

There are two options to connect the battery holder (a minimum of 3 cells) or a power adapter: via the power supply connector K3, which is on top of the circuit board (center pin = positive), or via connector K2 which is plugged into the breadboard. In the latter case you will have to take into account that large currents will flow through the breadboard contacts. It is preferable to connect a separate power supply to K3.

When the power supply connector is plugged into K3, the internal switching contact will disconnect the ground connection to K2, to prevent a ground loop when the circuit on the breadboard and the T-board are powered from the same adapter (not recommended). Otherwise part of the common-mode filter choke L3 would be effectively short circuited.

Component List

Resistors

Default: 0.1 W, 1%, SMD0603
R1 = 1kΩ
R2–R6 = 100kΩ
R7 = 22kΩ
R8,R10 = 10kΩ
R9 = 20kΩ
R11 = 390Ω
P1 = 10kΩ, 0.5W, 10% preset, Vishay Sfernice T73YU103KT20

Capacitors

C1,C2 = 1µF 25V, 10%, X7R, SMD 0805
C3,C6,C11,C12,C14 = 100nF 16V, 10%, X7R, SMD 0603
C4,C5 = 220nF 10V, 10%, X7R, SMD 0603
C7 = 10µF 6.3V, 20%, X5R, SMD 0603
C8,C9 = 1nF 50V, 5%, C0G/NP0, SMD 0603
C10 = 47µF 100V, 20%, bipolar, 13mm diam., 5mm pitch, I_r 240mA
C13 = 22µF 6.3V, 10%, X5R, SMD 1206
C15 = 10µF 25V, 10%, X5R, SMD 1206

Inductors

L1,L2 = 1.3A 0.15Ω, 600Ω @ 100MHz, SMD 0603 (Murata BLM18KG601SN1D)
L3 = 3A 2x50 mΩ, 230Ω @ 100 MHz, SMD Common Mode Choke (ACM4520-231-2P-T)
L4 = 10µH 2.1A, screened, SMD (Laird TYS5040100M-10)

Semiconductors

D1 = PESD5Z2.5, SMD SOD-523
D2,D3 = PMEG6030EP, SMD SOD-128
D4 = LED, low-current, green, 3mm, wired
IC1 = TSV912AIYST, SMD MSOP-8
IC2 = SSM2305RMZ-REEL7, SMD RM-8
IC3 = ADP2300AUJZ-R7, SMD UJ-6

Miscellaneous

K1,K2 = 4-pin pinheader with thin pins, 0.1” pitch, Harwin D01-9923246 (Newark/Farnell # 1022218)
K3 = supply connector 12V 3A, 1.95mm center pin
PC1,PC2 = PCB pin, 1.3mm diam.
JP1 = 2-pin pinheader, 0.1” pitch, with jumper

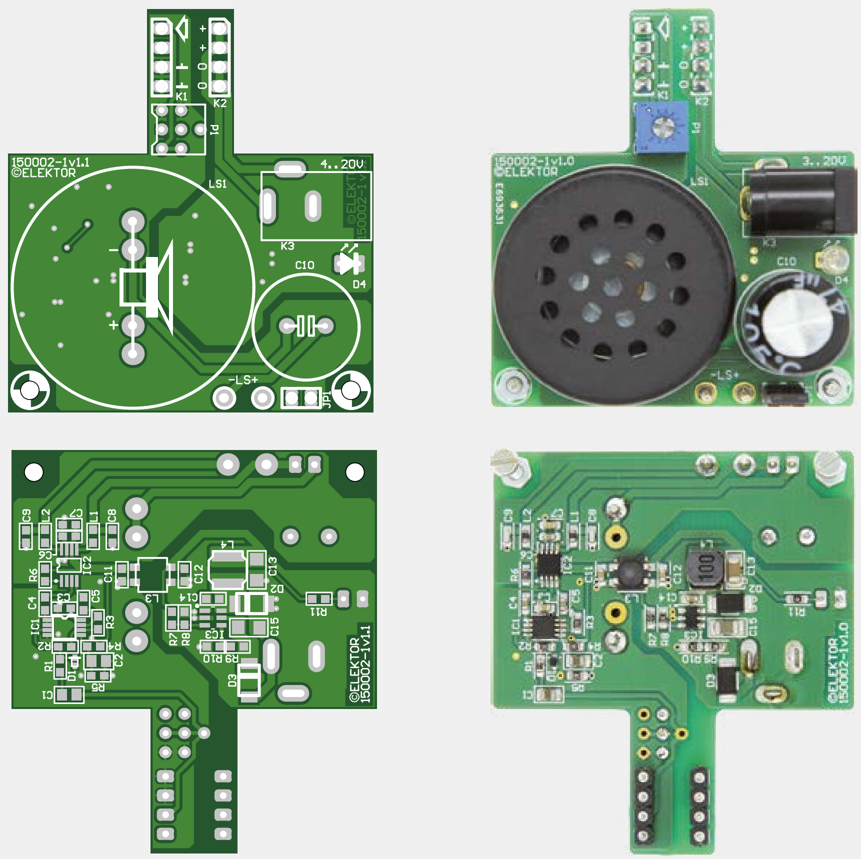


Figure 2. The double-sided circuit board contains components on both sides: the leaded components on top and on the bottom all the SMD components and two connectors.

LS1 = loudspeaker, PCB mount, 31.9mm diam., 17.53mm pitch (RS-online/Avnet 7243119)
Alternative for LS1: Multicomp MCABS-201-RC (Newark/Farnell 2361100)
Alternative for LS1: Visaton 2823, K 23 PC - 8 Ohm (Newark/Farnell 2357167)
PCB # 150002-1
Alternatively, ready assembled board # 150002-91

Construction

The circuit board for the audio T-board is double-sided, both the layout as well as the mounted components (**Figure 2**). All the leaded components are on the top side, only the connectors K1 and K2 are on the underside (you plug these into the breadboard later). All the SMD components are on the bottom. The sizes of the SMD components are such that they are still relatively easy to solder by hand. The bipolar electrolytic capacitor in series with the loudspeaker looks quite large for its value, but the advantage is that it is cheap and can handle a ripple current of 240 mA (this value has to be larger than the maximum current through the loudspeaker, < 200 mA). Note that this is true for the 100-V version, do not use a version for a lower voltage.

The footprint for P1 is suitable for 3 different pin layouts for potentiometers from the series from Vishay Sfernice, but types from other manufacturers will probably fit as well.

For those who prefer not to solder the SMD components themselves we offer the completely assembled module (including the little loudspeaker) in the Elektor Store as item number 150002-91.

Figure 3 shows clearly how the SMD components are fitted on the bottom side of the audio T-board. In the two mounting holes, fasten two M2 bolts with a length of 15 mm and using a couple of nuts. These serve as supports when the circuit board is plugged into a breadboard. **Figure 4** shows a view of the T-board 'in action' on a breadboard. It is plugged in right at the end of the breadboard so that as much as possible of the breadboard area remains available for building a circuit.

Efficiency

In this project we have given quite a bit of attention to the efficiency of the circuit, both for the power amplifier as well as the power supply. That is why we have also made a few measurements to determine the overall efficiency. On the Labs website [1] you can find the extensive measuring results, here we just mention the most important results.

We measured the efficiency using a pure ohmic load and with a simulated loudspeaker load by inserting an inductor of 100 µH in series with the load resistor. The efficiency is slightly increased by the inductive behavior of the speaker and the remnants of the switching frequency are also better suppressed. The average switching frequency of the SSM2305 is 280 kHz. At a load of 8 Ω the lowest efficiency is obtained at 20 V with 52.5% for an ohmic load and 57.1% for a simulated loudspeaker load (as can be expected, the efficiency of the DC/DC converter drops at higher input voltages). We measured the highest efficiency at 5 V: 58.4% with an ohmic load and 65.7% for a loudspeaker load.

When using a 4-Ω loudspeaker the efficiency is some 5 to 10% lower. The higher currents and bigger voltage drops across several components in the chain have a bigger influence at such a low input voltage.

(150002)

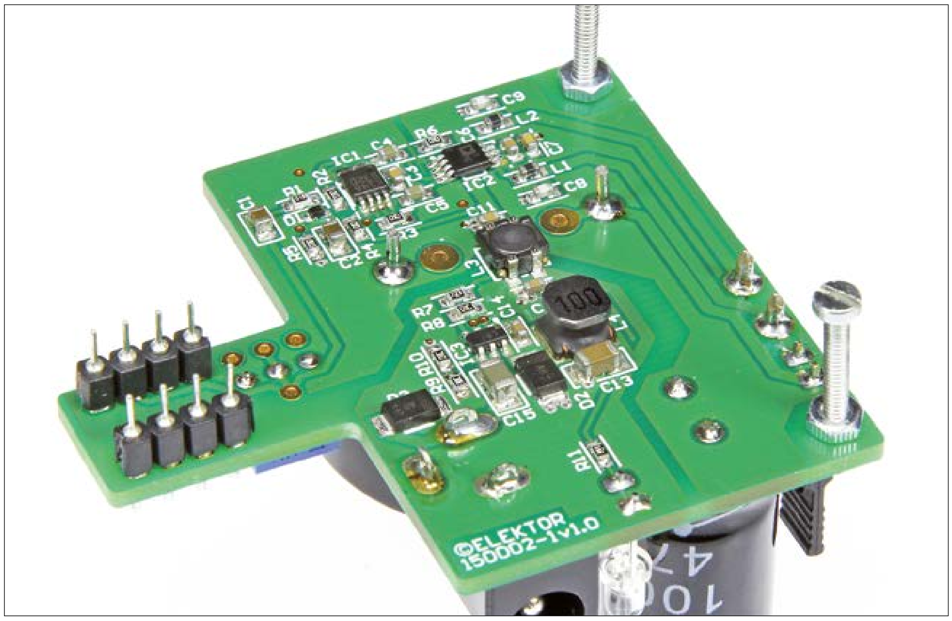


Figure 3. In this photo the SMD components can be clearly seen. Two M2 bolts with a length of 15 mm ensure that the T-board will remain reliably connected when overhanging the end of the breadboard.

Web Link

[1] www.elektor-labs.com/node/4436

Figure 4. The circuit is plugged in right at the end of the breadboard so that as much free space as possible remains on the board.

An SMD solder station made from bits and pieces!

Platino Solder Station

By **Martin Kumm** (Germany), **Clemens Valens** (Elektor Labs) and **Sunil Malekar** (Elektor Labs India)

This experimenter's solder station is built using the Elektor Platino Controller board and is both compact and low-cost. It uses an RT type of solder bit from Weller which has an integrated temperature sensor and heating element. Altogether it makes a controllable and precise solder station, ideal for soldering SMD components and more.

As modern component packages get ever smaller the need to work with SMDs becomes unavoidable. It shouldn't be too much of a problem providing you have access to the correct tools and soldering equipment. A really thin soldering bit fitted to a standard soldering iron is often unsatisfactory; it results in only a small proportion of the heat actually arriving at the soldering point. This arrangement means that the iron can only react quite slowly to temperature drops at the bit during soldering.

The answer is of course to use a modern (and expensive) SMD solder station. The irons used in some of these stations have replaceable bits that incorporate the heating element as well as a temperature sensor. These integrated solder bits are consumables and are therefore relatively inexpensive compared to the cost of the complete station.

Key Features

- Power supply: 12 to 18 V DC, 5 A
- Elektor Platino with ATmega328P microcontroller
- 16 x 2 LC-Display
- Weller RT-type solder bit with a 3.5-mm-jack connector
- 3-pole jack socket to accept the 3.5-mm-Stereo jack plug
- Temperature select range from 90 °C to 450 °C
- Temperature regulation via Platino PWM signal
- Display showing actual and setup bit temperature
- Rotary encoder to select the setup temperature

Pick a bit

The tool manufacturer Weller offers a complete arsenal of different types of replacement solder bits. The model most interesting to hackers wanting to make their own solder station is the RT type used with the WXMP MS soldering set. These bits have a useful feature that separates them from the other types: the bit connects via a standard 3.5 mm stereo jack plug (**Figure 1**). The three contacts supply the bit temperature sensor information and also connections to the built-in heating element. It also incor-

porates a finger-tip grip collar so that the complete assembly looks like a small soldering pencil.

The Weller catalog lists more than 30 different designs in this range. The common feature is the type of connector and the maximum power rating (40 W). The choice includes curved, straight, chisel-tipped, round and knife-edged with many different diameters and lengths etc, etc. Take a look at the Weller web site [1] to work out which model will best suit your needs.

The supply to power the heating element can be either a regulated or unregulated type with a maximum output voltage of 18 V (3 A minimum). The higher the supply voltage within this range, the faster the tip will heat up and regain temperature during use. This voltage level is a common choice for adapters to power laptops and mobile radio rigs. A standard in-car accessory socket can also be used as a power source. Powered by an 18 V supply, the heat up time from 20 °C to 330 °C is around 4 s. Despite the fine tip, a fast control loop makes the iron suitable for soldering tin plate and tin-plated cooling fins. The soldering station is therefore not only ideal for fine SMD work but also as a general purpose and versatile lab tool.

The solder station PCB

A solder station has little else to do but regulate the bit temperature: The actual bit temperature is measured and compared to the set temperature so that power to the element can be adjusted accordingly. The soldering temperature range is adjustable from 90 to 450 °C.

Thanks to the versatility of the Platino board, the solder station PCB circuit is very simple. **Figure 2** shows the circuit consisting of a Low-noise amplifier to boost the temperature sensor signal and a power MOSFET to switch power to the heating element. A prototype PCB for the circuit was quickly produced in the lab using a PCB milling machine, as you can see from **Figure 3** it's probably not going to win any ribbons at a beauty pageant! Don't worry; the supplied board will be up to our usual standards.

A thermocouple with a temperature coefficient of approximately 16 µV/K is integrated in the RT soldering assembly to measure bit temperature. The maximum temperature of 450°C produces a voltage of around 7 mV. This is scaled up to

Figure 1. The Weller RT solder bit is practical, compact and available in many different forms.

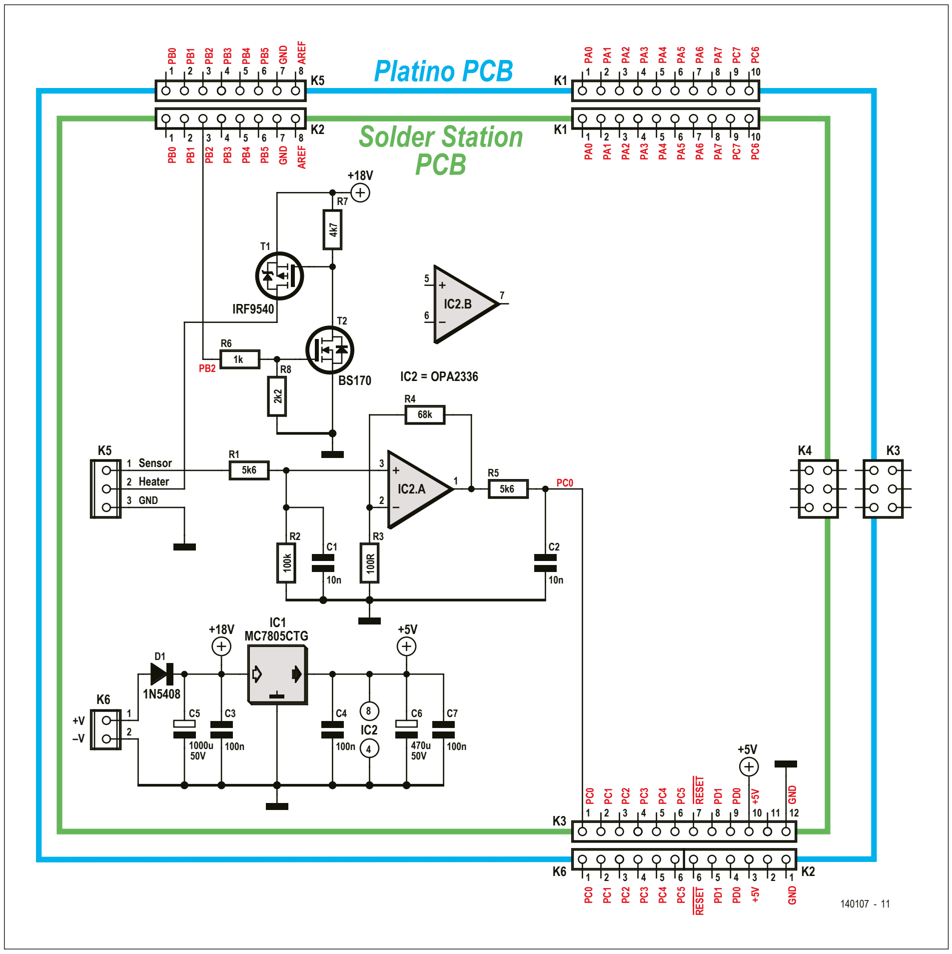


Figure 2. The solder station circuit showing connections to the Platino board.

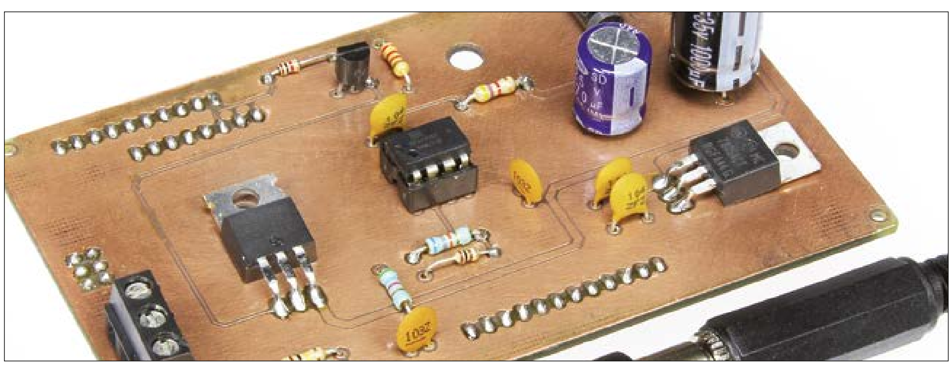
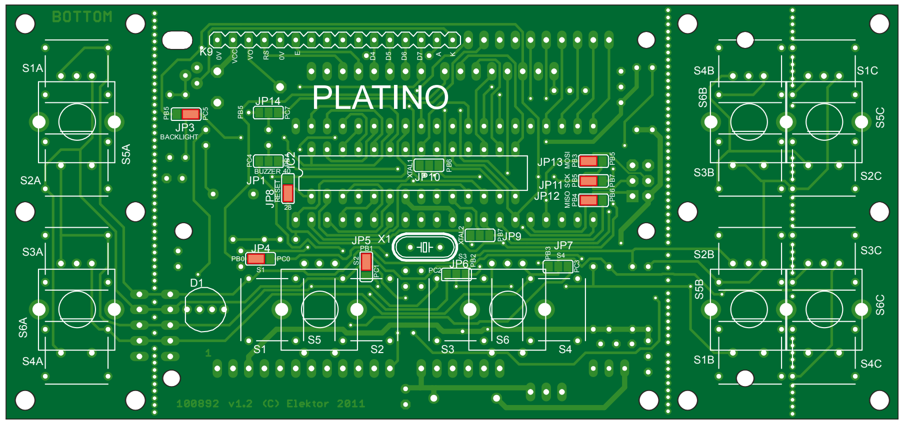


Figure 3. The prototype (milled) PCB for the solder station.

Table 1. Jumpers fitted to the Platino. All other positions should remain open.

Jumper	Position
JP3	PC5
JP4	PB0
JP5	PB1
JP8	28
JP11	PB5
JP12	PB4
JP13	PB3



Component List, Platino*

Resistors
All 5%, 0.25W
R3 = 47Ω
R4,R5,R6,R7,R10,R12 = 10kΩ
R11 = 4.7kΩ
P1 = 10kΩ trimpot, horizontal

Capacitors
C5,C6 = 100nF, 0.2” pitch

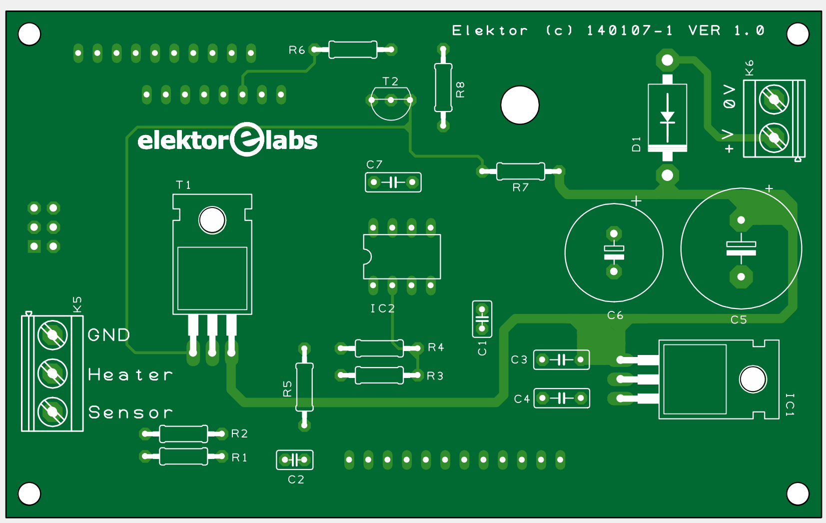
Inductor
L1 = 10µH

Semiconductors
IC1 = ATmega328P-PU, programmed (Elektor Store # 140107-41)
T1 = BC547C

Miscellaneous
S5A = rotary encoder with integrated pushbutton
K2,K6 = 6-pin pinheader, 0.1” pitch, straight
K3 = 6-way (2x3) pinheader socket, 0.1” pitch, straight
K5 = 8-way (2x3) pinheader socket, 0.1” pitch, straight
K9 = 16-way (2x3) pinheader socket, 0.1” pitch, straight
LCD1 = LCD, alphanumeric, 2x16** (Elektor Store # 120061-74)
DIP28-narrow IC socket
*See [3] for details on Platino.
** See ELPP: https://github.com/ElektorLabs/PreferredParts

correspond to the 5 V maximum input voltage of the AVR controller’s analog input. The opamp IC2.A performs this signal multiplication. It’s an OPA2336 which has a particularly low offset voltage (typ. ±60 µV) and simple power supply requirements. Resistors R4 and R3 set the amplification factor to around 680. Resistor R1 acts as an input current limiter during the heating phase when the full heating voltage appears at this input. The networks formed by R1 with C1 and R5 with C2 form low pass filters to filter out any high frequency switching noise spikes. The amplified and filtered sensor

Component List, Solder Station



Resistors
All 5%, 0.25W
R1,R5 = 5.6kΩ
R2 = 100kΩ
R3 = 100Ω
R4 = 68kΩ
R6 = 1kΩ
R7 = 4.7kΩ
R8 = 2.2kΩ

Capacitors
C1,C2 = 10nF, 0.1” pitch
C3,C4,C7 = 100nF, 0.2” pitch
C5 = 1000µF 50V, 0.3” pitch
C6 = 470µF 50V, 0.2” pitch

Semiconductors
D1 = 1N5408
T1 = IRF9540
T2 = BS170
IC1 = 7805
IC2 = OPA2336

Miscellaneous
K2 = 8-pin pinheader, 0.1” pitch, straight
K3 = 12-pin pinheader, 0.1” pitch, straight
K1,K4 = not used
K5 = 3-way PCB screw terminal block, 0.2” pitch
K6 = 2-way PCB screw terminal block, 0.2” pitch
DIP8 IC socket for IC2
Solder tip, Weller RT series [1]
3.5-mm stereo jack, cable socket
Bopla case type 2616 (Newark/Farnell 127479)

voltage is output from K3-1 to PC0, an ADC input of the Platino.
The switching signal controlling the heater element is output from PB2 of the Platino board which connects to connector K2-3. A low-power N-channel MOSFET type BS170 (T2) controls the IRF9540 power MOSFET, which can easily handle the 2.5 to 3 A current (at a maximum voltage of 18 V) flowing to the element. The 18 V supply voltage (which could also be 12 V or 15 V) connects to the 2-pin connector K6 on the solder station PCB. To simplify the wiring, a 5 V regulator has been included in design to power both the opamp and Platino board. Connector K5 provides the earth, heating element and sensor connections to the soldering pencil unit.

The Platino and its software

If you are not familiar with the Platino, it's worth checking out its capabilities described in this introductory article [3].
The amplified sensor signal connects to the ADC0 input on PC0 (Pin 23) of the Platino board where it gets converted to a digital value. The PWM output signal controlling power to the heating element is produced by Timer1. The PWM signal appears at the Timer output OC1B, connected with PB2 (Pin 16). The solder bit setup temperature is selected using the rotary encoder on the Platino while the temperature values are shown on the LCD. There are no critical timing constraints with this design so the controller is clocked using its internal 8-MHz oscillator.
The software for this project is written in C and is quite straightforward. It is available as an Atmel-Studio4 project for the ATmega328P.
At turn-on after hardware initialization a greeting appears on the display and then the software enters the main loop. Here the bit temperature is read and compared to the setup value (stored in EEPROM). The mark/space ratio of the PWM signal is adjusted according to whether the bit temperature is too high or too low. The algorithm uses a simple proportional-derivative (PD) control loop. The value of power to the heater is proportional to the temperature difference between the actual and setup values. The loop achieves a regulation accuracy of 3 to 4 °C.

To heat or not to heat

As long as the actual temperature of the soldering bit is more than 5 °C below the set temperature it is continuously supplied with power. As the bit temperature approaches the set value the power is throttled back using pulse width modulation (PWM). When the actual bit temperature is above the set value (or when a lower temperature is setup) the PWM power signal switches off completely. This ensures that the bit settles to the correct temperature as quickly as possible. When the actual temperature is just above the set temperature the PWM signal will be modulated in increments of 1/7 (PWM=PWM-PWM/7).

To generate the PWM signal Timer1 is configured in 9-bit fast-PWM mode together with Compare Register B. The prescaler is set to divide by 256. This configuration produces a low frequency PWM signal that gives good temperature stability and accuracy. The PWM frequency is calculated using:

PWM frequency = clock / (N × prescaler)
8 MHz / (512 × 256) = 62 Hz

with N = 512 for 9-bit fast PWM mode ($2^9 = 512$)

NB: The PWM signal is turned off during the times the temperature sensor output is read. This is necessary because the power signal to the heating element has a connection with the sensor and makes the sensor signal unreadable.
To ensure accurate measurement the heater element signal is turned off completely during sensor measurement periods. Turning off the PWM signal directly before a measurement cycle (OCR1B = 0), will allow some residual noise spikes to interfere with the ADC measurement. For this reason it's turned off 7 ms before reading the ADC.

Sensor signals

With the temperature sensor connected, the ADC output value at 50 °C is 67 and at 450 °C 1020. With a temperature range of 50 to 450 °C and an ADC range from 67 to 1020 gives:

Table 2. The ATmega328P fuse settings.

Fuse	Value
Low	0xe2
High	0xd9
Extended	0xff

multiplier = (450 – 50) / (1020 – 67) = 0.419

An ADC value of 0 corresponds to a bit temperature of around 30 °C. This indicates we need to add an offset of 30 to the formula:

temperature = temp_adc × 0.42 + 30

The driver for the rotary encoder determines its rotational information via controller Pins PB0 und PB1, a new set value is entered into EEPROM when the knob is pressed.
To save energy and prolong the solder bit lifetime the software automatically switches the iron to lower temperature operation after approximately 15 minutes use. The program doesn't know when you are about to use the iron again so just check the temperature on the display and press the rotary encoder switch for full heat.

Build it, Test it... Solder-on!

The Elektor Platino PCB needs to be 'jumpered' in accordance with **Table 1** (we just used solder bridges). The template shown is a useful aid here. First off you can start mounting the components and the LCD, next comes the rotary encoder and the socket for the ATmega328P microcontroller. Note that K9 (for the LCD) and the rotary encoder at position S5A are mounted on the other side of the board.
Mounting all the components should not present any problems. Connector strips K2 and K3 are fitted from the solder side of the board. Before soldering, plug them into the Platino board connector strips, this will ensure they are correctly aligned.

Web Links

[1] www.weller.de/en/Weller--Products.html?cat_id=ID151

[2] www.elektormagazine.com/140107

[3] www.elektormagazine.com/100892

[4] www.martin-kumm.de/smd_solder_station

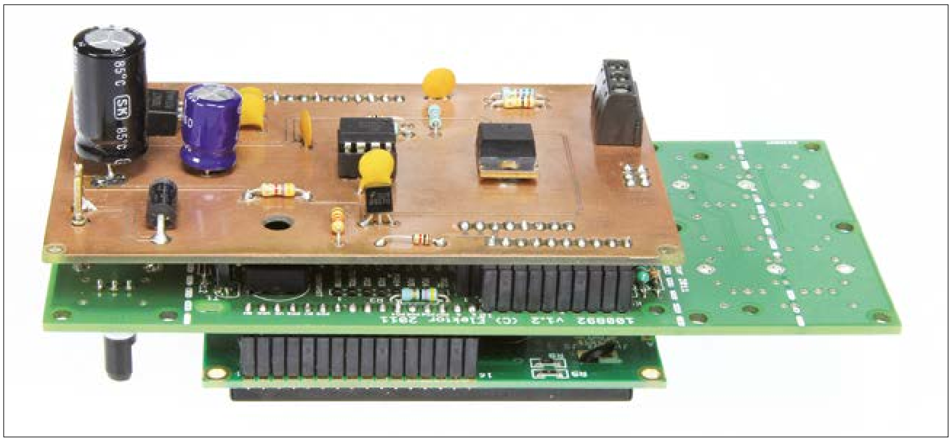


Figure 4. A triple-decker with the Platino, solder station and LC display boards.

Figure 5. The complete assembly plus AC line supply unit in the case.

Now all you need is the programmed microcontroller… what, you haven't got one? The simplest solution is to order one pre-programmed from Elektor (# 140107-41) or alternatively you can download the hex file [3] for free and program the microcontroller yourself. Don't forget to set the fuses in accordance with **Table 2**. The controller is configured to run using its internal oscillator running at 8 MHz.
Once the controller board is populated, plug all three boards (Platino, solder station controller and LCD) together. The resulting triple-decker assembly is shown in **Figure 4**. Once you've got this far you must be pretty good at soldering already so your new solder station is bound to work straight away! All three boards can now be fitted into a standard Bopla case (**Figure 5**). There's enough room for the power supply also. Wire up a 3.5-mm free jack socket to the connections at K5 and plug in the soldering pencil. Connect the power supply to connector K6 (here you need a power supply that can deliver at least 50 watts, otherwise when you switch the unit on it won' t be the soldering bit that heats up but the power supply unit itself). Now with the unit in operation you can use the rotary encoder and display to dial up the bit temperature required. Unless you've got super-human senses your eyes won't be able to see the infra-red heat of the tip but you can read off its temperature on the display. Happy soldering! ⏮

(140107)

Platino

The Platino [3] is a powerful microcontroller board using a 28-pin 8-bit AVR-microcontroller from Atmel, developed in 2011 it is a product brewed up in a wizard's kitchen somewhere in the depths of the Elektor Labs. The basic version uses an ATmega328P but it also operates just as happily with an ATmega168, ATMega324 or the more powerful ATmega1284. The Platino's user interface used here consists of a rotary encoder and an alphanumeric 16x2 LC-display with backlighting.
It's no accident that the Platino name sounds a bit like that world famous Italian star, the Arduino. The author originally designed the solder station as a shield for the Arduino system [4]. There are some differences between the Platino and Arduino but they share a common pin out for shield connections so that shields can also be used in the Platino environment.
The versatility of the Platino design (October 2011) makes it suitable for a wide range of applications including a Transistor Tester (March 2015), a lab power supply (April 2014) or a function generator (January 2015). Should you be interested in building any of these designs you can go to the Elektor Store and order a ready-made high quality PCB and the pre-programmed microcontroller:

Magazine	Project	Bare PCB	Controller
October 2011	Platino	100892-1	-
March 2014	Platino expansion board	140433-1	-
October 2012	Combi I/O Shield	120306-1	-
April 2014	Lab Power Supply	130406-1	-
January 2015	Function Generator	130407-1	130407-41
March 2015	Transistor Tester	130544-1	130544-41
July & August 2015	SMD Solder Station	140107-1	140107-41

Arduino as I²C Slave

By **Clemens Valens,** Elektor.Labs

The venerable I²C bus has never been more popular. Most modern microcontrollers either have a hardware I²C interface or are capable of bit-banging one in software. Many sensors, AD and DA converters, memories, real-time clocks and displays exist in versions sporting an I²C interface.

Connected to the I²C bus are two or more devices of which one — and one only – at a time is Master while the others are Slaves. Only the Master talks to the Slaves; they cannot talk to each other directly. Usually the Bus Master role is assigned to a microcontroller.

But what if you want two or more microcontrollers to communicate over an I²C bus structure? They cannot all be Bus Master at once, and a Master can only communicate with Slaves anyway. Since only one can be Master, the others have to be Slaves (or must be passive, i.e. not interfere with the bus). So how do you make a microcontroller an I²C Slave? Let's head over to the Arduino playground to dip our feet in Slave concepts that have to be mastered (pun intended).

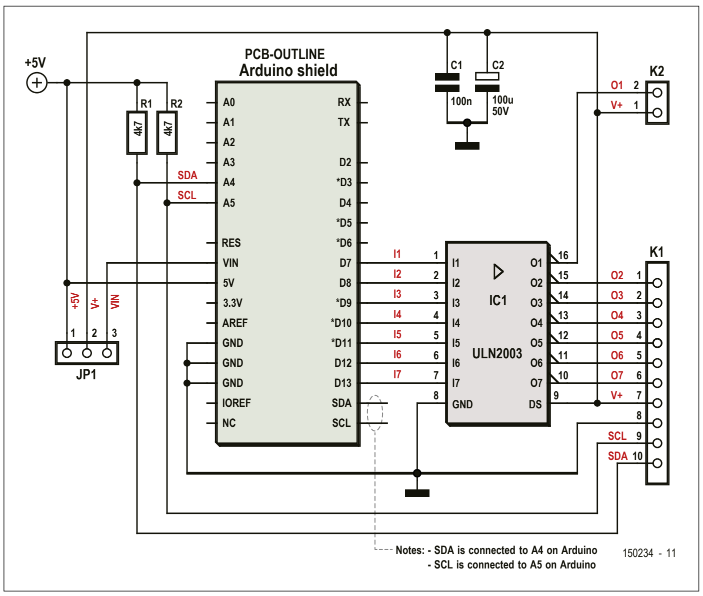


Figure 1. The test circuit used for our I²C Slave experiments.

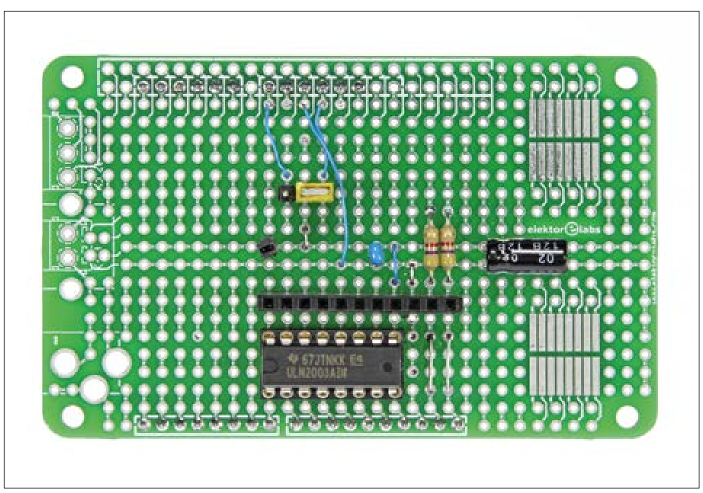


Figure 2. We assembled the circuit on our new Elektor.Labs Prototyping Board (ELPB-NG) described elsewhere in his edition.

The Arduino IDE includes the Wire Library that handles I²C communication. Configuring it as a Slave is easy: simply pass the function `Wire.begin` the Slave address you have chosen. You probably want to receive data or commands from the Master and maybe also return some. For this you have to install two *call-back* functions in your sketch, one for receiving and one for sending. Here is the complete Arduino Slave setup sequence:

```
Wire.begin(I2C_SLAVE_ADDRESS);
Wire.onReceive(receiveEvent);
                    // Called for master write commands.
Wire.onRequest(requestEvent);
                    // Called for master read requests.
```

In this case you should provide both the functions `receiveEvent` and `requestEvent` (you are of course allowed to change their names). The first one is called by the MCU's I²C peripheral when the Master sends data to the Slave, the second one when the Master wants data from the Slave. After a call to `receiveEvent` you can read the data by calling `Wire.read`. When `requestEvent` is called you must send data with `Wire.write`.

Now we have arrived at "a potential issue" because the Slave doesn't know how many bytes the Master wants to read. There are two solutions to this problem:

- Define a high-level communication protocol as is done in the datasheets of I²C Slave devices.
- Write data until the Master cuts the connection.

The first solution is of course the best and highly recommended, but requires more effort from you. The second only works if the MCU's I²C peripheral has sufficient relevant qualities.

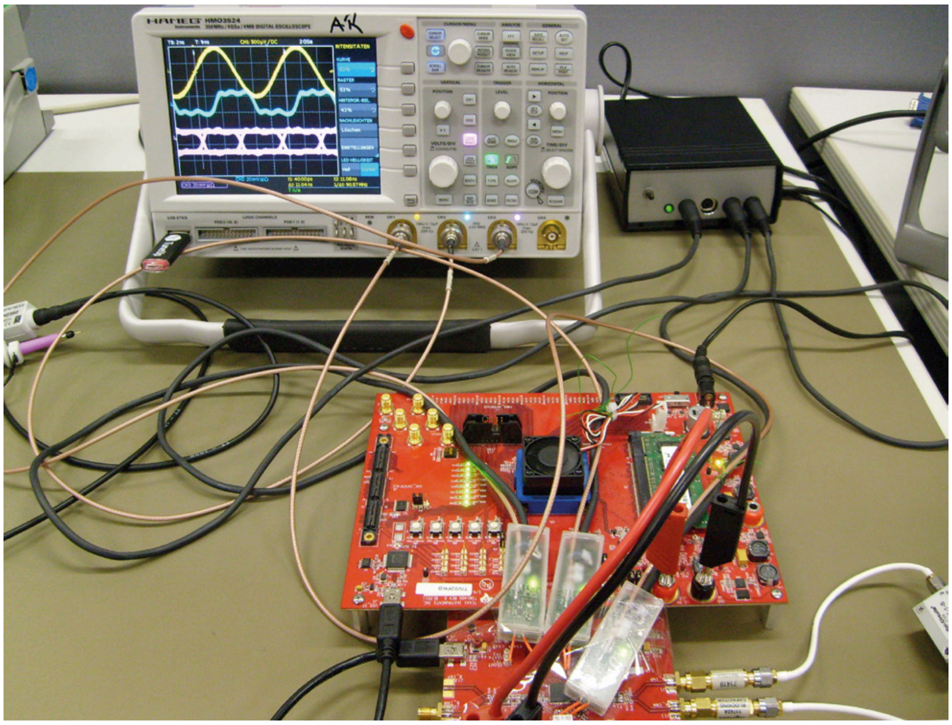
Another important thing to keep in mind is to make the functions `receiveEvent` and `requestEvent` as fast as possible (which doesn't necessarily mean as short as possible), otherwise they may result in data loss, slow down the I²C bus or both.

I have prepared two sketches for you to play with. One is an I²C Slave Stepper Motor Controller, the other a Serial-to-I²C bridge. Together they make two Arduino boards communicate over an I²C bus and control a stepper motor from the serial terminal. Elektor Members, everyone, download them from www.elektor.com/150243.

(150243-I)

2-GHz Active Differential Probe

Budget design, vast bandwidth



By Alfred Rosenkränzer (Germany)

High-speed digital signals such as HDMI, DVI and USB are usually transferred differentially. For measuring these signals you have to use active differential probes but the steep price of these special probes puts them beyond the reach of enthusiasts and small firms. This article describes the making of an active differential probe in a USB stick-style case, offering an impressive bandwidth of almost 2 GHz.

Technical specification

- Attenuation: 10:1 with a differential signal and 50 Ω termination in the 'scope
- Differential input resistance: 5 kΩ
- Single-ended input resistance: 2.5 kΩ
- Output resistance: 50 Ω
- Bandwidth: 1.9 GHz (–3 dB)
- Rise/fall time: 300 ps
- Power supply: ±8 to 12 V DC

Rapid digital signals are nowadays delivered differentially. Examples we could mention include HDMI, DVI, Display Port, SATA, USB, Firewire and Panel Link. The protocols and coding methods used, such as TMDS and 8b10b, vary but many commonalities exist at the electrical level, the so-called Physical Layer. The signals are propagated differentially over two wires, i.e. in a push-pull manner. Their amplitude amounts to only a few hundred mV, whereas the offset is a few volts in the main. The two signal conductors are usually terminated with 100 Ω between the two wires.

The receiver evaluates only the voltage differential between the two conductors, with common-mode interference on the wires being suppressed in this way. The small signal variation (swing) helps to minimize EMC radiation. In this way high data rates can be transferred with only moderate slew rates. ECL (emitter-coupled logic) ICs have employed this technique for some decades now, although now mainly CML (current mode logic) or LVDS (low-voltage differential signaling) are used. This type of I/O is also provided by FPGAs.

It goes without saying that standard high-impedance probes can be used to measure these signals. If you want to display the actual difference between two signals you will then require two probes and use the mathematical function of the oscilloscope. In this application the probes must be as close to identical as possible, not just amplitude-wise but also in terms of timing.

In the professional test and measurement field active differential probes for this kind of measurement are provided, for example, by Keysight (formerly Agilent), Tektronix, Rohde & Schwarz and others. Their bandwidth ranges from a few hundred MHz up to more than 10 GHz. Being active probes, they require a power supply, for which corresponding contacts are provided on the 'scopes.

It's hardly surprising that equipment from one manufacturer is generally incompatible with that of another. At the lower end of the price range there are probes that can be driven via a USB connection, for

example that of a 'scope. If you wish to make use of multiple probes, for instance to measure data and clock signals simultaneously, you may find yourself short of USB sockets. Relying on 9-V battery operation is not so clever either, as these don't last long (especially when you forget to switch off a probe).
Finally the price of $900 / £600 / €800 upwards makes these probes prohibitively expensive for enthusiasts and even small firms. This could change now...

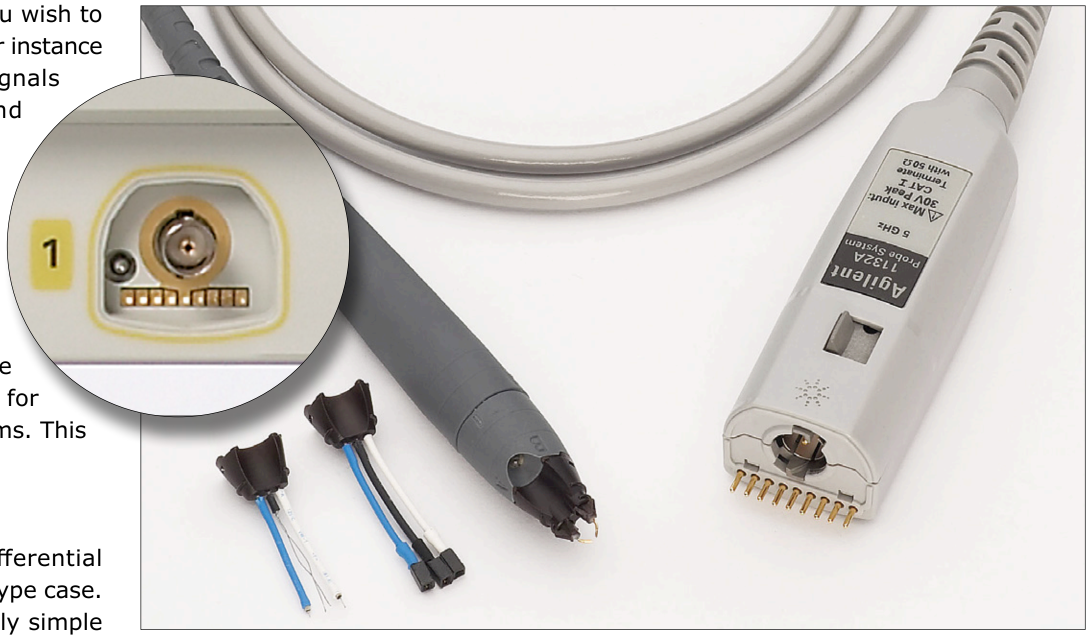


Figure 1. Input of a 'scope with special contacts and a matching differential probe (source: Keysight).

Circuit

We present here an active differential probe in a USB memory stick-type case. **Figure 2** shows the disarmingly simple schematic.
An ADA4927-1 'Fully Differential Amp' from Analog Devices is what we use. It has two inputs and outputs, both elements being wired identically. Amplification amounts to 1/5 in each case, corresponding to the relationship R7/ (R3+R4). The precise resistance value of R7 and R8 was selected to achieve as broad a flat frequency response as possible. In this case it's around 1.9 GHz, which is broad enough for many signals and 'scopes.
The input signal is present on the IN+ and IN– contacts. For transmitting the output signal we use only the negative output (–OUT), which drives, via a 50 Ω source resistance, the oscilloscope input, which must be terminated in 50 Ω (ideally on the internal function, otherwise directly at the input connector). Referenced to the amplitude of one of the input signals (not the sum of them), the probe has an amplification of 1/10, like a passive high-impedance probe (when terminated with 50 Ω).

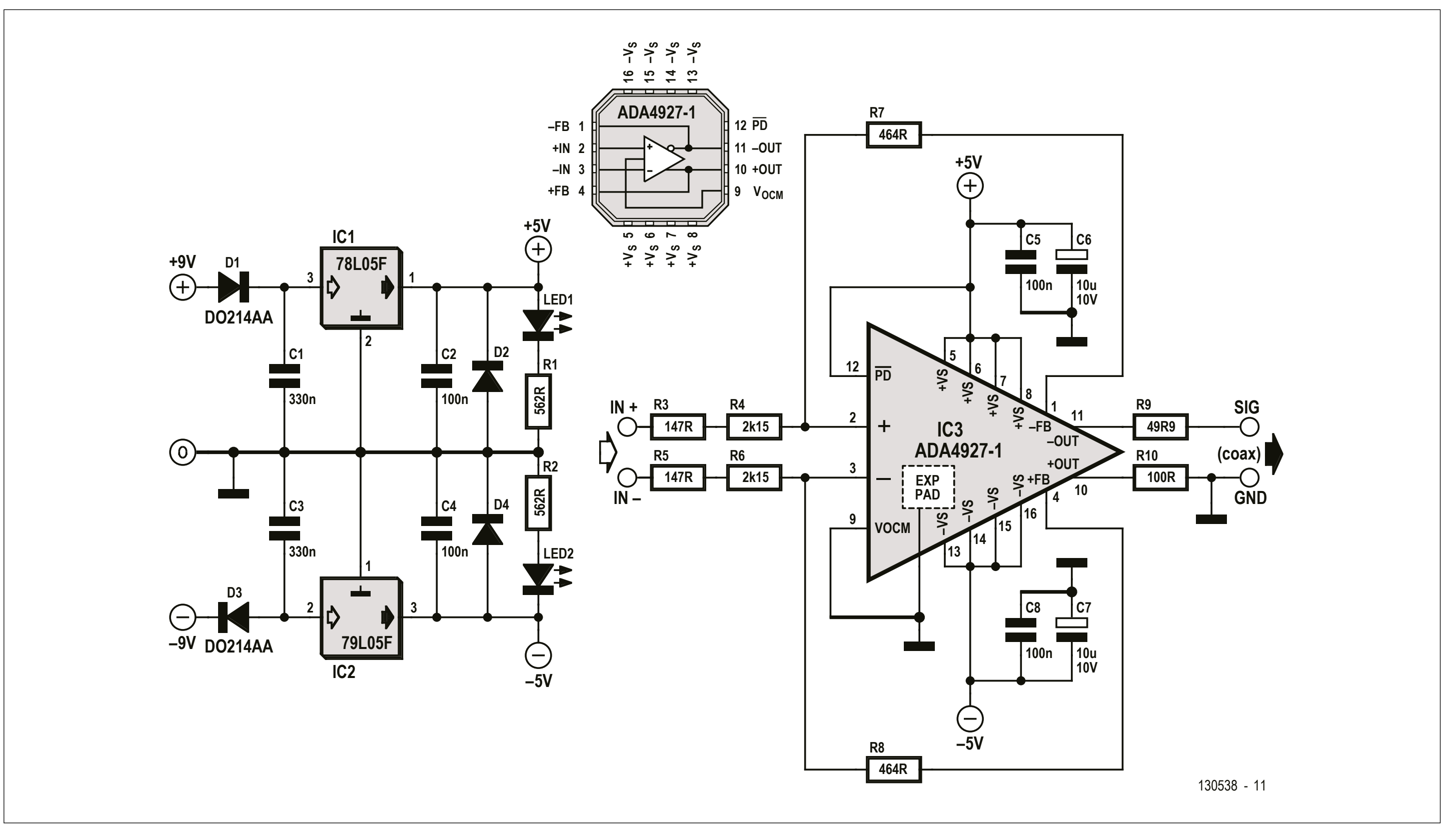


Figure 2. Schematic of a differential probe.

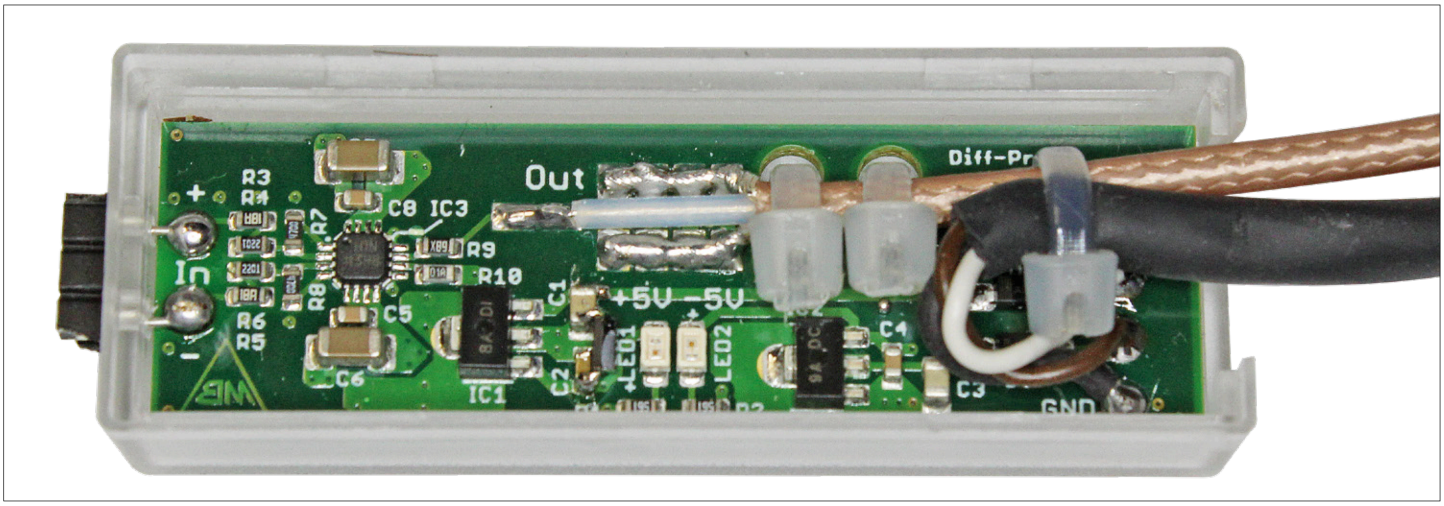


Figure 3. Completed probe in a transparent USB case.

The differential input impedance lies around 4.6 kΩ. This appears very low compared with a passive probe. However, high-speed signals are of very low impedance (100 Ω), so we can get away with this.
The unused output of the IC is taken to ground via 100 Ω, in order to guarantee a symmetrical load.
The IC has a V_OCM input, with which you can equalize the offset of the IC. Here, however, we shall refrain, as offset is compensated at the 'scope end. Accordingly, we connect the pin to GND.
The shutdown input is connected to the positive supply voltage and thus the IC remains always active.

The IC has a so-called exposed pad (EP) on its underside and this must be connected to GND. Both supply voltages of

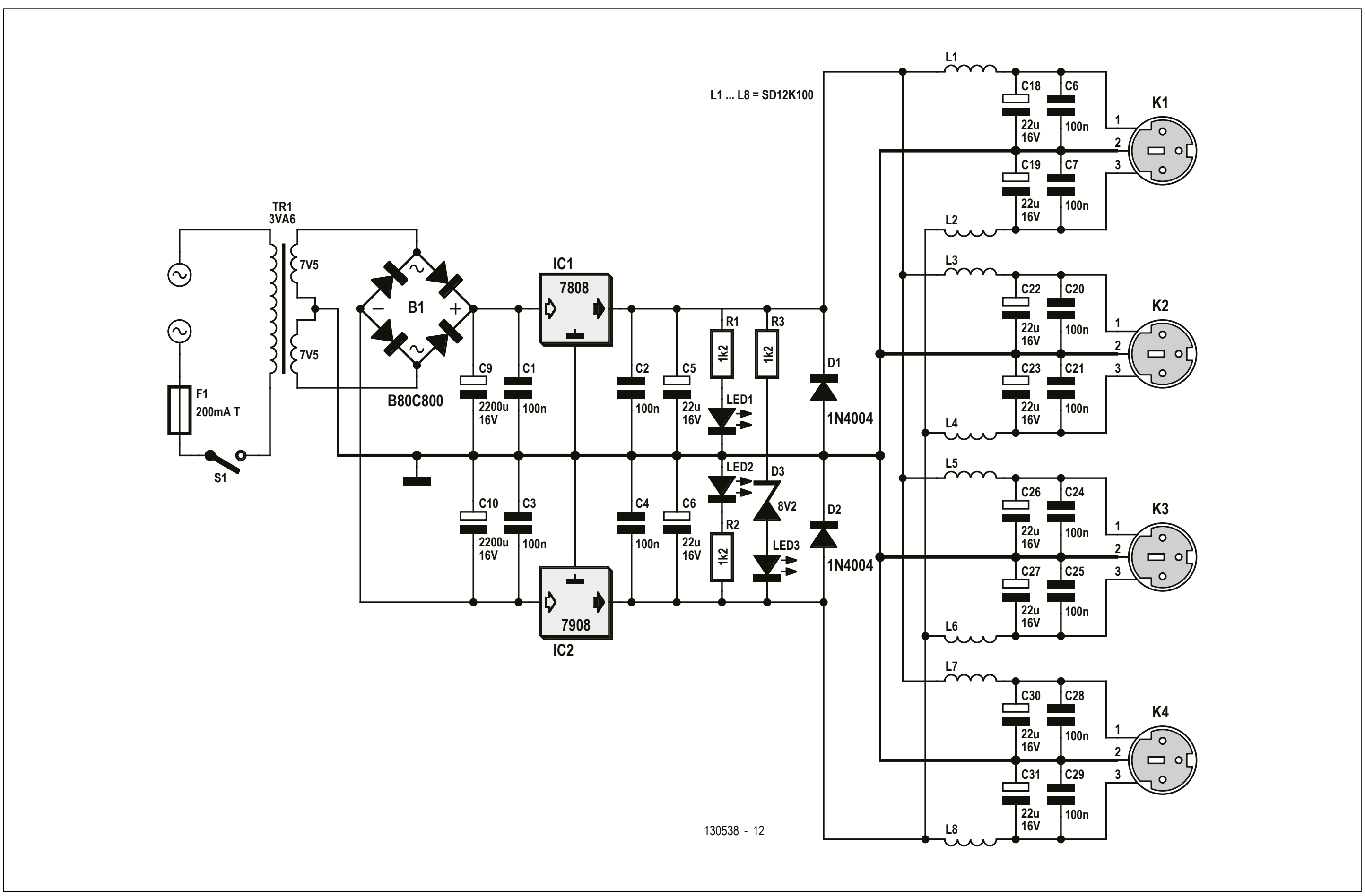


Figure 4. Schematic of benchtop PSU for powering probes.

Professional-quality differential probes are too expensive for enthusiasts and small firms

±5 V are blocked (decoupled) with two capacitors to GND. They are produced using two regular linear regulators, IC1 and IC2. D1 and D3 protect against reverse polarity of the supply voltages. D2 and D4 prevent the voltage regulator from latching up should one voltage be applied earlier than the other. Two LEDs indicate readiness for operation.
Utterly simple though the circuit may be, laying it out correctly is highly critical for achieving the desired function.
The author uses a 4-layer board. The top layer contains the signal connections, whilst the next layer is a continuous ground plane acting as a reference point. The two remaining layers serve for the power supply. As mentioned earlier, the IC has an exposed pad on its underside, as it must be connected to ground. Since this is not easy for hobbyists to solder, the author offers a fully assembled and tested PC board.
The IC has two pairs of outputs. The links located right next to the inputs (+ FB; -FB) are used on R7 and R8 to close the gain loop. The other two on the right are used as outputs. The connections of the two supply voltages above and below are decoupled to ground as close as possible using two capacitors. Several vias are used for both the supply voltage and ground plane in order to keep inductance as low as possible.

Mechanical matters

The PCB for the probe fits inside a transparent USB case (**Figure 3**). The coax cable with the BNC connector has its inner conductor soldered to the Out pad and the screen to the pad on the right of this. The adjacent openings are to make it easy to fix the co-ax using cable ties. At the solder pads +9V, –9V and GND we solder the power supply lead. After placing the PCB in the case, we insert a 3-pin stud connector into the openings on the front side, after first removing the center pin, and make solder connections to In + and –. Into this 'receptacle' we insert the counterparts onto which we can solder short, thin wires to which in turn the signal wires are connected. This enables us to mount the receptacle first and plug in the probe later, so that you can switch between several signals. If the receptacle becomes worn out you can construct a new one. Holding probes with two inputs is rather impractical...

If you own several probes, you should take care that the lengths of co-ax cable used are identical. In this way you avoid variations in transit time between probes and possible false readings. Any residual balancing can be compensated on most 'scopes (skew adjust).
For measurements of differential signals the offset common to both signals is suppressed, only the difference being displayed. If you want to measure the offset, you can use a high-impedance probe or ground one of the two inputs. You should, however, pay attention to the relatively low input resistance.

Power supply

Power supply for the probes can be provided from a laboratory power supply of > ± 8V. The operation of a single probe like this is straightforward but with several probes in use the wiring becomes a bit trickier and somewhat confusing. Therefore, a suitable bench-top power supply has been developed (**Figure 4**), which can serve up to four probes corresponding to the four inputs maximum of an oscilloscope. The connector device selected is a 3-pin mini-DIN plug. This prevents mismatching. The four outputs have comprehensive internal filtering, in order to minimize crosstalk from one probe to another.
The power pack consists of a transformer with two secondary windings, rectifiers, capacitors and two linear regulators, including the usual decoupling capacitors. Two LEDs indicate operation of the two internally isolated voltages, with a third in the front panel showing that both voltages are present (thanks to a zener diode in series with the LED). Two diodes prevent damage caused by reversed polarity, which might be applied accidentally to the output.
Both voltages are filtered with chokes and capacitors before they reach the output connector.

Summing up

For a relatively modest outlay you can construct at home an active differential probe with very high specifications (see **Figures 5** and **6**), for a fraction of the price of comparable commercial products. It is of course necessary to use high-quality components as well as a well thought-out PCB layout.

For readers who are interested the author offers ready-to-use and tested PCB modules, also a kit consisting of case, RF cable with BNC connector and power supply lead with plug. Further information from: alfred_rosenkraenzer@gmx.de.

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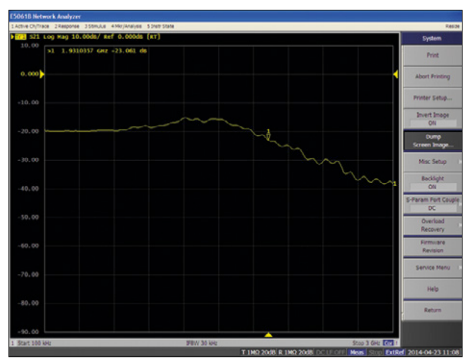

Figure 5. Frequency curve for the probe up to 3 GHz. The –3 dB point is located around 1.9 GHz.

Figure 6. Measuring a 300-MHz clock signal with a 2-GHz 'scope.

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EDITOR'S CHOICE

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Raspberry Pi Advanced Programming

This book is about advanced programming of the Raspberry Pi computer using the Python programming language. The book explains in simple terms and with examples: how to configure the Raspberry Pi computer; how to install and use the Linux operating system and the desktop; how to write advanced programs using the Python programming language; how to use graphics in our programs and how to develop hardware based projects using the Raspberry Pi.

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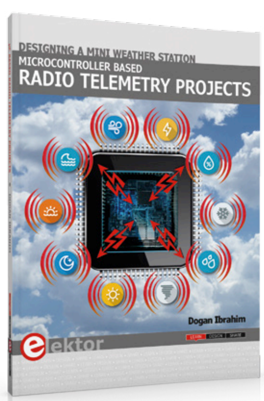
Microcontroller Based Radio Telemetry Projects



This book is written for people who want to learn more about radio telemetry applications and microcontroller programming using the PIC18F series of microcontrollers. The design of a radio telemetry based mini weather station is considered as an example system in the book where the developed system can measure the temperature, humidity, atmospheric pressure, carbon monoxide level, nitrogen dioxide concentration, air quality level, wind direction wind speed and more.

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Bert van Dam's book *Piccolino – 30 Projects, Mods, Hacks and Extension Boards* contains 30 projects based on the Piccolino. The clear descriptions along with circuit diagrams and photos will make the building of these projects an enjoyable experience!

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This kit is a faithful and functional transistor-scale replica of the classic NE555 timer integrated circuit, one of the most classic, popular and all-round useful chips of all time. The kit is designed to resemble an integrated circuit, based around an extra-thick matte-finish printed circuit board. The stand is made of formed semi-rigid PVC foam which gives the circuit board eight legs in the shape of DIP-packaged integrated circuit pins.

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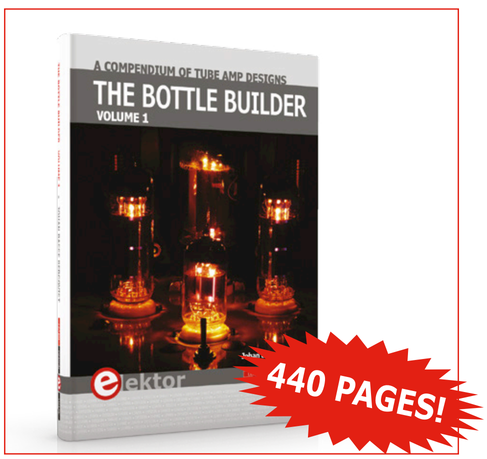
The Bottle Builder



This massive compendium of tube amplifier designs presents an impressive gallery of tube amplifier projects described not just with a personal stance, but also humor, an open mind, good anecdotes, and an equally good emphasis on all the technical aspects of design and implementation. With every project, the focus is on what makes a particular amplifier "special" in terms of design or performance, which as we all know are not necessarily in agreement.

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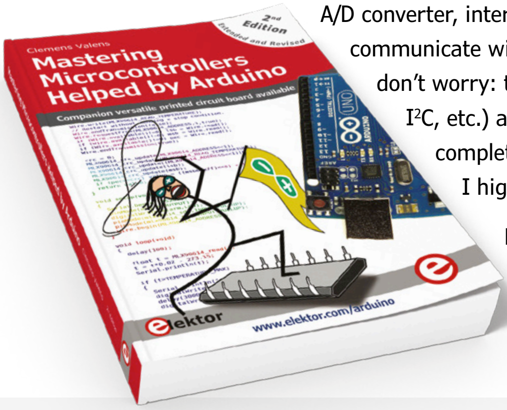
REVIEW OF THE MONTH

BY MARCEL ČLOVEČKO

Are you a newbie in the exciting world of (digital) electronics? Have you ever wondered what a microcontroller is and what can be done with this mighty little chip? If you answered "yes", then this is one of the best books for you. For me, as the owner of a first edition of this book, it was a really inspiring and eye-opening experience. I had some previous experience with Arduino (and Atmel AVR chips in general), but it was usually quite frustrating as there was no useful introductory book available. Until the day I got my hands on this book, and everything changed. The book is masterfully written and I have really enjoyed the author's sense of humor. After an introduction into the realm of Arduino (and microcontrollers in general) the author takes us on an exciting tour of basic and more advanced features of microcontrollers (digital input and output, A/D converter, interrupts). However, the microcontroller often needs to communicate with various sensors and/or other microcontrollers. But don't worry: the secrets of several communication protocols (serial, SPI, I²C, etc.) are revealed as well. All of this is accompanied with working program examples and complete program listings.

I highly recommend this amazing book!



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OBD USB KKL Diagnose-interface

New in the Elektor Stores the K²L901 OBD USB KKL Diagnose-interface at a very interesting price. Features a very small and transparent connector housing with integrated OBD-2 connector with gold-plated plug contacts. The cable outlet can be rotated by 180 ° (by opening the case) and three LEDs: USB voltage, data send, receive data are installed so that they can always easily be seen, no matter how the OBD connector has to be plugged in. With the K2L901 diagnostic interface you can quickly get into the vehicle diagnostics. It is simply plugged into the OBD II connector in the car and connected to the USB port of your computer. Functions available may vary based on what diagnostic software you install on your computer.

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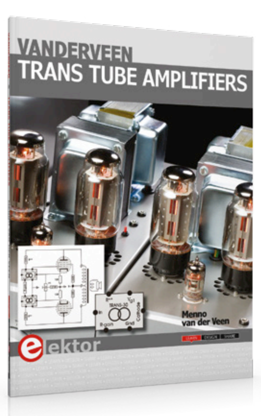
Vanderveen Trans Tube Amplifiers



In this book Menno van der Veen describes one of his research projects focusing on the question of whether full compensation for distortion in tubes and output transformers is possible. A variety of methods have been developed with the aim of attaining this goal. One of them has largely been forgotten: transconductance, which means converting current into voltage or voltage into current. Menno van der Veen has breathed new life into this method.

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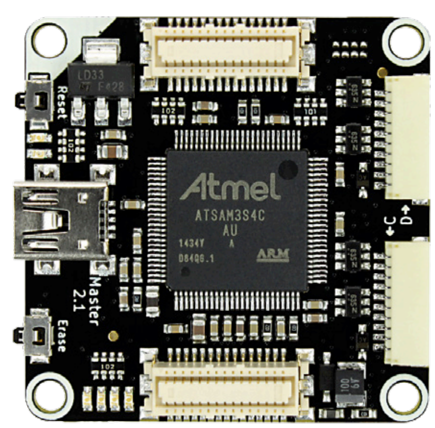
Tinkerforge Master Brick 2.1



New in the Elektor Store: Tinkerforge acclaimed Bricks and Bricklets! This Master Brick has four Bricklet ports and therefore is ideally suited for applications where many sensor Bricklets (also found in our Store) are being used. These can be directly controlled over the USB interface of the Master Brick. This way USB sensors, like temperature or humidity sensors, or USB actors like relays, can be created according to your individual needs.

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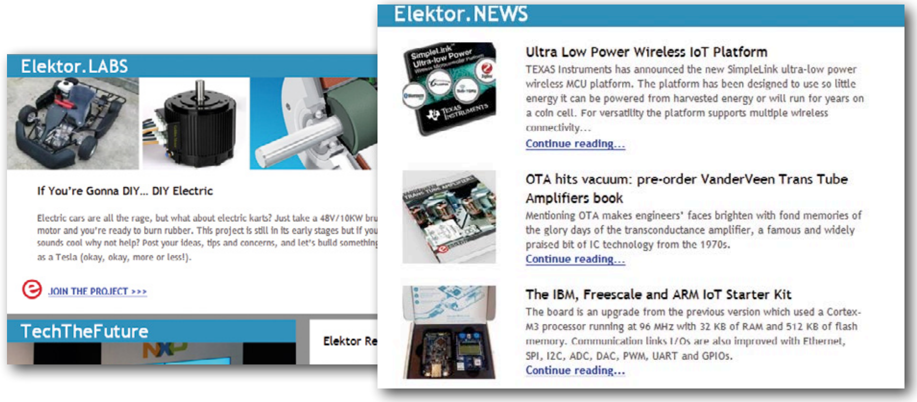

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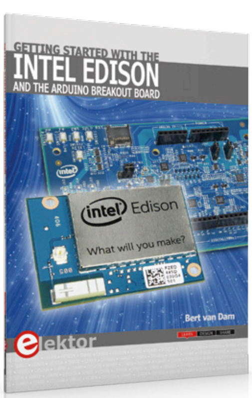
Getting Started with the Intel Edison



This book is a must have for all those with an active interest in the Internet of Things. 'Getting Started with the Intel Edison' focuses its attention on the Edison, a tiny computer, the size of a postage stamp, with a lot of power and built-in wireless communication capabilities. In 128 pages, renowned author Bert van Dam helps readers get up to speed with the Edison by making it accessible and easy to use. Explore the wonderful world of the Intel Edison now!

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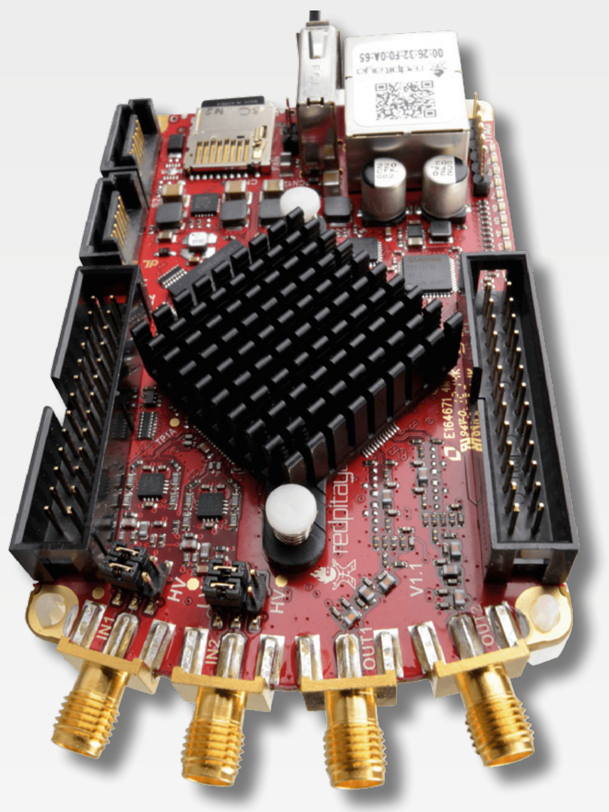

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Red Pitaya, the open source measurement and control tool at the size of a credit card can replace many expensive laboratory measurement instruments. The Red Pitaya unit is a network attached device based on the Linux operating system. It includes Radio Frequency signal acquisition and generation technologies, FPGA, Digital Signal Processing and CPU processing. The Red Pitaya unit is equipped with a Micro USB socket used for console connection, a microSD slot, a RJ45 socket for Ethernet connection and a USB socket used for standard USB devices. This high performance hardware now comes at a totally surprising price tag.

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Welcome to the **SHARE** section

By **Jaime González-Arintero**
jaime.glez.arintero@eimworld.com

while(1){ reinvent(yourself); }

An unbeatable expert in just one narrow field, or a Swiss knife with quick solutions for every case? To design engineers, specialization is key. But in other fields like service engineering, improvisation and knowing a little bit about everything helps — a lot. Although I am not an expert, I always say that we electronics engineers are more versatile since we end up knowing that bit extra about mechanics, photonics, chemistry, etc. without even noticing it. It's just a consequence of trying to stay up to date in these fast-moving areas. Some EE's are constantly reinventing themselves. But as we grow older, learning new things gets more difficult. The same seems to happen with companies. Some big, rigid, all-specialized enterprises are unable to diversify or cope with new trends, and eventually fizzle out. Like individuals, surviving companies always reinvent themselves.

At some point last week, browsing around I stumbled on the blog of the American entrepreneur Steve Blank, who posted a memo that obviously made me smile. I highly recommend reading the entire article at [po.st/hpmemo], but in any case, here's a brief summary. In 1956, Provost at Stanford University, Frederick Terman wrote to one of his former students, William Hewlett. Fred asked for advice in the name of the US Army Signal Corps Advisory Board, since they were about to acquire their first computer for research purposes. Together with David Packard, Hewlett was the co-founder of the company that still bears their names. Hewlett's reply was: "I have no personal knowledge of computers nor does anyone in our organization have any appreciable knowledge." Who would have thought that!

Already in the early 1960s, HP was an incredibly successful company specialized in test and measurement equipment. Packard wanted to get into the computer business, but Hewlett wasn't that supportive. It is said that Packard even made an attempt to acquire fledgling Digital Equipment Company — without success. Curiously, in 1998 it was absorbed by Compaq, which in turn was acquired by HP in 2002; so Packard made it, at last! In any case, in 1966 HP introduced their first minicomputer, the 16-bit 2116A — more of an instrument controller than a computer. Two years later, their first programmable desktop calculator, the 9100A: more like a desktop computer than a calculator. After adding several (digital) products to its portfolio, in the 1970s HP became the world's largest technology vendor. Indeed, until at some point in 2013, it remained the world's leading PC manufacturer. Not bad for those guys without a clue about computers, huh?

But HP's reinvention never meant discontinuing its measurement instruments business, the activity that made the company famous. Indeed, in 1999, HP spun off this division as Agilent. And last year, Agilent separated the product lines once again, creating Keysight Technologies, which now holds the electronics and radio division. And what about the genuine Hewlett-Packard? After adverse times during the crisis, they seem to be reinventing themselves yet again. Look what we have today: Memristors! ◀

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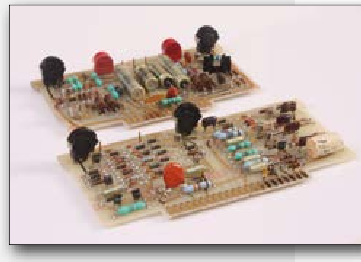
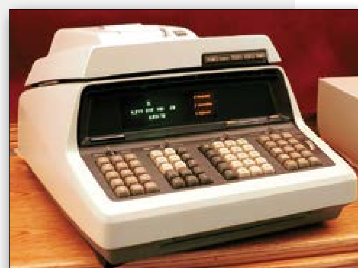
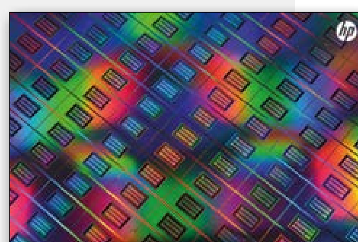


Not a motherboard from a modern HP workstation, my friend, but a couple of boards recovered from a 1969 Type 3300A function generator. Pic stolen with malice aforethought from Jan Buiting's Retronics. +6 dB to Jan! ☺



HP 9100B with printer attached. © David G. Hicks, The Museum of HP Calculators [hpmuseum.org]



HP Memristors on a 300-mm wafer. © 2015 Hewlett-Packard Development Company, L.P.

"It is not enough to be industrious; so are the ants. What are you industrious about?" – Henry David Thoureau

Electrifying Paintjob

Bare Conductive is a young company that “designs and manufactures technologies that connect any surface, object or space to the digital world”. They stepped into the hiatus where design, technology and material innovation come together, having developed an electrically conductive paint, *Electric Paint* that enables you to “draw a circuit, cold solder a component or turn any surface into a sensor”.

Of course we had to try this out for ourselves and back it up with some measurements. So we ordered a couple of tubes and while waiting for UPS/FedEx etc. got mesmerized by ideas of painting circuits on mugs, tables, windows and huge glass doors using LEDs and fancy sensors. Before we started drawing any circuits, we put the paint into a syringe. This wasn’t really necessary, but we found we could manage the amount of paint applied a little better [**photo 1**]. We drew up a circuit with three duo LEDs found in a drawer on a viewfoil sheet [**photo 2**] and used the paint to connect a couple of thin leads to power the circuit [**photo 3**]. Especially this connection of the leads proved very delicate. We waited an appropriate time for the paint to dry — it doesn’t conduct when wet — and then hooked up a lab power supply. After setting the current limit to 20 mA we started turning up the voltage. It took a staggering 12 V before the LEDs lit up [**photo 4**].

photo 1

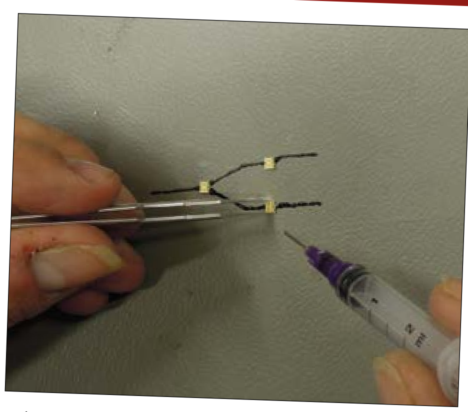


photo 2

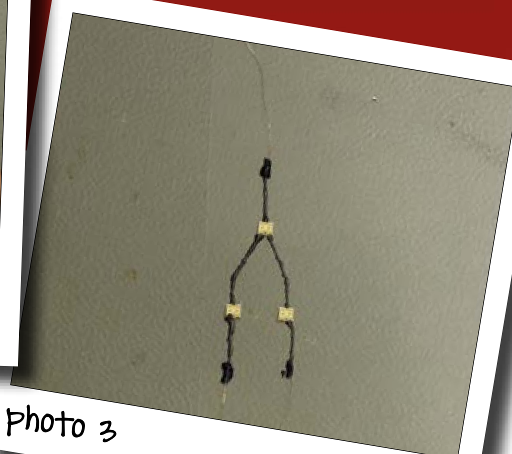


photo 3

Ok, so the paint was indeed conducting electricity, but it wasn’t exactly an MIT-grade superconductor. The specification sheet states “Surface Resistivity 55 Ω/Sq @ 50 microns”. This somewhat odd description is elaborated further down in the datasheet. It means that when you paint a square, its resistance will be 55 Ω when the layer is 50 microns thick. It doesn’t matter how big the square is, as long as it’s a square. As long as the length and width increase or decrease equally, the total resistance will not change.
Back to our measurements. There were only two LEDs connected in series, which means they were accountable for a voltage drop of about 5 V. Consequently the remaining 7 V were wasted, the resulting heat being dissipated by approximately 7 cms of paint. At 20 mA that’s just 140 milliwatts so nothing getting hot, no worries there. A voltage drop of 7 V with 20 mA carried also means a total resistance of 350 Ω, or 50 Ω per cm.

The recommended maximum voltage that can be applied to the paint is 12 volts, which did limit the number of LEDs in our tryout to two. So painting a big surface with long lines, like a door and applying roughly 100 LEDs... not a bright idea.

We moved on to do some rudimentary measurements. We laid down a line of paint straight from the tube and measured its resistance. Our results: roughly 80 Ω per cm of paint. That’s 60% over the value from our first tryout. *Ergo*: consistency in resistance could prove hard to achieve. Not unimportant either, consider that that copper wire with a diameter of 0.5 mm (AWG 24) has a resistance of approximately 80 mΩ per meter. That’s a huge difference!

For comparison, a colleague brought a tube of conductive glue, recently bought on eBay. Not only did it stick much better (glue *vs* paint), the conductivity was about 5 times better. Looking

By **Thijs Beckers** (Elektor Labs)

At Elektor Labs we're not fearful of new technologies. In fact, we try to keep a keen eye on things happening on the market. Lately *Electric Paint* popped a buzz. Though not really a new concept, we decided to give it a quick try.

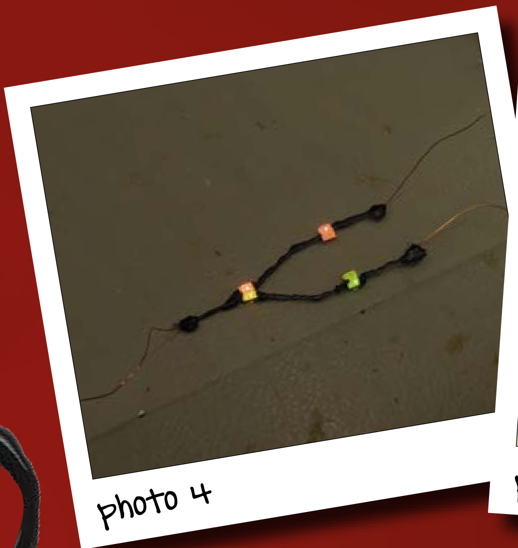


photo 4


photo 5

at its color, this glue probably contained a metal compound as the conductive component, whereas Electric Paint seems based on carbon by the looks of it.

The paint doesn't withstand folding well. Soft curves are ok, but with hard bends it just breaks and the continuity is gone, depending of course on layer thickness and substrate material. A thin layer creates the most flexible result. And as you can see, thin plastic is not the best substrate [**photo 5**]. Non-stretchable substrates are highly recommended.

So what's our verdict? We think Electric Paint is usable in applications where resistance is not that important. For example with capacitive sensor setups. Or for very short distances, where resistance doesn't build up with the length of the paint trail. It is washable with water and soap, so make sure it stays dry. In a way this makes sense, as hardly any electric circuit really likes water. But don't expect it to be a substitute for copper wire as its resistance is way too high. ⏮

(150230)

About the Author

Thijs Beckers joined Elektor back in 2005 as a freshman in the Dutch editorial department, immediately following graduating for his BSc degree in Electrical Engineering. After assisting in the English editorial team for a short time while also part-timing for Elektor Labs, he was appointed full time to the Elektor Labs team in 2014. He currently responsible for setting up the production and ensuring the accurate manufacturing of Elektor Kits and Modules. His personal interests are electronics design (with a focus on audio-related electronics), loudspeaker design, repairing electronics and (e-)drumming, where e-drumming can be the ultimate combination of all three other interests.

Dot Labs Slash Cool

Your e-creativity never fails to amaze us

Adapt and Survive also applies to electronics. Let's have a look at recycling an old phone's AC adapter and how to make a 'scope useful for slow-changing events by making it *hold its horses*. Besides, we'll be monitoring atmospheric pressure, operating switches remotely and adding a really precise RTC to our projects. It's all happening at www.elektor-labs.com.

No Rush

Most of the signals we work with on our daily basis just go by so fast we wouldn't even dream of interpreting them by ourselves without the help of instrumentation. In contrast some events take place at a snail's pace, and funnily the same instruments are not entirely suited to capture them. This Arduino-Mega Based Voltage Tracker for Oscilloscopes allows you to monitor painfully slowly changing events (like the charge or discharge of batteries), expanding the tracking time up to 12 hours. Just slow down and take it nice and easy!

http://po.st/voltagetracker

Do You Believe in Reincarnation?

At Elektor Labs we do! Reincarnation of old enclosures, we mean. Bringing devices back to life is not only cost-effective, but also useful and fun. This simple circuit may be used as a night light for hallways or rooms, and it fits in the case of an old phone's wall adapter. Being powered directly from an AC outlet is a feature here as it allow wall mounting without the drilling.

http://po.st/nightlight

It's Too Loud (This Time it Really is)

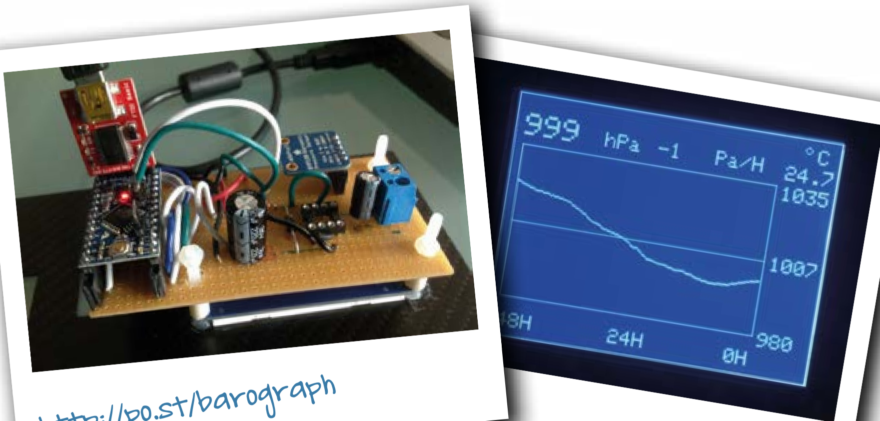
"If it's too loud, you're too old," so they say. But sometimes you just have to be a considerate neighbor, you may need to chill, take care of your ears, maybe your roommate is having a siesta or you just don't want to get a hefty fine for disturbing the peace! Whatever the reason, wouldn't it be really convenient if you could monitor the ambient noise and show the level on a display to give some visual feedback. This Arduino-based "Sound Level Traffic Light" makes use of a 3-pin bicolor LED to show color changes as the noise level exceeds three user programmable thresholds: code green, orange or red.

http://po.st/tooloud

The Distance between Us

Turn a switch remotely via a web browser: Welcome to the future. Okay, it's just a project to get started, but the implementation is so straightforward that expanding it will be a piece of cake. This remote power switch uses a Seeeduino Ethernet to establish an Internet connection, and displays the IP address on an OLED display. Now, once you type this address into a browser, a red or green socket will be displayed, so you can change the status of a relay from anywhere in the world. The graphics are generated from an SVG file. These are vectors drawn directly by the browser itself, and thus platform-independent.

http://po.st/remoteswitch



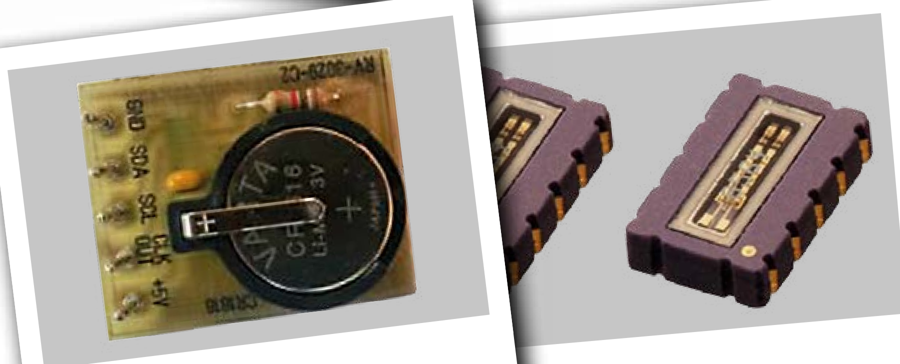
http://po.st/barograph

Sail Away...

...but don't forget your DIY barograph! Sailors know that monitoring the atmospheric pressure can be crucial in order to get ready for upcoming winds. This Arduino-based barograph plots the evolution of the air pressure over 48 hours on a TFT display, saving the data on an SD card. It also provides a flashing LED and a buzzer to advise in case the pressure drops below certain threshold. In case we need it, the pressure sensor also provides temperature readings.

Perfect Timing

Adding a real time clock (RTC) to your design can't be easier, just pick one of the several ICs available in the market. For an outstanding accuracy and I²C connectivity, you may want to use the RV-3029-C2, but soldering this tiny buddy can be tough. Breakout boards to the rescue! This small PCB will ease the job, including the RTC IC on one side, and the CR2032 battery with the rest of the required components in the other one. From now on, you'll have no excuses for being late!

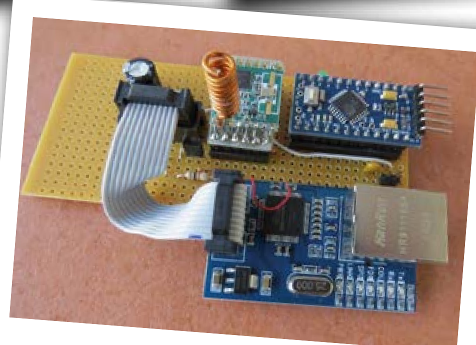


http://po.st/RTCBOB

http://po.st/clapactivatedlamp

Night Lamp Sorcery

Turning the lights on with a finger snap... sorcery, definitely. Wait, it gets worse. If you clap once again, the intensity goes up, and if you do it for the third time, it will turn off again! With this circuit, you can easily modify any night lamp and turn it into a sound-activated one. And indeed, no microcontrollers involved.

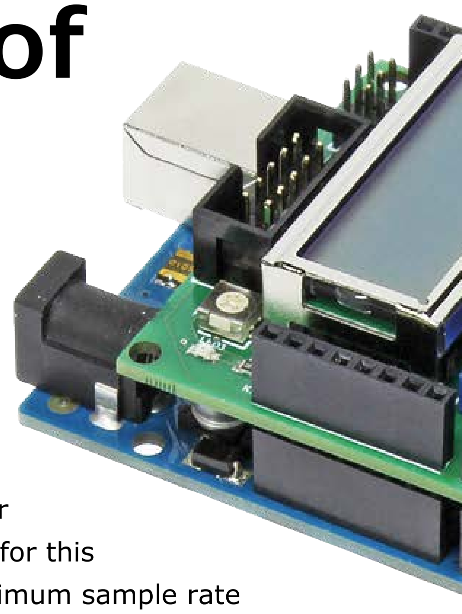


http://po.st/MQTTgateway

Yet Another IoT Gateway

The title says it all, but it doesn't mean this project is not cool. Of course it is! It consists of a main module that acts as a *radio hub*, and communicates with the different nodes of the network using the MQTT protocol. Such nodes are based in the popular RFM69 module, and since the communication is duplex, each party acknowledges reception of each single message to the gateway. The whole project is fully downloadable, so you can start turning things on and off remotely right off!

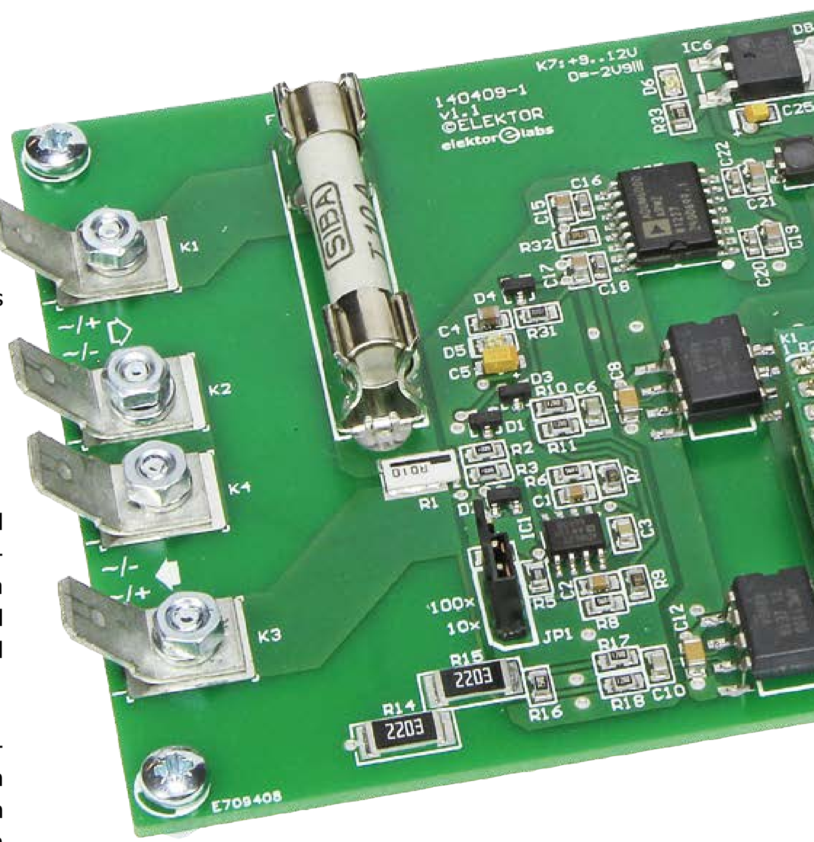
And Then Just a Bit of Software...



It's not always that easy

By Luc Lemmens (Elektor Labs)

While we were developing the ADS1115 BoB, which features a four-channel, 16-bit A/D converter with an I²C interface and was published in the December 2014 issue of Elektor, we asked ourselves: what would be a good application for this breakout board? Although the Texas Instruments IC is very versatile, its maximum sample rate of 860 Hz is not exactly lightning-fast. However, it's fast enough for monitoring the AC line voltage and putting together a power meter, as one of us suggested. That's how the project described here — an AC power meter — was born.

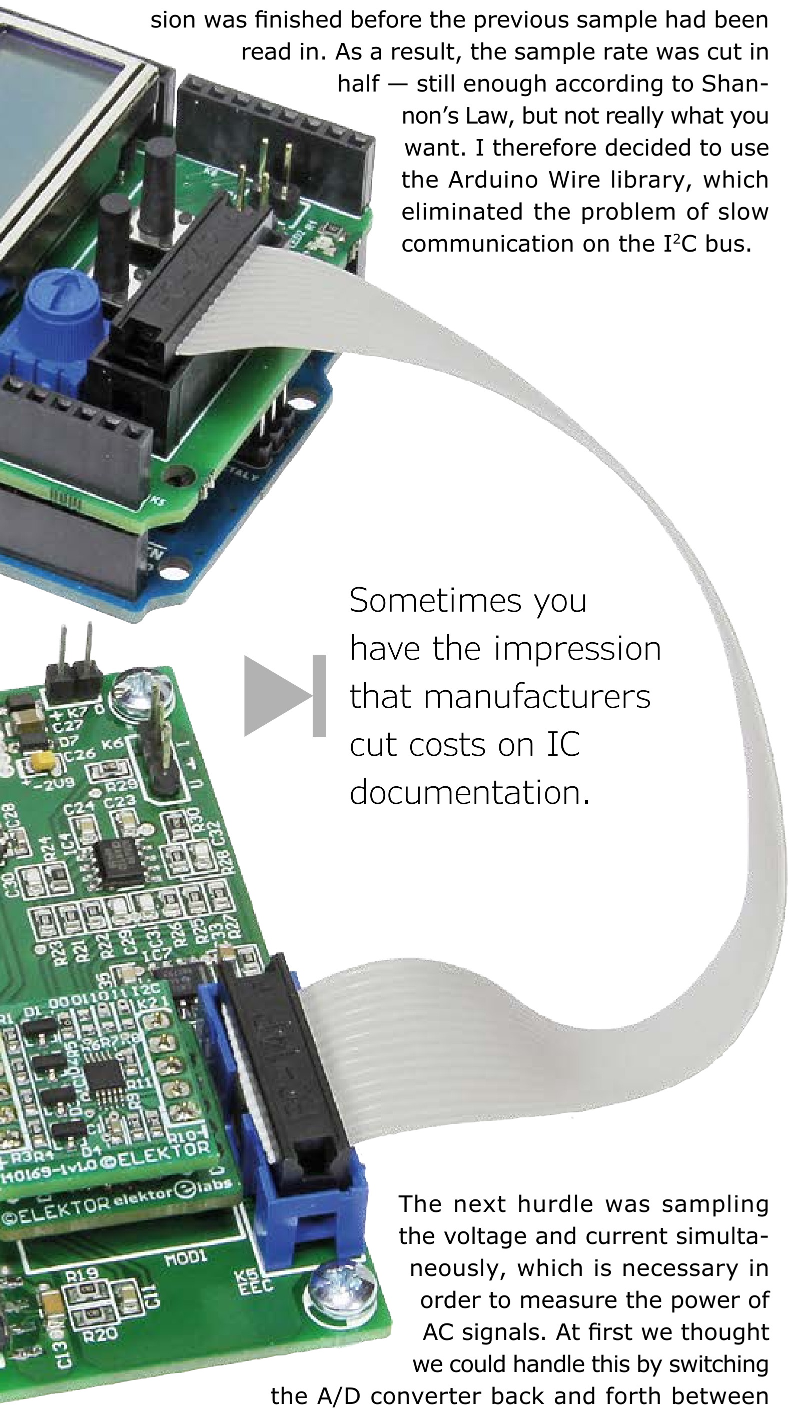


Of course, you need a good deal of additional circuitry to safely measure the voltages and currents involved. We entrusted that task to the skilled hands of Ton Giesberts, who does most of the analog designs in our lab. With a microcontroller and the right peripheral circuitry, it should be easy to acquire voltage and current samples and process them to obtain usable data for voltage, current, power and power factor.

After the prototype of the power meter was built and tested (see 'Power Meter' on the **.**Labs website), I was recruited to do the digital portion and the firmware. The task description was reasonably simple: connect it to an Arduino. That should have been fairly easy, since a code library and a demo program for configuring the A/D converter and reading in data over the I²C bus had already been developed for the published BoB project. That's also what I thought until I actually started working on it.

The demo program for the BoB used a wait loop to acquire sample data from the A/D converter, to make sure the conversion was finished each time before the data was read. That's much too slow if you want to utilize the maximum sample rate, even if it is only 860 Hz. I decided to configure the ADS1115 in continuous mode instead, so the Ready pin of the IC would send an End of Conversion (EOC) signal to the Arduino each time a new sample was ready. That only involved setting a couple of bits in the configuration register to the right values, and it didn't take too long to figure out how to do so. In the process I discovered that the data sheet from Texas Instruments is something less than a shining example of completeness and clarity, and I could not find any reference circuits or application notes from the manufacturer. Sometimes you have the impression that manufacturers cut costs on documentation, or perhaps even the smallest ICs now are so complex that nobody knows all the details. The most annoying part is that you have to figure out some things by trial and error, so you are never really certain.

The demo program also had routines for handling the I²C bus that did not use the standard Arduino Wire library. That was done to allow the code to be used in other development environments. Unfortunately, it did not work well in this application. It made the I²C bus so slow that the next conver-

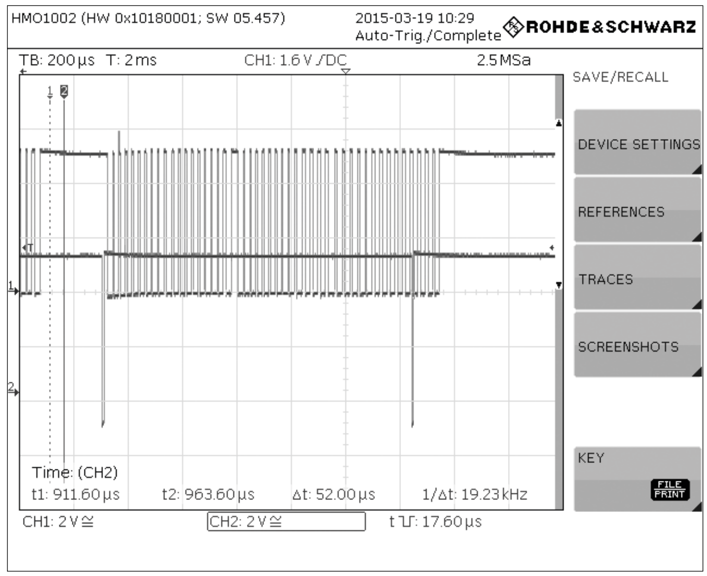


sion was finished before the previous sample had been read in. As a result, the sample rate was cut in half — still enough according to Shannon's Law, but not really what you want. I therefore decided to use the Arduino Wire library, which eliminated the problem of slow communication on the I²C bus.

Sometimes you have the impression that manufacturers cut costs on IC documentation.

The next hurdle was sampling the voltage and current simultaneously, which is necessary in order to measure the power of AC signals. At first we thought we could handle this by switching the A/D converter back and forth between voltage and current after each sample and simply tolerate the resulting inaccuracy or shift the timing of the samples for one of the two signals. We realized that this would effectively cut the sample rate in half, but at first we didn't realize that switching back and forth also takes time. Here again this meant we would have to skip sampling periods, reducing the effective sample rate to 25% of the original 860 Hz — which would leave us with very little margin.

In the end it appeared that the best solution was to acquire a string of voltage samples, then switch to current and acquire the same number of current samples. As long as the voltage and current are reasonably constant, the resulting power measurements should be sufficiently reliable. Of course, you also have to measure the phase relationship between the two signals somehow, but there was no provision for that in the design of the power meter. It might have been possible to handle this in software, but to avoid pushing the limits of the Arduino's processing power (and risking additional timing problems) we added a comparator to the hardware to detect



the zero crossings of the voltage signal. Its output changes state on every zero crossing (from high to low). This signal is used as a trigger to start a series of voltage measurements and synchronize the following series of current measurements after the voltage measurements are done. After these measurement series, the Arduino is given time to process all the samples and display the results on the LCD before it starts a new measurement cycle.

With DC measurements (which are also part of the spec), there are no zero crossings and therefore no synchronization signal. For this reason, the firmware has a time-out that automatically switches from AC to DC if the trigger signal is not detected.

As so often happens, in the end it all looked reasonably straightforward, but still not as easy as we thought at first. Redesigning hardware is never an attractive option, but sometimes you have no other choice.

(150287)

Web Links

[1] ADS1115 BoB project page: www.elektor-labs.com/project/practical-4-channel-adc-140169.14145.html

[2] Power Meter project page: www.elektor-labs.com/project/140409-power-meter.14409.html

Best Tech

By **Gerard Fonte** (USA)

When you design a new product it's always tempting to use the newest and sexiest technology. It's fun and you learn a lot and the product can be described as "incorporating cutting-edge technology". It's a no-brainer. Right? Actually in situations like this, it's important to use your brain and think about the actual requirements of the product. You want to use the best technology, which is usually not the newest technology.

Getting Tense

A few years ago my client wanted a hand-held tension tester that would measure the force needed to extract an AC plug from an AC socket. This was to be a commercial product so price, performance and assembly were concerns. This was a small company and the expected volume was in the low 100's per year. I put together a simple design using a couple of opamps, a strain gauge, and an 8-bit micro that directly drove a bare LCD display. It fitted into their existing case nicely. I chose not to use SMT (surface-mount technology) because they hadn't converted yet. I took extra time to route the PCB (printed circuit board) with a single layer (which is almost always possible with discrete components and user-defined pins on the micro). I was also able to be very conservative and use 0.020" (0.5 mm) traces and 0.030" (0.75 mm) spaces for the PCB. The tension tester worked quite well, was inexpensive and easy to build. It certainly wasn't high-tech and didn't look very sophisticated. But, my client was happy.

A year or so later the same client chose a different company to design an AC-power distortion meter. They wanted a fairly basic tool that would fit into the same case and simply display the main AC voltage and harmonic voltages. The other group designed an elegant system with a high-end micro, a separate, high-resolution analog-to-digital converter and extensive front-end signal conditioning. In order to make it fit into the case, they had to use very small SMT parts and a multi-layer PCB board with traces that were nearly invisible. It used complex FFT software and worked very well. But it was expensive and difficult to service. The client wasn't happy — he told me so. (However, I did get more work from him after that.) (I would have tried a tunable, switched-capacitor-filter front-end instead of an FFT.)

Paving the Road

The best technology is also a state of mind. You're finishing the basic software for your new application and you have a lot of program space left over. So you decide to add an extra function. After all, somebody will probably find a good use for it and you will make a sale. It can't hurt can it? Except at the next project meeting everybody wants to add something as well. So now there are lots of extras and the design is considerably more complicated. With more complex software there are more bugs. What's more, all future upgrades will have to support all these new functions. You've also made it more difficult to enhance your product by adding in all the improvements already. And the instruction manual is bigger which makes it less likely that the user will read it or be able to find the necessary directions. Furthermore, the added complexity makes the operation less intuitive. This results in more customer support and more unhappy customers. Your good intentions may not have the effects you expected.

The important point to remember when adding an unnecessary function is not who will like it, but who will not like it. The impact of any non-required operation should be closely examined. You can't please everyone. And, pleasing one person while irritating two is not a good business model.

The basic rules for content are: Rule 1: Always give the customer what is necessary. (There are a surprising number of products that fail this obvious requirement.) Rule 2: Usually provide additional features that are clearly beneficial to the large majority of users. Rule 3: Do not modify your design for the small minority of users. The best technology is the one that creates the largest number of sales. A happy customer is a repeat customer (see above).

Being Needy

The truth is that most commercial products do not need the latest and most advanced technology in order to succeed. (Military, medical and aero-space applications are excepted.) Generally, you only have to meet or slightly exceed the current technology. Revolutionary products are those that use the current technology in creative ways.

The belief that the original Apple Computer was highly advanced technology is incorrect. The digital ICs were standard parts that hobbyists were already using. Numerous personal computers were already on the market: IMSAI, MITS, Scelbi. Jobs and Wozniak succeeded by packaging software and hardware into one single product. They brought the current technology into the home.

More recently, Ebay, Paypal, Facebook, Twitter and all the other social media are imaginative uses for the internet, but are not, in themselves, high-tech. Although it is true that new technology may make the idea feasible. You can't have a laser range-finder without a laser. But, lasers were around for quite a while before someone used them to measure distance.

Force-fitting something new into your design generally doesn't work. Take a step back and look for the best approach rather than the newest. In short, it's not the technology that is successful, it's the idea that is successful.

(150202)

Connector Pinouts

Handy overviews

By Harry Baggen (Editor, Elektor Netherlands)

Over the years there have probably been dozens of different types of connectors developed for interconnecting electronic equipment and circuits. But how can you get the pinout data for a particular connector? Fortunately, the Internet makes it fairly easy to find out how to wire various connectors and what signals are present on the pins.

However, it can be handy to have a couple of addresses tucked away somewhere, or in the favorites list of your browser, of sites where you can find data for most connectors. That saves a good deal of search effort, particularly with the more exotic connector types.
A good starting point is **The Hardware Book** [1]. This site claims to be have the Internet's largest free collection of connector pinouts and cable descriptions. I haven't counted them all, but the website does indeed have a sizeable collection. Although the Hardware Book website may be a bit slow in adding the latest specifications, such as USB 3.1 or HDMI 2.0, you can find just about anything you can think of that is related to electronics on the site. There are separate sections for audio, video, computers, keyboards, game consoles, power supplies, extension modules for all sorts of equipment and much more. If you are looking for information about an Atari, Amiga or Commodore, you can find it here. The layout of the website is admittedly not polished, but what matters to us as electronics enthusiasts is the content. When checking out all sorts of connectors I occasionally encountered a page that did not work (at least not any more), but that was rare.

Another handy site is **Pinouts Guide** [2]. It also has wealth of information on all sorts of connectors. This is a Russian website that originally had the address pinouts.ru, but fortunately all the documentation is available in English as well as Russian. Here as well you will find many computer connectors, as well as connectors for video games, UPS devices, smartphones, GPS receivers, audio and video equipment, cameras, and diagnostic interfaces for vehicles (such as OBD-2). In addition to the pinout data, in many cases there is extra information about the connector signals and relevant standards. This website is augmented by user-provided information. Anyone who has information about a connector not yet available on the site can personally add the information using a convenient submission form.

The **AllPinouts** website [3] might have deserved the top ranking for its enormous collection of connectors, but the way the site is structured makes it difficult to find a particular connector. AllPinouts is a community project with freely available content in accordance with the GNU Free Documentation License (GFDL), with information collected directly by the users. The website is built as a sort of wiki, which means you have to click through a number of sublevels to reach the information you are looking for. On each page you stumble over various adverts, often awkwardly placed, which makes everything very inconvenient. However, you might find a connector here that you cannot find on the other sites.
With these three addresses in your favorites list, you should be in good shape to quickly track down the right pinout data for your connectors.

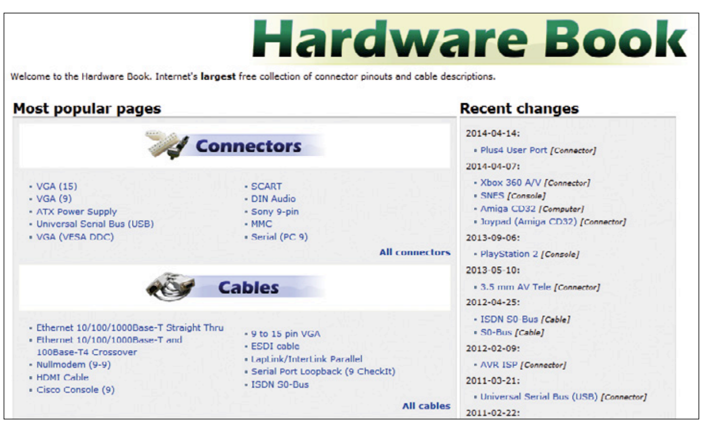
(150290)

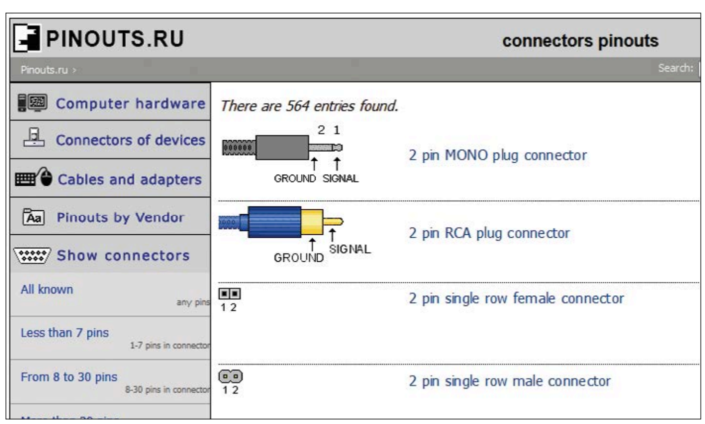
Web Links

[1] www.hardwarebook.info

[2] http://pinoutsguide.com or http://pinouts.ru

[3] www.allpinouts.org





Made in Germany

Rohde & Schwarz, Wandel & Goltermann, u. v. A.

By Jan Buiting, Retronics Resident Editor

Over the past months some friendly advice ("*einige Beschwerden*") came in from German readers saying their national products are not receiving enough coverage in the Retronics section. Amends are made here with descriptions of top-grade lab equipment that may have launched a good number of ambitious German students into a professional career in electronics.

Faithful Elektor readers may recall my description in the May 2013 edition of a Wandel & Goltermann NE-171 high-voltage regulated supply with the lovely EL156 in it. The instrument was part of a carload full of 1960s/1970s test and measurement equipment I was asked to help clear from a former electronics classroom/lab at a technical college in Germany, not far from Elektor House. The equipment, once classified as "educational aids" had been "discontinued and written off". I was tipped off by an Elektor contributor who phoned to say "be quick about it, the dumpster is waiting".

I was thrilled to see mostly tube based equipment. Not surprisingly most of the instruments I was able to route away from the dumpster (with the help of 2.5 students) and bring over to the *Retronics* collection at Elektor House was of German origin and of the best, most expensive variety from manufacturers with a formidable reputation: Siemens, Wandel & Goltermann, Rohde & Schwarz. In the unlikely case you haven't heard these names before, maybe BMW, Audi, Mercedes Benz, Kraftwerk, or Bayern München ring a bell?

ESTD 2004

www.elektor.tv

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

A Student Set to Carry

As part of their curriculum, students between 1970 and 1985 (my best guess) had to explore the world of filters, not just in theory (Bessel, Butterworth, notch, passband ripple, Q factor, remember?) but also with practical experiments and classroom assignments. From the equipment I was given, I guess the response of a filter 'XYZ' in question had to be analyzed, verified, proven and recorded by a student duo. Not sure if the filter structure was either "assigned" by the professor, or drawn by the students — or who built the thing. From a storage locker and under supervision each duo was given an equipment set to rig up on the classroom desks. As a minimum, the set may have comprised a precision sine wave generator with a large frequency range, a millivoltmeter and some

cables. All calibrated, of course, not forgetting grid paper, pencils and possibly a slide ruler. As a coincidence, on that rainy Friday afternoon back in 2013 as we were carting the vintage gear down to my Suzuki SX4 — the building almost deserted — I noticed two hapless students at a table staring at an exotic filter response on their laptop screen and trying to find a matching drawing in a thick textbook. Their professor had just left, gloating.

Two student sets for filter response studies were included in the lot kindly donated to *Retronics*. Originally each set as a minimum comprised of the following (quasi portable) instruments:

- A Rohde & Schwarz RC Generator Type SRB, 10 Hz – 1 MHz, 1 mV – 30 V; **or** a Wandel & Goltermann MG-47 RC Generator, 30 Hz – 300 kHz; 1 mV – 100 V;
- A Wandel & Goltermann ESM-1 Effective Level AC voltmeter, 30 Hz – 15 kHz, 3 mV – 30 V_{eff} (–50 to +30 dB).

Mild variations were observed in some of the equipment, for example one W & G MG-47 generator had a slightly different style dial for the frequency tuning.

The use of 300-kHz and 1-MHz generators seems to indicate that filter technology beyond the audio range was also taught, which is good.

All instruments were nicotine free and looked well maintained. The front panels were covered with stickers which, being made in Germany, were tough to remove. With a few exceptions, the original manuals of the equipment were successfully unearthed the College's deep archive, and sent to me by post for copying and returning, together with a set of Elektor DVDs covering 1980 to 2010. Both the R & S and the W & G equipment have German and English print with the major controls on the front panel, although the German decimal comma is persistent.

Rohde & Schwarz Type SRB R-C Generator

You can spot 1960s-70s R & S test gear from a mile from their pale grey cases. The smaller instruments have an extremely solid carrying handle on the case top, and can be stacked with confidence thanks to four hollows on the top of the case to secure the "feet" of the instrument placed on top. All R & S equipment has a three-letter identifier like SRB, URV, etc.

Figure 1. You can't be mistaken about the type numbering of Rohde & Schwarz test equipment.

Figure 3. The SRB instrument can be lifted out of its case by undoing four screws. It's a solid, compact construction, wouldn't you agree?

printed very conspicuously on a reflective (!) panel under the handle (**Figure 1**) so you could learn e-engineers' abbreviation-ridden techtalk at an early age.

An elegant little instrument, the SRB (**Figure 2**) is not too heavy to carry along a college corridor or two, except of course by female student Helga. Its design and ergonomics appear a compromise between use in the lab, in the field, or in a field lab. Its protective snap-on cover with the R & S logo is missing — these covers are now collectibles. Two of the SRBs I got suffered from the same fault, which is also my single objection: an intermittent, broken AC power cord or a dried out sleeve right where the cord enters on the front panel. All SRBs were fully working after a light clean. I tested the harmonic distortion in the audio range using an Audio Precision analyzer and found –75 dB on average. In one SRB the output frequency in the highest range (1 MHz) required slight recalibration although at around 2% the error was not upsetting. Philips 30-pF 'beehive' trimmers are used for these adjustments.

The oscillator proper is an R-C type with a variable tuning capacitor enclosed in a box. It is operated in tandem with a potentiometer. The oscillator has a slow but effective amplitude stabilization with a regulation of 0.2 dB across the frequency range.

Among the remarkable things about the SRB is the light yet solid feeling of the frequency control, the availability of five output impedances (50/60/75/150/600 ohms), the high output voltage (to 30 V_{RMS}), and amusingly the steadfast use of 'db' instead of

Figure 2. The Type SRB RC Generator from Rohde & Schwarz. That frequency dial is sweet to operate.

Figure 4. Basically an alternative to the R & S SRB, the Wandel & Goltermann Type MG-47 generator has a smaller frequency range but more options in terms of balanced, unbalanced and isolated (transformer) outputs.

'dB' in the print on the front panel. Besides a normal Hz / kHz readout with a 1 – 10 scale the frequency dial also has a smaller concentric one for 'lg f' which I surmise is a logarithmic representation — very useful for the students' filter graphs and plots. Opening the SRB (**Figure 3**) reveals the usual, large HV electrolytic capacitors, and conventional tubes from the Philips Miniwatt EL/E(C)C series as they were found in consumer radios of the age: I saw two EL86s, two ECC81s and one E88CC, all Siemens manufactured, and duly stamped MADE IN GERMANY, which is good. The power supply is solid state with diodes. A quick ripple measurement on the HV lines in the instrument revealed that the can electrolytics are beyond suspicion and still do a good job. I gave all equipment a gentle start on my variac. The SRBs were modified to have a common BNC output socket instead of the eccentric original. This might be R & S specific, but also Dezifix which is highly specific to Germany and a nightmare to get plugs and adapters for. The brass adapter was very likely crafted on a lathe in the mechanical workshop at the college, which was an absolute dream to see (I was not allowed to enter and touch).
The dial tuning mechanism is not visible without taking the SRB apart, which I feel is not necessary, but I expect to see a precision crafted construction there with ball bearings.
I used one of the SRBs to surprise Rohde & Schwarz staff at the *electronica* show in Munich, 2014 [1][video], as well as to demo to a live audience at the Elektor booth with amusing but convincing results [2][video].

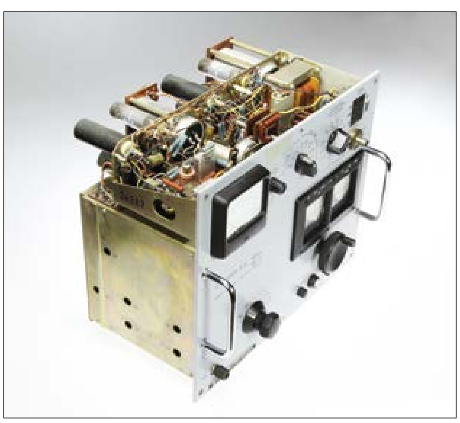


Figure 5. A look inside the "wago" MG-47.

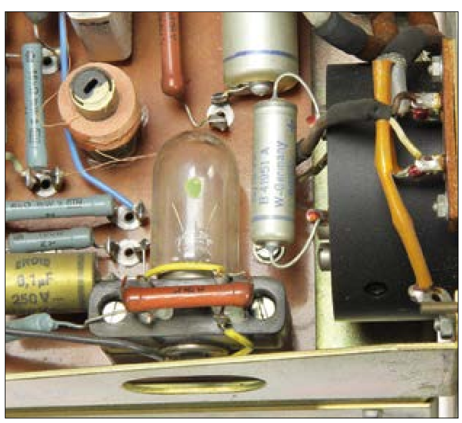


Figure 6. The bulb your can see here is described as a Kaltleiter by W & G; it acts as the amplitude stabilizing device for the central oscillator.

Wandel & Goltermann Type MG-47 R-C Generator

This unit (**Figure 4**) is considerably larger and heavier than the SRB, and unlikely to be meant for field use. Mine is the BN92-2 version i.e. with voltmeter and 60-ohm transformer output. The stove enamel case color is petrol (grey with a hint of blue), while the front panel is light grey (possibly Shade # 23 in the novel). I gave the front panel an initial clean with liquid car wax. In place of a round dial there's a scrolling scale with 6 ranges behind two windows. Another difference with the SRB is the availability of balanced outputs and even more impedances to choose from. The rather cheap looking output level meter is Spartan with just two scales, 0-11 and 0-40 and not a unit in sight, although that must be volts (V) or millivolts (mV) as every freshman knows. Compared to the SRB the controls are chunky but remarkably light to operate.
Wisely the AC power cord entrance on the front is sealed with a plastic disc, and the instrument is modified to have an IEC appliance socket at the back side. Here, too, the original output socket got replaced by a round-flange BNC type.
Inside (**Figures 5, 6**), not many surprises: a solidly built instrument again with tubes common of the epoch. EL/ECC/EF tubes again, and one lamp with a rather large glass bulb which I suspect is the amplitude stabilizer mentioned in the docs (*Kaltleiter*).
Two of the three MG-47s were found to work well, the other one produces an unsettling, crackling noise hinting of HV failure, so declared it *Ersatzteilträger* (spares donor).
The electrical performance of the working units is superb — even 25 years since their last use they meet and even exceed all specifications seen in the user manual. The most active collector of Wandel & Goltermann (W & G; "wago") equipment I have come across is Max Koschuh [3].

Wandel & Goltermann ESM-1 Audio Voltmeter

To record and analyze the response of a filter you need a precision voltmeter. For that purpose the student set for the *Under-*

stand Your Filters course once taught at the college comprised a W & G Type ESM-1 instrument (**Figure 7**).

Although this instrument has the same look and feel as the MG-47, it has German texts only on the front panel. This too is a table-top instrument. Like R & S equipment, it can be stacked securely using a system of interlocking parts on the top and bottom of the case. For the operator's convenience the large meter can be tilted 30 degrees and locked into position. The 60-µA moving coil type 137-8101 is manufactured by Gossen and as with the R & S generator, has 'db' printed on the scale. Maybe older German readers can enlighten me. I was fortunate to find two Gossen benchtop supplies among the equipment. The meters on them are elegant designs.

Although the instrument I got is in pristine condition it does suffer from one of more bad contacts in the AC power switch. Set to the ON position (*Ein*), even gently rapping the switch lever causes the meter needle to flick, which is not good. However, with some care I was able to get stable operation and verify proper operation thanks to the Calibrate position (*Eichen*) on the measurement range switch. The needle is supposed to deflect full scale then to the red 10 V mark, which it did after turning the *Eichen* control just slightly. There is nothing in microcontroller-LCD-A/D/A land that beats the feeling of getting an indicator needle on a scale mark.

Thanks to its signal output with an impedance of about 15 kΩ (unbalanced) the ESM-1 can also be used as a measurement amplifier, possibly for driving a pen plotter. A simple switch on the front panel selects between 'instrument' (i.e. the meter with its db/V scales) and 'output'.

And suddenly there's riveting stuff inside the instrument (**Figures 8, 9**)! C3m vacuum tubes all over the place. Some say the C3g/m/o tube made by Lorenz, Valvo, Siemens and Telefunken, is the best low-signal pentode ever made. The ESM-1's construction is classic and yet another example of pure craftsmanship. Apart from the C3m tubes there's zero special electronic components used, in fact any electronic part in the ESM-1 can be sourced today with no great effort. It's utterly unnecessary though.

Figure 7. The Wandel & Goltermann ESM-1 30 Hz – 15 kHz audio voltmeter, pictured here with its meter in the tilted-up position.

Und viele Andere!

There was more equipment in the lab clearance than (a) can be described in this installment and (b) could be loaded in my car that Friday afternoon. Technologies like SHF radio and audio distortion measurement were also taught at the college and relevant test equipment was used, although given the complexity I am not sure this was for undergraduate students. All equipment of course from these great German companies: Wandel & Goltermann, Siemens, and Rohde & Schwarz. I hope to cover some if this more esoteric gear in a future installment of Retronics. I also hope to do a short video on the equipment discussed here, look for 'Retronics' at www.elektor.tv.

(150232)

Web Links

[1] Rohde & Schwarz interview: https://youtu.be/AwwdW-mPYRk

[2] Retronics Hits electronica 2014: https://youtu.be/Yrqf3YLZAWY

[3] Max Koschuh's Wandel & Goltermann Online Museum: www.koschuh.com/museum/wandel_goltermann/wago.htm

Figure 8. Interior view of the ESM-1. All conventional design, electronically, but with a touch of craftsmanship that made W & G instruments top notch at the time.

Figure 9: A pleasant surprise: there's a bunch of C3m vacuum tubes inside the ESM-1. Very much a *Made in Germany* product, the C3m today is a hype in high-end audio land.

Compiled by **Beatriz Sousa**

Summer Campaign Team has kicked off. Any ideas?

On June 21 Elektor launches its traditional Summer Campaign. Market Director Germany, Ferdinand teWalvaart leads the Summer Campaign Team (SCT) with fellow Elektorians in it like Muhammed Söküt serving the members and Margriet Debeij serving our business clients and suppliers. Anyone who has an idea on crazy offers is welcome to contact them. If you take 30 minutes of scanning & scouting the world wide web, you will for sure find something you would like to buy. Bring that suggestion to us before you purchase and if the SCT can integrate it in the Summer Campaign, we will send you that product with 100% discount, limited to a maximum price of $/€/£200.

Revamped 'elektormagazine' website

Elektor's activities this summer are not limited to huge promotions. We have just launched the new and improved website www.elektormagazine.com, where you can find all Elektor content under one roof. Elektor GREEN and GOLD members can access the vast archive of digital Elektor articles and magazines. If you are not a member you can read news and articles about your favorite electronic topics. With our improved search function, you can easily find the article(s) you are looking for. You can also select articles by favorite author, subject and much more. Check it out: www.elektormagazine.com

READ ONLY MEMORY

Elektor magazine and its parent publishing company boast a long and rich history. In this space we picture a gem from the past.

DIY CD Player

In January 1992 Elektor presented the first CD player for home assembly. At that time the compact disc was already quite popular, but good CD players came with a hefty price tag. Thanks to intensive cooperation with Philips, one of the world's leading manufacturers of CD deck units, Elektor arranged for electronics stores to buy and retail a large number of ex-factory decks and associated control boards at a reasonable price. The magazine printed a fantastically detailed description of the first DIY CD player enabling many readers to make a start with the new technology.

Ethics and electronics intersect

Testing the waters — that's what the editorial staff of Elektor's sister network www.techthefuture.com did these past twelve months. Besides technology itself engineers increasingly digest information about the effects of technology, real and potential, on societies and individuals. Whether they like it or not, ever more companies and designers are pulled into discussions between pessimists (*''technology will kill natural human living*!'') and optimists (*''technology will improve life immensely''*). How far can you go in changing people's life using electronics? Think about smart cars (programming a car means deciding beforehand if it will brake for ducks, besides children obviously). About life science: insurance companies are very interested in electronic tools that stop people craving for

PEOPLE NEWS ● Sibe Jan Koster has joined the Elektor expert team and starts writing a book about STM32 Cortex developing plans for a Turkish Summer Campaign with the help of Agent Manager Raoul Morreau ● In Italy, Elektor clients/sponsors in the winter to join Elektor than he did in the winter of 2014 ● The book *Arduino in Control* by teacher Maarten Timmers Verhoeven is setting up a brand new Printing-on-Demand Service for members and book buyers outside

at Tech the Future

nicotine, but can one make that mandatory or what? What do you think: should electronic engineers and companies play a pro-active role discussing ethics and electronics? Or should we leave that to politicians and blindly follow what they and their voters seem to decree? Join us on Tech The Future. Editor-in-Chief Tessel Renzenbrink is keen to have your point of view. You can contact her through Tessel.Renzenbrink@eim-world.com or on twitter @ _Tessel. After the summer Tessel will reshape her pioneer website with your input into the platform where companies and engineers can learn and share thoughts and actions concerning ethics and electronics.

M4 micros • In Turkey, Elektor agent Cumhur Cakmak is
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EXPERT PROFILE

Elektor works closely together with more than 1,000 experts and authors for the publication of books, articles, DVDs, webinars and live events. In each installment of Elektor Word News we put one of them in the limelight.

Name: **Rémy Mallard**

Age: **48**

Country: **France**

Education: **Electronic Higher Education diploma (F2 A levels)**

Publications: **3 technical books (FM radio, electronics for beginners, PIC for beginners), several short works.**

Training: **Several courses in audio and electronics applications**

Who is Rémy Mallard?
I am 48 years old and have 6 children (five girls and a boy). I actually work in several activities: as a comedian/ VoA (Voice-over Artist), teacher in audiovisual/cinema school and electronic developments (radio and studios domains).

What is your experience?
I have many years of win32 software writing, PIC developments and audio devices repairs or mods, technical teaching in a large company and in school, radio and events animation.

Who is your biggest role model in electronics?
My father, my god-father and all folks out there who contributed to stimulate the desire to go on, even when all went down and produced smoke unwanted.

What will be the most key electronics development?
The ability for everyone to make their own devices we now have to buy manufactured. 3D printing is a way to this, and I'm surprised by what we can do with this sort of device. Tomorrow you'll be able to make your own phone or TV with any shape or color you want.

What topics will you be writing about in the future?
Don't really know about the subject, but if I have to write a new book, it will be targeted at beginners. It's a hard but very interesting job to keep words simple in the face of ever more technical objects.

Suppose Elektor gives you £100. What would you buy? Why?
I'll make electronic kits for beginners and supply them for free. Some people hesitate to start in electronics because they think they feel incapable, or because they lack money. A kind of 'impulse' is needed to help people take the next step.

What was THE development of electronics?
When I was young, I was fascinated by He-Ne Laser tubes (yes, the Ray of Death). Later, when Laser diodes became affordable, I decided to get some of them to give toys and musical instruments extra functionality. I now have more than 150 lasers. ⏮

(150281)

Hexadoku The Original Elektorized Sudoku

Even if puzzle solving is not among your biggest talents you should have a go at cracking this edition's Hexadoku. Don't feel pressed though since you have a good eight weeks for the assignment, and real electronics engineers don't give up easily. Give it your best shot, 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 September 1, 2015, 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 May & June 2015 Hexadoku is: **8205E**.

The €50 / £40 / $70 book vouchers have been awarded to: Julian Muscat (Malta), Denis Moucharte (Belgium), Philippe Monnard (Switzerland), Martin Kübel (Germany), and John Jones (USA).

Congratulations everyone!

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

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

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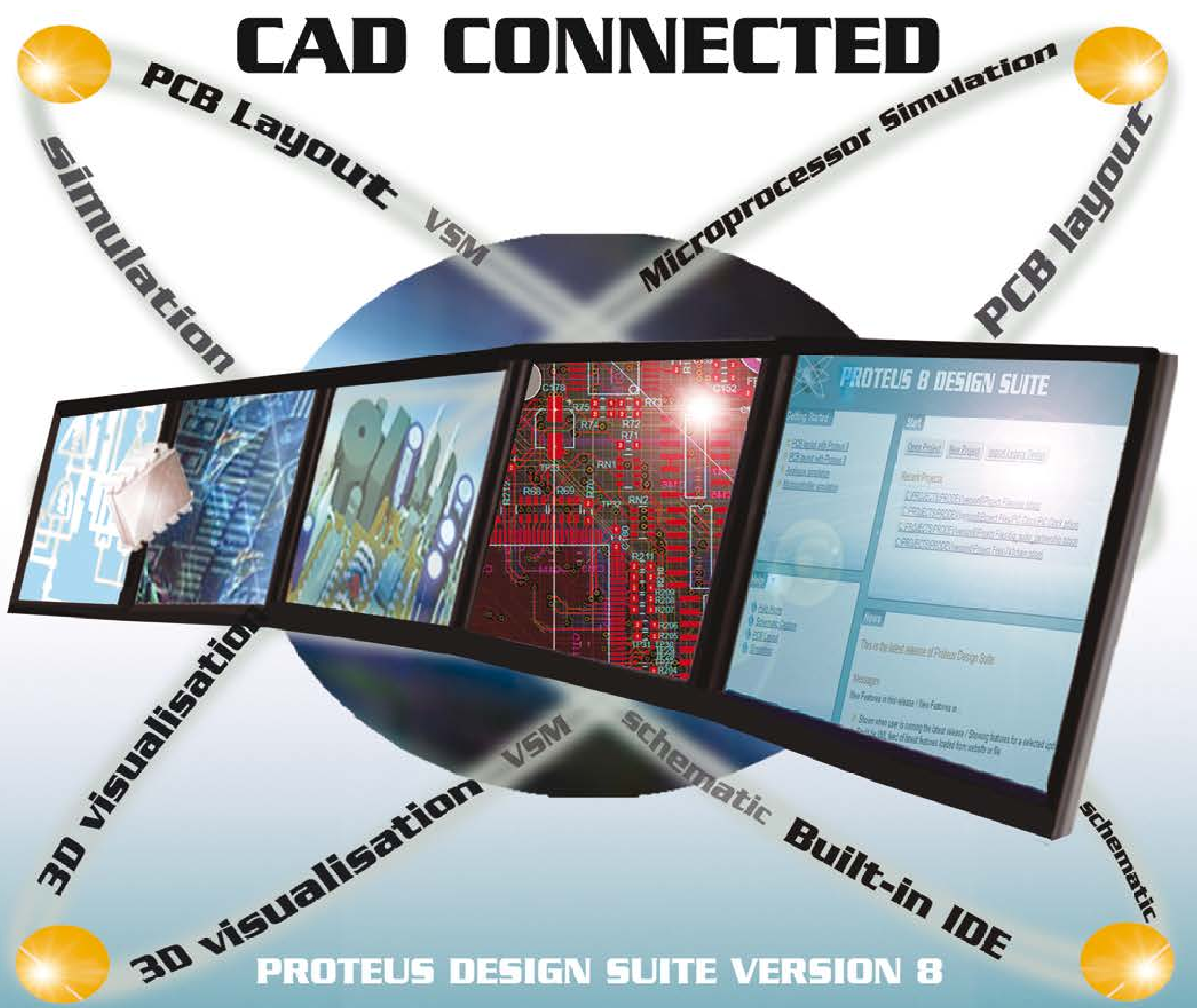
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